King County
METRO

TRANSIT SPEED AND RELIABILITY
GUIDELINES AND STRATEGIES

FINAL

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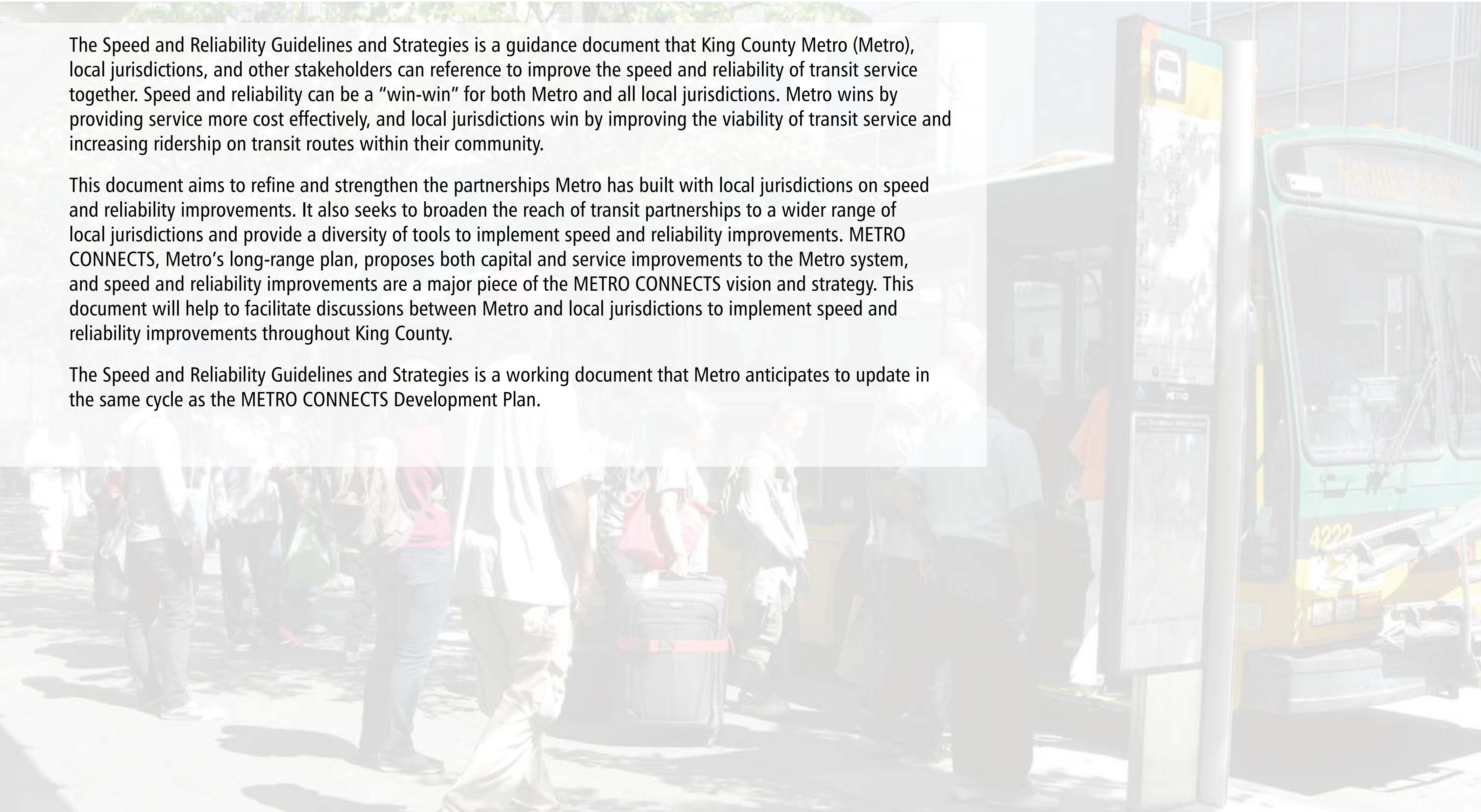
Providing fast, reliable service is paramount to creating and operating an efficient and effective transit system. Transit agencies around the world are interested in making transit as attractive as possible and work to put improvements in place to speed and enhance bus operation. King County Metro participated in an international case study with 14 other worldwide transit agencies in 2014 to share and identify physical infrastructure and technology improvements that would enhance transit. The results of this case study can be found here: http://bit.ly/bus-priority-schemes

1. INTRODUCTION

The Speed and Reliability Guidelines and Strategies is a guidance document that King County Metro (Metro), local jurisdictions, and other stakeholders can reference to improve the speed and reliability of transit service together. Speed and reliability can be a “win-win” for both Metro and all local jurisdictions. Metro wins by providing service more cost effectively, and local jurisdictions win by improving the viability of transit service and increasing ridership on transit routes within their community.

This document aims to refine and strengthen the partnerships Metro has built with local jurisdictions on speed and reliability improvements. It also seeks to broaden the reach of transit partnerships to a wider range of local jurisdictions and provide a diversity of tools to implement speed and reliability improvements. METRO CONNECTS, Metro’s long-range plan, proposes both capital and service improvements to the Metro system, and speed and reliability improvements are a major piece of the METRO CONNECTS vision and strategy. This document will help to facilitate discussions between Metro and local jurisdictions to implement speed and reliability improvements throughout King County.

The Speed and Reliability Guidelines and Strategies is a working document that Metro anticipates to update in the same cycle as the METRO CONNECTS Development Plan.



This guide:

Establishes a framework for how Metro, local jurisdictions, and other agencies and stakeholders will work together to plan, design, implement, and monitor speed and reliability improvements. All speed and reliability improvements are partnerships. The success of speed and reliability projects depends on Metro, local jurisdictions, and other agencies understanding one another's process for project planning, design, and implementation. This document identifies the best practices of how Metro, local jurisdictions, and other agencies can successfully plan, design, fund, build, and manage speed and reliability improvements together in the context of the street environment.

Defines speed and reliability improvements and their benefits. Transit speed and reliability improvements are essential to the functionality of the Metro transit system. Because Metro works with local jurisdictions and other agencies that own and manage the public streets in which transit operates, it is important that everyone understands what speed and reliability improvements are, how they are measured, and how they benefit not only Metro's transit operations but the broader community goals that rely on a quality multi-modal transportation system.

Introduces transit-supportive strategies that increase speed and reliability. Metro improves transit speed and reliability by employing a variety of bus operations, traffic control, and infrastructure strategies. Some of these are small adjustments while others are more major investments that require the consideration of trade-offs with other street users.

Provides details on the benefits, trade-offs, and implementation of specific speed and reliability strategies. National best practice documents provide a thorough summary of the considerations of using different transit speed and reliability tools. This document integrates those best practice documents with the uniqueness of Metro's system and needs of local jurisdictions. The Metro Speed and Reliability Group provides the lessons from the significant experience of Metro in implementing speed and reliability projects at the same time as providing guidance for strategies that Metro has not yet used. For each of these tools, we outline the considerations so that Metro and local jurisdictions will be able to understand the benefits and trade-offs of employing a particular strategy.

With this document, you will be able to:

- Understand what transit speed and reliability improvements are and why they matter to both Metro and local jurisdictions – see SECTION 2.1 and SECTION 2.3.
- Understand the range of opportunities to partner with Metro on speed and reliability improvements – see SECTION 3.3.2 and SECTION 3.3.3.
- Have the tools to work with Metro on specific transit-supportive strategies – see SECTION 4.
- Understand the trade-offs of implementing a transit-supportive strategy – see SECTION 4.
- Review case study of speed and reliability projects and understand their benefits and trade-offs – see SECTION 5.

2. OVERVIEW OF SPEED AND RELIABILITY

The *Overview of Speed and Reliability* section defines the issues of transit speed and reliability – what it is, the challenges, and the benefits.

2.1 WHAT ARE SPEED AND RELIABILITY?

Speed is the ability of transit vehicles to move along their routes in reasonable amounts of time. ***Reliability*** is the ability for transit vehicles to arrive at stops at consistent and predictable times. They are closely related because schedules are designed to maximize the efficiency of the system, the slowing of buses affects the maintenance of those schedules, and inconsistent arrival times present much of the same challenge to passengers as slow service. Both speed and reliability help transit agencies reduce operating costs, help people travel faster and more conveniently, and help local jurisdictions make transit an attractive transportation option.

For Metro, speed and reliability means maintaining good travel times for its buses that riders can depend on throughout the region it serves—whether in urban core cities such as Seattle and Bellevue or in outlying cities.

Transit speed and reliability requires coordination among Metro, local jurisdictions, and other agencies. This guide focuses on ways that Metro and local jurisdictions work together to improve speed and reliability on Metro's bus routes. These speed and reliability improvements, or projects, can benefit transit by providing an operating environment where bus travel times are more predictable and competitive with other modes of travel, and remain steady over time. In some cases, speed and reliability projects simply create a "level playing field" for balancing transit needs with the needs of other traffic. In cities that have prioritized transit as a transportation mode, speed and reliability are a way to incentivize travel by transit: a transit vehicle may be given the advantage to bypass a point of congestion or a long signal. And in many cases, speed and reliability improvements for transit improve conditions for all modes of transportation in the improved transit corridor.

Speed and reliability projects can range from spot improvements at a single traffic signal or bus stop to a set of coordinated improvements along the full length of a route. In recent years, Metro has implemented corridor improvement projects on six RapidRide bus rapid transit lines throughout the county as well as other selected high-ridership routes, such as Route 120 and Route 101. Over the same time period, partner jurisdictions have expressed interest in planning for and providing speed and reliability improvements on corridors beyond those that Metro has invested in to date. Seattle has led corridor improvement projects for several routes, including for Routes 7 and 44.

This guide aims both to streamline the process of planning and building speed and reliability projects with current partners, and to help local jurisdictions understand what the opportunities are to partner with Metro to improve transit service. This guide is intended to help facilitate speed and reliability projects and partnerships in a range of policy environments.

2.2 CHALLENGES TO TRANSIT SPEED AND RELIABILITY

Transit vehicles are one mode among many that cities are striving to balance in the right-of-way of public streets. These include general purpose traffic, pedestrians, bicyclists, freight traffic, trains, parking, and public space. Within this context, the following are some key challenges to transit speed and reliability that the strategies in this guide seek to overcome:

- **A congested street or intersection with general traffic delay.** The growth of the region and increasing use of streets by all kinds of traffic affect the street performance; traffic congestion reduces transit speed and reliabilities.
- **Delay in turning.** Turning movements can be challenging for transit vehicles, which must contend with crossing oncoming traffic, signal phasing, crossing pedestrians, stopped vehicles, through-moving bicyclists, and small curb radii. Parked vehicles that encroach upon the intersection can also complicate turning movements for transit vehicles.
- **Bus zone issues.** Bus operations are dependent on balancing the mobility of transit vehicles along their routes with their ability to pick up passengers at designated stops. This balance affects the speed and reliability of overall transit trips. Speed and reliability can be compromised when a bus has trouble moving in and out of a bus stop ("bus zone"), when it takes too long to load and unload passengers, and when there are too many stops.
- **Complementing other users such as pedestrians or cyclists**. The needs of other motor vehicles must to be balanced with buses but also the needs of people walking and riding bicycles. These modes of transportation directly support transit ridership and access, and in recent years many cities throughout the region have dedicated more right-of-way to making them safer and more convenient. Better conditions for pedestrians and bicyclists improve access to transit, but at times conflicts arise between these modes and transit vehicle mobility, such as with bicycle traffic at bus zones or pedestrian crossings.

The range of tools in the TOOLBOX SECTION address these challenges individually or in combination. These tools propose ways to improve transit speed and reliability while still complementing the other users of the street.

2.3 BENEFITS OF SPEED AND RELIABILITY IMPROVEMENTS

The following are key benefits of transit speed and reliability improvements.

2.3.1 CRITICAL TO A GOOD TRANSIT SYSTEM

Consistently offering reliably fast transit trips is important to a variety of aspects of Metro's success:

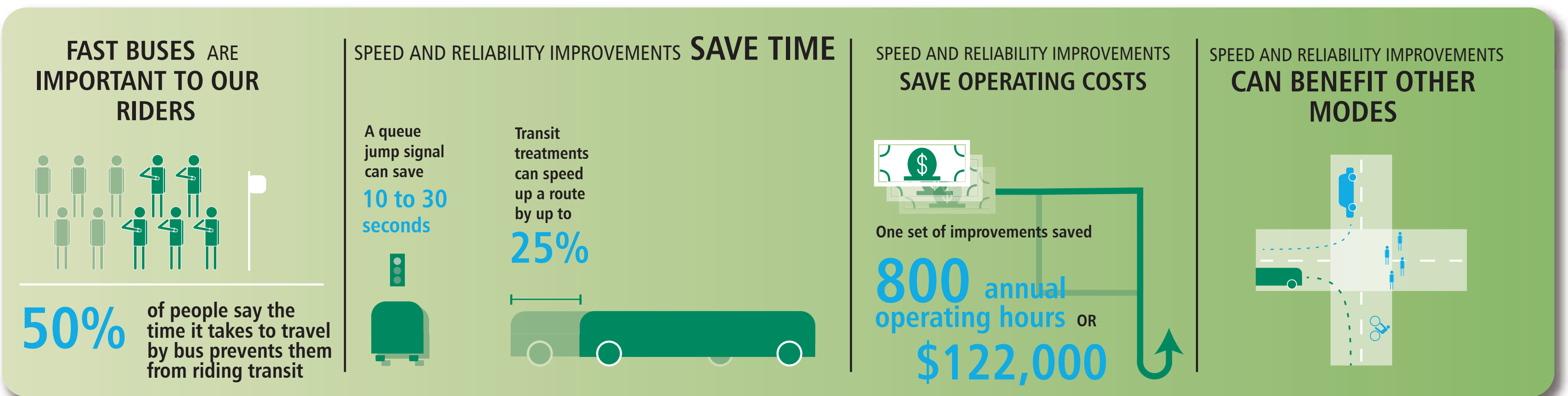
Customer satisfaction and experience: Speed and reliability are major attributes among riders and member communities. Metro's Rider/Non-Rider Survey found that less than half of our riders are happy with travel speeds, and the same for on-time performance. We have learned through an online survey, visioning events, and open houses that street improvements to improve speed and reliability were the top-rated transit improvements.

Benefit to other modes: Speed and reliability improvements may offer benefits to other modes by reducing potential conflicts at problem locations.

Service quality: Investments to improve speed and reliability are particularly important for frequent service and overall transit performance. Better transit service performance is important to maintain the branding as well as to attract more transit riders.

Expanding ridership: By bringing passengers to their destinations in less time and on schedule, transit becomes a more attractive replacement for private vehicle use. This would allow Metro to attract new riders.

Cost-savings/efficiency: By allocating more Metro schedule time for moving people and less time for getting delayed buses back on schedule, Metro saves operating dollars that can be used for new service.



Sources: King County Metro 2009 Rider/Non-Rider Survey; King County Metro Annual Spot Improvements Report; King County Metro E Line Report

2.3.2 IMPROVEMENTS ARE EFFECTIVE

The speed and reliability improvements described in this document are effective tools to address the challenges outlined in SECTION 2.2. Metro's experience has shown that when the tools are applied in appropriate ways, they decrease route travel times and increase predictability.

An example of effective speed and reliability improvements is the RapidRide E Line, which connects Downtown Seattle to Shoreline and the Aurora Village Transit Center. The E Line opened in February 2014, primarily on Aurora Avenue. The E Line project included a number of speed and reliability improvements, including Business Access and Transit (BAT) lanes and transit signal priority at 20 intersections, as well as smaller projects such as bus stop spacing and streamlined routing.

Metro studied the effects of the improvements on speed and reliability. It was found that the BAT lanes saved up to 6.1 minutes per trip and the transit signal priority saved up to 1.8 minutes per trip. The other treatments saved up to 2.6 minutes per trip. All these treatments combined saved a total of 5.2 – 8.8 minutes, which constituted 19-24 percent of the total route trip time.

The E Line route operations benefited as well – the improvements removed up to 11 minutes from the schedule and saved some 800 annual operating hours.

2.3.3 HELP ACHIEVE REGIONAL AND LOCAL GOALS

Speed and reliability improvements do not just benefit Metro and its riders. Fast and reliable transit reinforces and helps achieve many community goals. An effective transit system positively affects:

- **Efficient transportation system**: Public transit's ability to move more people over long distances is unmatched; as our region grows, it is a key part of the solution to moving people from homes to jobs and other destinations. Speed and reliability improvements often improve conditions for other modes as well, whether improving traffic signal phasing for general purpose traffic, or complementing a walking or biking leg of a trip with a quick transit ride.
- **Maximize use of existing roadway infrastructure**: In many locations, it is not possible to add additional capacity to roadways to accommodate traffic demand. Transit helps maximize the use of the region's existing infrastructure by moving more people in less space than personal vehicles.
- **Transportation and lifestyle choice**: A transit system offers a major alternative to driving, and enables walkable communities.
- **Sustainable communities**: Transit is a major component of compact growth.
- **The environment**: Compact growth reduces the ecological footprint of our metro regions; shifting more trips away from single-occupant vehicles helps improve air and water quality.
- **Urban design**: Public transit, requiring little or no parking and inducing pedestrian trips, augments the public space of a city.

One example of a set of regional goals that transit speed and reliability can help achieve is the Puget Sound Regional Council's Vision 2040, which includes several goals that are directly aided by an effective transit system, including "Care for our air, water, land, and climate," "Promote healthy living," "Provide clean and efficient transportation," "Encourage quality urban design," and "Build and sustain vibrant cities, centers, and compact communities."

2.3.4 A RANGE OF SOLUTIONS

One of the major benefits of speed and reliability improvements is that they are scalable to meet local needs. A local jurisdiction can work with Metro to implement vastly different solutions that work within local needs and constraints. For example, while dedicating bus lanes in one jurisdiction may be feasible, a less substantial but worthwhile speed and reliability benefit could be achieved in another jurisdiction with less intensive improvements, such as signal phasing adjustments or intersection geometry changes. Improvements can also scale to meet local needs.

The TOOLBOX SECTION of this document allows you to review this range of strategies and to understand the differences among them in terms of what issues they will solve and their cost and feasibility.

2.3.5 BENEFITS TO OTHER MODES

Improvement of transit mobility often benefits other street users.

Good urban design can apply speed and reliability tools and combine them with best practices for multi-modal street design in ways that benefit all street users:

- In a spot improvement project at SW Alaska Street and California Ave SW in Seattle, Metro and the Seattle Department of Transportation worked together to create a new timing plan to improve safety and service on Route 128 as well as for numerous pedestrians that cross the intersection.
- At 2nd Avenue and Union Street in Seattle, a speed and reliability improvement provided a benefit to pedestrians with a protected left turn.
- In a spot improvement project at 2nd Avenue and Pike Street in Seattle, general purpose traffic turning left illegally from a wide bicycle lane were blocking buses from making the left turn. Metro and the Seattle Department of Transportation worked together to narrow the bicycle lane at the intersection to preserve it for cyclists and allow buses to make unobstructed left turns.

2.4 THE OPPORTUNITY TO BE VISIONARY

Metro brings extensive experience in building speed and reliability projects. At the same time, there is an emerging richness of guidance for transit-supportive street planning and design, and local jurisdictions throughout the region are increasingly building sustainable transportation networks and communities. The combination of these factors provides the opportunity to achieve a visionary future of a transit system complementing other uses of the street environment.

This guide provides a flexible framework for this visionary future, by combining guidance for how to form partnerships among Metro and local jurisdictions, and guidance for the technical tools to build speed and reliability improvements. The more the partners can implement solutions together, the more we all learn about the effectiveness of these projects in achieving everyone’s goals.

3. FRAMEWORK FOR PARTNERSHIP

The *Framework for Partnership* section describes how Metro works together with local jurisdictions and other agencies to implement speed and reliability improvements.

3.1 METRO'S VISION FOR TRANSIT PARTNERSHIP IN THE REGION

METRO CONNECTS, Metro's long-range plan, envisions working with local jurisdictions and agencies to create more frequent and reliable transit service throughout the day and week. If the plan's vision is achieved, Metro would dramatically expand the number of places people could go and decrease the time it takes to get there.

Similar to current service, future service will comprise three service types:

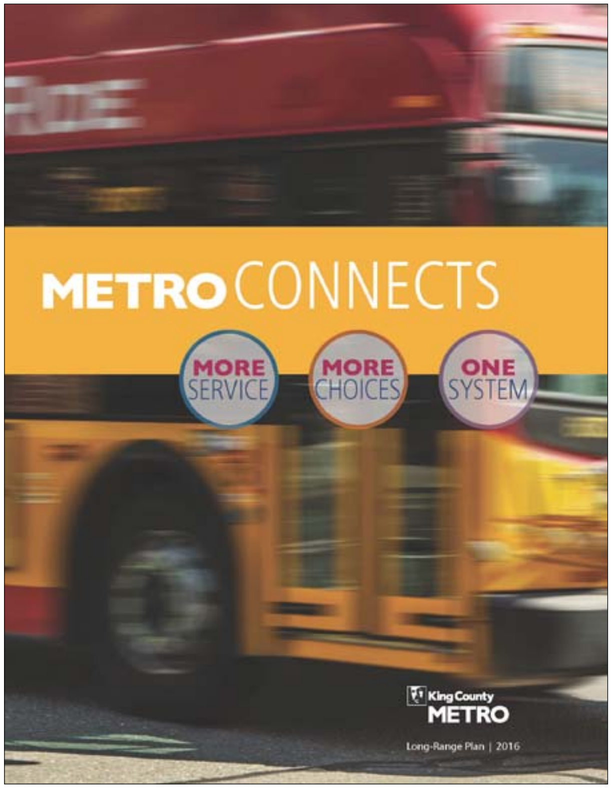
- Frequent: "Show-up-and-go" service with speed and reliability improvements; these routes (RapidRide and non-RapidRide) start early and run late in the day.
- Express: Limited-stop service between regional centers, all day, both ways. These routes include additional peak-period service.
- Local and flexible: Fixed-route buses and alternatives such as vanpools, Dial-A-Ride Transit, community shuttles, and real-time ridesharing.

The enhanced system will:

- Connect people to Sound Transit's existing and planned **regional rail and high capacity transit (HCT) system**.
- Meet **current transit needs** identified in Metro's annual Service Guidelines analysis, and future transit needs identified in cities' growth plans.
- Expand funding for **alternative services**.
- Move Metro toward a service network that **operates all day**, from earlier in the morning to later at night.

Metro continues to collaborate with jurisdictions, transportation agencies, and the public to move toward this vision. METRO CONNECTS is a living document that is expected to be updated every six years, incorporating intermediate changes that occur on the ground and in local plans. This iterative process will contribute to an enduring consensus about the future of transit and will help cities realize their visions for the future as well.

In addition to updating the METRO CONNECTS vision, a rolling six-year implementation program will focus on internal coordination and collaboration with local jurisdictions to make sure Metro is on track to attain our vision. This program is intended to better prepare Metro to support the existing legislative processes for service changes and capital investments.



3.2 METRO'S SPEED AND RELIABILITY STRATEGY

3.2.1 SPEED AND RELIABILITY IN METRO CONNECTS

Speed and reliability are a major part of the METRO CONNECTS vision and a major aspect of working with local jurisdictions to achieve the vision. METRO CONNECTS proposes dedicating nearly half of the capital budget for METRO CONNECTS to investments that improve transit speed and reliability[1].

This investment will pay off—for every dollar invested, Metro and our riders will save $2. By keeping buses moving through congestion and on schedule, Metro can deliver more service, and customers will have an alternative to sitting in traffic.

3.2.2 SPEED AND RELIABILITY STRATEGY

Using METRO CONNECTS as a reference, Metro wants to continue working with local jurisdiction partners with whom the agency has already partnered with to improve speed and reliability. Metro also wants to form new partnerships with additional local jurisdictions and other agencies.

VARYING LEVELS OF INVESTMENT

METRO CONNECTS proposes different levels of investment to keep buses moving fast and reliably and benefiting transit riders. These levels include high-level investment features targeted to save over 20 percent of route travel time, such as new bus-only lanes and transit signal priority; medium-level investment features targeted to save 10 to 20 percent of route travel time, such as queue jumps, transit signal priority, and bus bulbs; and low-level investment features targeted to save 5 to 10 percent of route travel time, such as spot improvements at key locations.

PRIORITY ON FREQUENT SERVICE

While all of Metro's service types will receive some speed and reliability investments, the highest levels of speed and reliability investment will be focused where service is most frequent. Service that is less frequent, such as service in rural communities, will receive lower levels of speed and reliability investment. Capital investments should follow service improvements.

- New RapidRide lines will have the highest level of investment, with roughly half of service in bus-only lanes. Existing RapidRide lines and frequent service will benefit from extended and improved bus-only lanes and more speed and reliability features.
- Several express service lines will benefit from medium or low investment levels.
- Many local service lines will receive low-level investments.

IMPLEMENTATION

To achieve the vision, Metro plans to invest $2 billion in speed and reliability improvements over the next 25 years. Those investments will have to be leveraged with additional grant funding and in-kind partnerships with local jurisdictions to create a complete network of infrastructure that keeps transit riders moving.

Some of these investments may include but are not limited to:

- Incorporating transit speed and reliability improvement design elements in capital projects led by local jurisdictions.
- Studying and funding operational changes to reduce the amount of time buses are stopped in traffic or at stops, improving reliability.
- Increasing staffing and technology to monitor and adjust service in real time to maintain spacing between buses and respond to service disruptions.
- Using new technology applications to inform roadway users of alternative routing options during incidents in real time.
- Working with partners to improve incident response options that keep buses moving through delays, such as installation of temporary bus-only lanes.
- Making boarding faster and easier through off-board fare payment and other improvements.

1 King County Metro, METRO CONNECTS, page 32, accessed at http://www.kcmetrovision.org/wp-content/uploads/2016/08/Metro-Connects_Plan.pdf

- Investing in large regional projects that would benefit transit in partnership with others, such as bridge or highway crossings. An inventory of candidate projects would be maintained, including new transit pathways and service connections, major crossings (bridges, overpasses), and transit bottlenecks.
- Building on Metro's existing Intelligent Transportation Systems architecture to support both the management of vehicles on the road to make service faster and more reliable, and customer information tools that would make the system easier to use.

This guide provides a framework for how Metro and partner local jurisdictions can work together to plan, design, and build projects that work toward the visions of both METRO CONNECTS and local jurisdictions.

3.2.3 TYPES OF PROJECTS

Metro builds speed and reliability projects in different types of increments that make sense from operational and local jurisdiction perspectives. These include:

- Corridors,
- Spot improvements, and
- Hubs.

Metro has completed most of its projects as corridors or spot improvements. Regional hubs are a new way Metro is considering bundling improvements where a series of projects can improve service to a transit center or key destination.

METRO'S SPEED AND RELIABILITY PROJECTS

CORRIDORS
provide the opportunity to bundle a series of improvements along a pathway that is often home to multiple routes.

SPOT IMPROVEMENTS
generate quick fixes to transit speed and reliability issues that have emerged at specific points or segments along a route or corridor.

HUBS
are centers of activity such as a transportation center, a rail station, or a major destination where multiple routes converge. Speed and reliability improvements at hubs can enable the movement of a lot of people to and from a popular location.

CORRIDORS

A corridor is a physical pathway with one or more transit routes. Corridors provide the opportunity to bundle a series of spot improvements or corridor-long improvements along a pathway that is often used by multiple routes.

Corridors are attractive ways to build speed and reliability improvements because they:

- Provide an economy of scale for the process needed to build the improvements;
- Are a way for multiple jurisdictions to contribute and benefit from a coordinated set of improvements; and
- Often benefit multiple routes, especially for high-frequency corridors.

In accordance with METRO CONNECTS policy, Metro primarily considers corridors with frequent service, defined as a peak frequency of 15 minutes or better, for speed and reliability improvements. Metro employs a formal process to select its priority corridors for speed and reliability investments. Every few years, Metro analyzes the pathways its routes run along. The analysis focuses on identifying where problems exist in the system, where they might exist in the future, and where improvements might uphold social equity and geographic value.

Partner jurisdictions are very important to the corridor planning process. Metro uses the corridor analysis to provide actionable information to potential partner jurisdictions. When pursuing grants, Metro must coordinate with local jurisdictions and agencies and request letters of support. Because of the multiple benefits of corridor-wide improvements, corridors are good candidates for grant applications and have scored well in competitive grant processes

SPOT IMPROVEMENTS

Spot improvements are projects targeting specific points or short segments along a route or corridor. They are typically smaller improvements that generate quick fixes to transit speed and reliability issues that have emerged. The identification and addressing of spot improvements is generally a less formal process than the corridor process.

Metro typically generates spot improvement projects by feedback from bus operators, riders, or others. Metro works with the local jurisdiction or agency to analyze the transit and traffic conditions and whether the issue can be improved, as well as whether a similar type of issue has been addressed before.

Some cities have spot improvement programs of their own. For example, Metro has worked closely with the City of Seattle on over 20 spot improvements in 2016. Metro and Seattle define the problem together and jointly develop a solution and funding resources.

HUBS

Hubs, where multiple routes converge, present an exciting opportunity for speed and reliability improvements. These centers of activity, such as transportation centers, rail stations, and major destinations, provide a way to bundle improvements in a small area (a 1-mile radius of the center) to enable the movement of many people to and from a popular location. Hubs provide an opportunity to improve bus flow where there are high passenger loads and many converging routes, allowing benefits to be passed along to multiple jurisdictions.

Consequently, hubs can be a focal point of investment for a partnership of agencies and jurisdictions. Transit speed and reliability upgrades at hubs can complement other improvements such as pedestrian connectivity, sightlines, security, and passenger amenity projects to improve passenger experience.

3.3 PARTNERSHIP OPPORTUNITIES

3.3.1 THE METRO CONNECTS VISION AND LOCAL JURISDICTIONS

Local jurisdictions are essential partners in the METRO CONNECTS vision, both in developing projects and in pursuing transit-supportive growth and policies.

As part of METRO CONNECTS, Metro is expanding collaboration with local jurisdictions and stakeholders to improve transit through partnerships in a variety of areas: financial, land use and zoning, transit-supportive policies, traffic operations, transportation infrastructure and policies, and grant coordination as well as new and innovative kinds of partnerships.

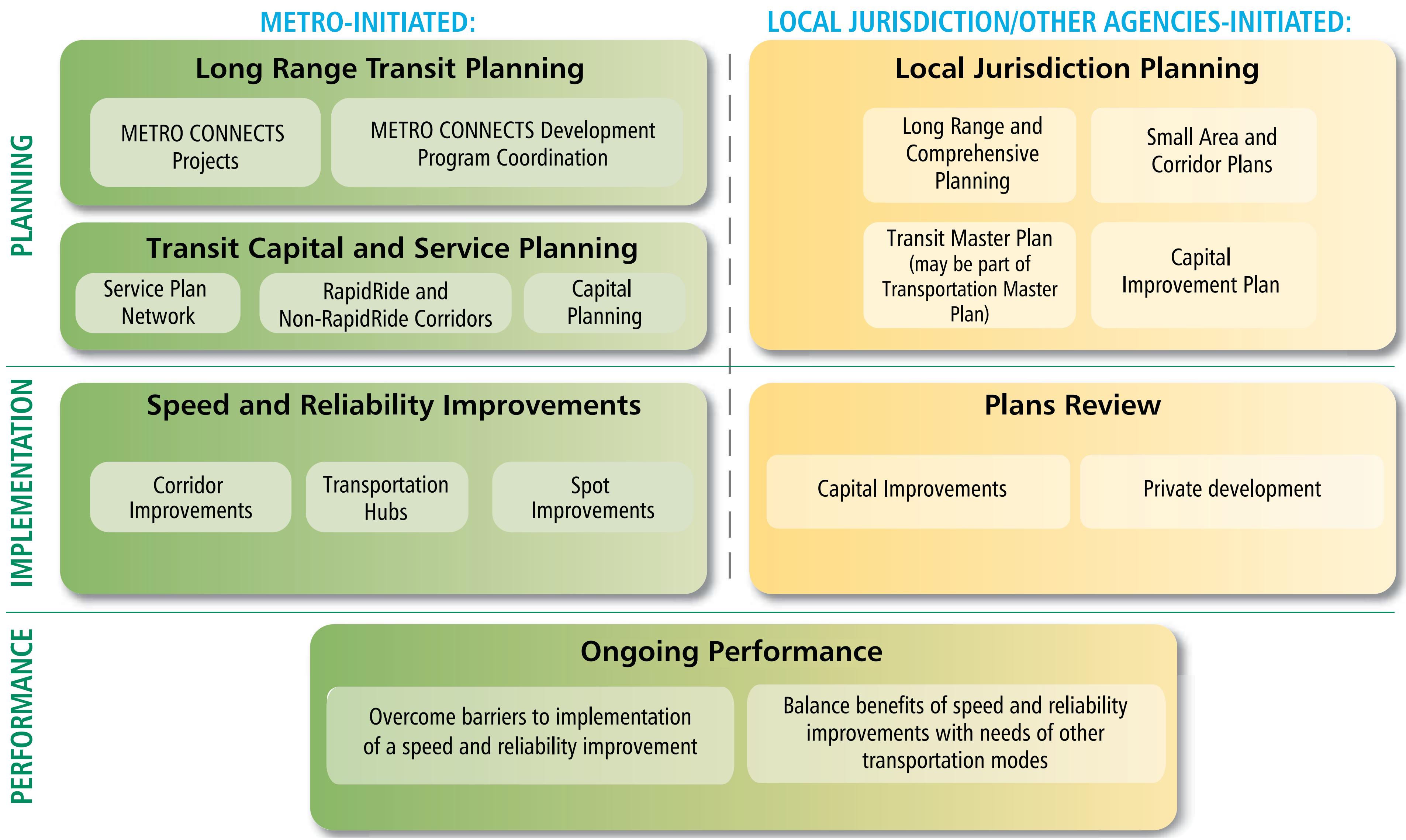
Partnerships for speed and reliability improvements are among the most important of these. The level of planned investment in speed and reliability in METRO CONNECTS requires Metro and local jurisdictions to work together at many different levels in an ongoing fashion.

3.3.2 OPPORTUNITIES TO PARTICIPATE IN AND SUPPORT SPEED AND RELIABILITY IMPROVEMENTS WITH METRO

Local jurisdictions have a range of opportunities to become involved in speed and reliability improvements. The initiation for partnerships may start from Metro or local jurisdictions. Metro may initiate collaboration with the local jurisdiction through transit and capital planning. Local jurisdictions may initiate collaboration with Metro in the development of a local transit master plan, long range plan, or capital plan. The goal of partnership is to plan and build infrastructure that will benefit all users as well as transit riders.

Within the partnership, the roles taken on by Metro and the local jurisdiction or other agency partner shift depending on what the opportunity is. While there are many ways for local jurisdictions to provide feedback and resources on efforts driven by Metro, there are also many ways for Metro to provide input and feedback on efforts driven by local jurisdictions and agencies. Both partners need to seek the input of the other in a wide range of situations that enable an effective transit system.

PARTNERSHIP OPPORTUNITIES



To get involved in any of these opportunities, follow the process described in SECTION 3.3.4.

LOCAL JURISDICTION/OTHER AGENCIES-INITIATED

LOCAL JURISDICTION PLANNING

Local jurisdiction's role: Implementation lead on local transit-related policy such as transit-supportive land use policy changes, identification of speed and reliability corridors and hubs, as well as networks of transportation modes that complement transit.

Metro's role: Collaboration in early phases and input throughout the planning process.

Long Range and Comprehensive Planning

Long-range plans, such as comprehensive plans and transportation master plans, can set the vision for transit service level and priority. This can happen both through policy language and the identification of important transit corridors and other areas for prioritized transit investment. Identifying these corridors and areas for transit can help the local jurisdiction and Metro create a foundation for reliable and fast transit service through policy.

Small Area and Corridor Plans

Medium-term plans for neighborhoods, districts, and corridors within communities can guide the integration of transit into the community. These plans can identify ways in which transit can complement future investments, such as how transit streets and streets geared to other modes complement one another.

This scale of plan also matches the scale at which Metro typically plans speed and reliability improvements. Jurisdictional corridor plans can coordinate with Metro's prioritized corridors; communities can collaborate with Metro to incorporate speed and reliability recommendations. This level of planning can help avoid future mode conflicts along high-frequency transit routes.

Transit Master Plan

A local jurisdiction can create a master plan specifically for transit. A transit master plan sets key transit policies; identifies priority corridors, hubs, and districts for transit; and recommends other transit-supportive infrastructure, amenities, and policies.

Capital Improvement Plan (CIP)

A local jurisdiction's capital improvement plan defines and prioritizes infrastructure projects. These projects often have implications for transit speed and reliability and also provide opportunities to include speed and reliability components.

PLANS REVIEW

Metro's role: Convey existing or potential future speed and reliability issues or opportunities within or around project areas.

Local jurisdiction's role: Actively solicit Metro's input on development entitlements and capital improvement project plans. Jointly seek opportunities to incorporate transit speed and reliability improvements into capital projects that would benefit transit riders who live in the jurisdiction.

Capital Improvements

When cities plan, program, and build capital improvements, they can work with Metro to include, complement, or avoid preclusion of speed and reliability improvements. One of the challenges of building speed and reliability improvements is fitting a change into a street with many other demands; integrating transit speed and reliability into a street design from the beginning can avoid costly and difficult retrofit projects and troubleshoot side effects.

Private Development

Similar to capital improvements, private development often provides opportunities to integrate transit speed and reliability into the circulation networks of new projects. New development may also pose challenges to transit operations that communities can work through with Metro.

The Bellevue Transit Master Plan, which provides Metro and the City of Bellevue the foundation for partnering on speed and reliability improvements along key corridors, was adopted by the City Council In July 2014. The plan establishes scalable short- and long-term strategies, and identifies projects that will foster a high-quality transit system that meets Bellevue's needs through 2030, connecting more people to more destinations in less time. An example of a partnership opportunity identified in Bellevue's Transit Master includes the Bellevue College Connector, which would improve transit service and reduce travel times between Bellevue College and the Eastgate Park and Ride. The Bellevue Transit Master Plan is available at https://www.bellevuewa.gov/transit-master-plan.htm.

METRO-INITIATED

LONG-RANGE TRANSIT PLANNING

Metro's role: Long-range transit planning

Local Jurisdiction Role: Input on long-range transit planning

METRO CONNECTS Projects

Local jurisdictions can provide input and collaborate on the plans and projects that will implement METRO CONNECTS.

METRO CONNECTS Development Program Coordination

The METRO CONNECTS Development Program will be a rolling six-year program that will focus on internal coordination and collaboration with local jurisdictions.

TRANSIT CAPITAL AND SERVICE PLANNING

Metro's role: Transit planning

Local jurisdiction's role: Input on transit service planning

Service Plan Network

Metro closely coordinates service plans with cities and public transportation agencies to achieve the METRO CONNECTS vision. Metro follows its Service Guidelines for restructuring, which include a detailed planning and community outreach process. Participating in coordinated service planning can ensure routes that will have the long-term support of the community and help reinforce speed and reliability in the future.

RapidRide and Non-RapidRide Corridors

Existing and planned RapidRide lines are a special type of corridor opportunity for communities and Metro to work together on. With partners, Metro invests in speed and reliability improvements in all existing and future RapidRide corridors.

Capital Planning

Metro's capital planning includes developing corridors, hubs, spot improvements, technology, and partnership with private providers. Metro, Sound Transit, and local partners have started to identify where major investments are needed to remove bottlenecks on corridors that have many riders and are slated for Bus Rapid Transit (BRT) service.

SPEED AND RELIABILITY IMPROVEMENTS

Metro's role: Prioritize high-ridership corridors for speed and reliability capital investments and work closely with local jurisdictions to plan, design, and implement. Support local jurisdictions to incorporate future changes that will benefit local communities as well as transit riders.

Local jurisdiction's role: Collaborate with Metro and seek opportunity to incorporate transit improvements in existing or planned capital projects. Support Metro in planning, design, and construction of improvements to benefit all users as well as transit riders.

These processes are described in SECTION 3.2.3 and SECTION 3.3.4.

ONGOING PERFORMANCE

Metro's role: Monitor transit performance and ridership. Evaluate the effectiveness of speed and reliability improvements and coordinate with local jurisdiction to make operational adjustments as necessary. Work with local jurisdictions to develop the key performance index for monitoring and evaluation for public benefit as well as transit riders.

Local jurisdiction's role: In most cases, local jurisdictions own and maintain the roadway and signal infrastructure. Local jurisdictions will continue to maintain the assets. Coordinate with Metro to develop a key performance index for monitoring and evaluating the speed and reliability improvement.

BALANCE BENEFITS OF SPEED AND RELIABILITY IMPROVEMENTS WITH NEEDS OF OTHER TRANSPORTATION MODES

Local jurisdictions are critical in helping to balance the benefits of a speed and reliability project with the needs of other transportation modes, such as the amount of parking to be provided or the design and location of a bicycle route.

OVERCOMING BARRIERS TO IMPLEMENTATION OF A SPEED AND RELIABILITY IMPROVEMENT

Support for the speed and reliability improvement should be at all levels of Metro and local jurisdiction staff. The process to build support begins with the planning process with city managers and representatives through METRO CONNECTS and the Development Program. Support throughout the project level, concept development, and design will streamline implementation. Local jurisdictions are also critical to helping Metro improve the general perception of speed and reliability improvements among the public. Public outreach and communication to the public are important components in ensuring project success. The level of public outreach needed will depend on the project; some speed and reliability improvements will require a more rigorous outreach process than others. Local jurisdictions and Metro should work together in developing communication materials as well as planning and conducting public facing events. Resources for building continued partnerships with Metro are described in SECTION 3.3.3.

3.3.3 RESOURCES AND CONSTRAINTS FOR BUILDING TRANSIT PARTNERSHIP

Jurisdictions throughout the region vary in their abilities to apply resources to speed and reliability projects. Yet every local jurisdiction and county has the ability to form an effective partnership with Metro.

The key is to understand how to best leverage the resources a local jurisdiction does have. These resources include staff: how many engineers, planners, and other professionals are on staff to analyze issues, define solutions, and craft and review plans and projects? Is there staff dedicated to transit performance? Resources also include local policies that support speed and reliability: Does a local jurisdiction have a transit master plan, or the capacity to create one? What is the priority for transit within how a local jurisdiction manages its streets? They include financial resources for studies and construction.

On top of the opportunities described in the above SECTION 3.3.2, the following offers additional guidance for cities with different levels of these resources.

HIGHER RESOURCE JURISDICTIONS

Opportunities for jurisdictions with staff dedicated to transit performance, resources to plan and execute projects, and extensive experience with speed and reliability projects are focused on working with Metro to implement their transit master plans as well as refinement of the coordination between jurisdiction staff and Metro. These could include:

- Implement local jurisdiction transit master plan as joint partnership
- Coordinate speed and reliability processes
- Convene regular speed and reliability improvement working group
- Innovate/test new speed and reliability concepts
- Concurrence on goals of local jurisdiction transit master plan

MEDIUM RESOURCE JURISDICTIONS

Opportunities for jurisdictions with some capacity to plan and execute transit projects and some experience with speed and reliability projects are focused on leveraging this capacity and growing this experience. These could include:

- Develop transit master plan in coordination with Metro
- Expand range of speed and reliability tools being employed
- Integrate speed and reliability review into local jurisdiction-driven plans and projects
- Articulate trade-offs between transit and other community aspects
- Increasing community awareness of speed and reliability improvements

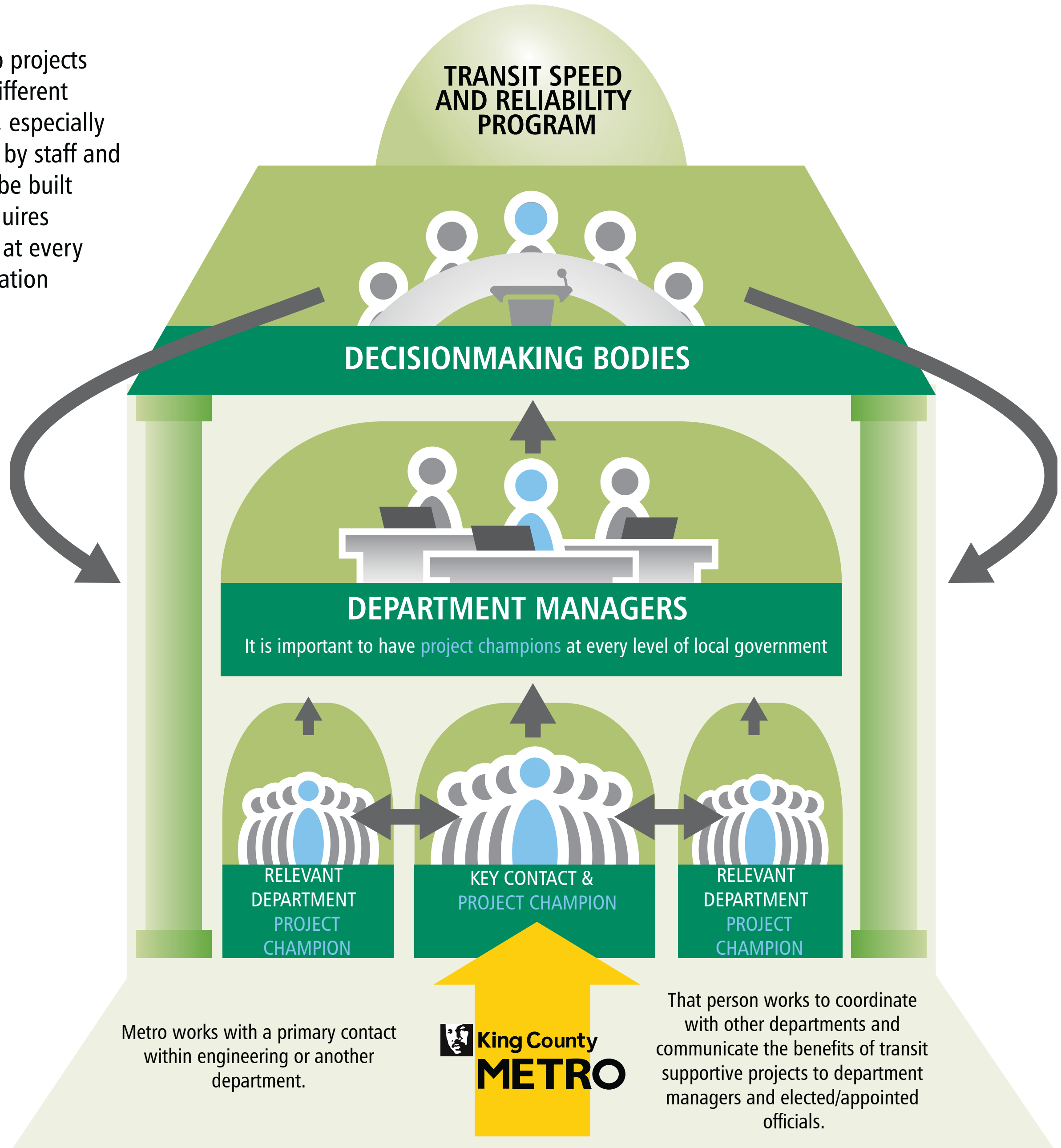
LOWER RESOURCE JURISDICTIONS

Opportunities for jurisdictions with limited resources for transit and no speed and reliability improvement experience are focused on introducing the idea of speed and reliability improvements into the jurisdiction’s dialogue among staff, elected officials, and throughout the community.

- Do a pilot speed and reliability project with Metro
- Invite review from Metro of capital projects potentially affecting speed and reliability
- Begin a community conversation about transit

BUILDING CONSENSUS

Transit speed and reliability partnership projects will benefit from a consensus among different departments and levels of government, especially when a local jurisdiction is constrained by staff and funding resources. This consensus can be built in all sizes of local jurisdictions, but requires champions for transit and transit riders at every level of government, and close coordination among different departments. It is vital to spread awareness of the impact, importance, and overall benefit to the public of speed and reliability projects throughout local government—this awareness will help to build a consensus.



3.3.4 HOW TO WORK WITH US: THE PARTNERSHIP PROCESS

GUIDING PRINCIPLES

A number of guiding principles can enable successful partnering with Metro to implement speed and reliability improvements.

PEOPLE
A single point of contact is critical to have within a local jurisdiction or agency. Internal coordination and communication is just as important as coordination between Metro and the local jurisdiction.

LONG-TERM VIEW
Transit and the jurisdictions and riders it serves will be better off if speed and reliability improvements are incorporated on an ongoing basis rather than implemented once there is a known problem. Long-term and coordinated planned improvements set the stage for successful speed and reliability streets and traffic operations that complement other users.

BE PROACTIVE
Both Metro and local jurisdictions should be proactive in involving one another in decisions affecting transit service and speed and reliability.

HIGH-FREQUENCY
METRO CONNECTS is heavily focused on improving the speed and reliability of high-frequency routes (RapidRide and non-RapidRide); the speed and reliability of RapidRide and other high-frequency routes in particular provide major local jurisdiction and rider benefits.

COMMON SOLUTIONS
Work together with the different stakeholders and riders to develop a solution everyone is interested in implementing.

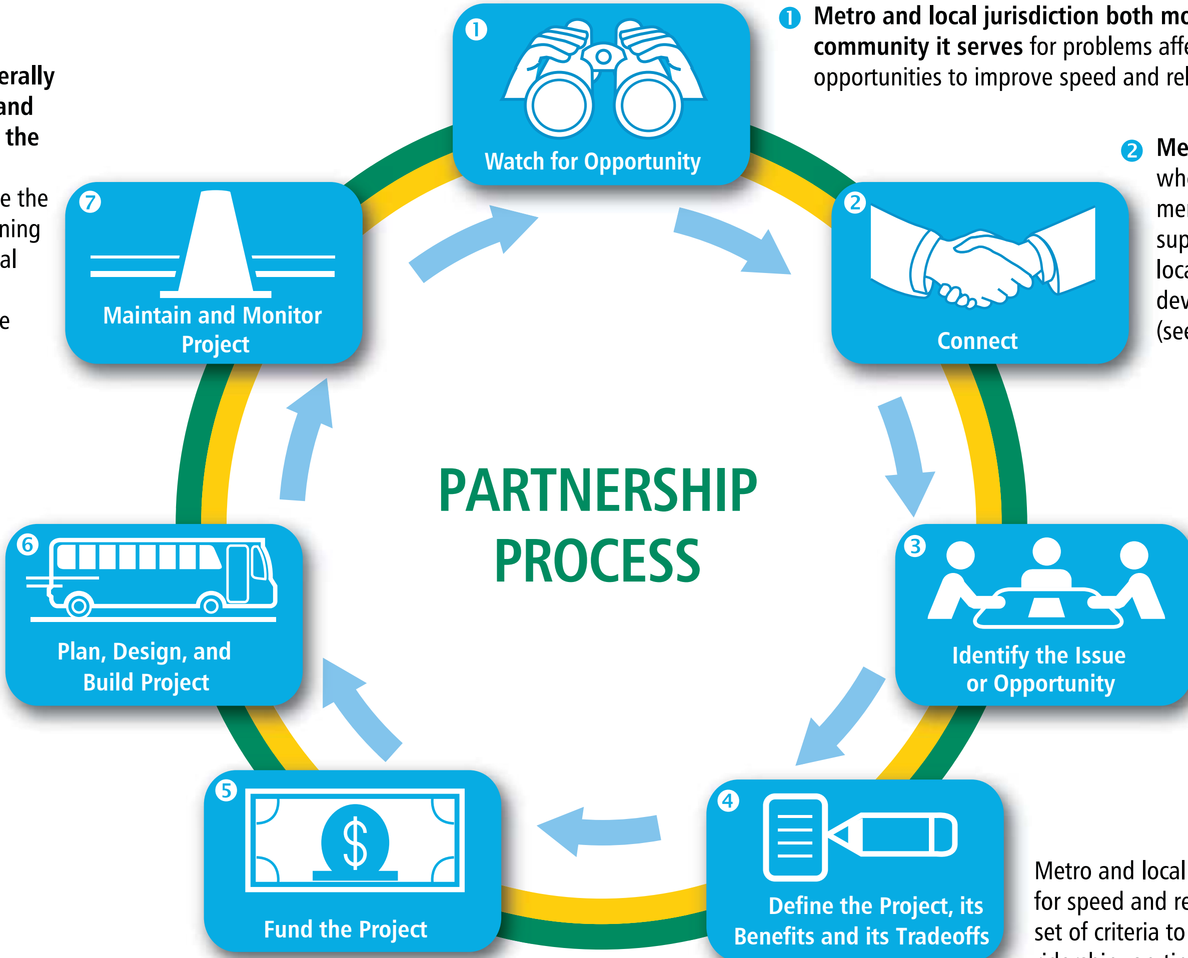
EQUITY AND GEOGRAPHY
Metro and METRO CONNECTS emphasize investments in social equity and regionally important centers of activity.

LOOK AT THE LOCAL TRADE-OFFS
Consider what trade-offs the jurisdiction and local transit riders are likely to be able to live with. Trade-offs should be considered as they relate to the purpose and need of the project. These trade-offs are framed in the TOOLBOX section of this document.

CONSIDER A WIDE RANGE OF TOOLS
Use this guide to help you select the right tool for the right situation.

PROCESS
OVERVIEW

Implementing speed and reliability projects is most effective when Metro, partner local jurisdictions, and other stakeholders work within a common process. This process is a cycle of jointly identifying issues, developing solutions, implementing the solutions, and monitoring performance. Use the FRAMEWORK FOR PARTNERSHIP and TRANSIT SUPPORTIVE STRATEGIES sections of this document to identify issues, opportunities, and solutions at different points of the process.



1. **Metro and local jurisdiction both monitor the transit network and greater community it serves** for problems affecting speed and reliability, as well as opportunities to improve speed and reliability.

2. **Metro and local jurisdiction contact one another** when an issue or opportunity arises. A lead staff member serves as a point person for gaining support from other departments. Both Metro and local jurisdiction are planning for future growth and development and not only responding to problems (see SECTION 3.3.2).

3. **Metro and local jurisdiction jointly identify the opportunity, problem, or issue.** The Metro contact will convene key members from both Metro and the local jurisdiction. A lead staff member then serves as a point person to foster and oversee the planning process.

4. **Metro and local jurisdiction jointly identify solutions to address the issue** - whether working together at a higher policy level, monitoring the issue, or pursuing a speed and reliability project. If the desired solution is a project, both partners define the project.

   Metro and local jurisdiction **identify the project benefits** - both for speed and reliability and for local goals. Metro uses a broad set of criteria to analyze priority for improvements such as speed, ridership, on-time performance, social equity, and the lifespan of the improvement.

   Metro and local jurisdiction also **identify the project tradeoffs** - usually how to balance the benefits of the improvement with other modes and the built environment.

5. **Metro and local jurisdiction will explore grant funding options.** Grant offices from each agency will provide funding strategies and work closely to provide a letter of support.

6. Metro and local jurisdiction staff work with stakeholders to properly **plan, design, review, and build the project**. Metro and local jurisdiction jointly develop a work plan. In some cases, Metro requires an acceleration of the permit process. When possible, Metro prefers that local jurisdiction crews construct the project.

7. **Local jurisdictions generally own the right-of-way and equipment invested in the speed and reliability improvements** and have the responsibility of maintaining them. Metro and the local jurisdiction continue to monitor the effects of the project.

LOCAL JURISDICTION ROLES AND RESPONSIBILITIES

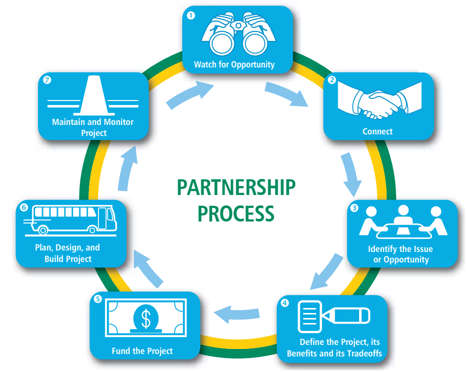
The table below outlines the roles and responsibilities of local jurisdiction planning and engineering departments when working with Metro on speed and reliability projects.

	Watch for Opportunity	Connect	Identify the issue or opportunity	Define the project, its benefits, and trade-offs	Fund the project	Plan, design and build the project	Maintain the project
COMMON TASKS	• Monitor roadway performance for all modes of transportation along frequent transit route corridors. Seek potential capital investments that will benefit communities as well as transit riders.	• Designate a lead staff person to be the main contact to partner with Metro.	• Work to jointly identify issue or opportunity.	• Work with team to define project parameters; planning study to determine potential improvements and benefits.	• Seek funding options.	• Review policy to facilitate future changes.	• Maintain operational changes and reevaluate its effectiveness.
PLANNING	• Monitor development plans and review for opportunities. • Identify any projects occurring along a frequent transit corridor and discuss possible partnership opportunities with Metro.	• Point person coordinates with Planning as to who will be the point person to work with Metro.	• Bring knowledge of transportation system and community goals and plans to discussion.	• Measure project against relevant planning documents and codes to determine feasibility and compatibility with jurisdiction goals.	• Provide letter of support for grant funding opportunities. • Identify any local agency funding sources available for transit improvements • Execute funding agreement.	• Coordinate agency review and approval of design plans. • Jointly conduct community outreach. • Develop a work plan or timeline for implementation.	• Monitor whether benefits of the project (i.e. transit performance) are maintained.
ENGINEERING	• Monitor Capital Improvement Plan (CIP) for transit speed and reliability opportunities.	• Point person coordinates with Engineering as to who will be the point person to work with Metro.	• Bring knowledge of infrastructure, transportation system, and traffic operations to discussion. • Identify any operational constraints or challenges within the project area.	• Measure project against city standards for capital improvements and traffic operations to determine feasibility. • Determine where project could fit into CIP.	• Provide supporting information needed to develop cost estimates.	• Review, provide inputs, and approve design plans. • Identify project elements that can be designed and constructed using City crews.	• Roadway/traffic improvements typically become assets of the local agency. • Add new improvements to agency's regular O&M programs.

METRO FUNDING TIMELINE

The following presents a timeline of coordination among Metro and local jurisdictions and agencies to set priorities, plan projects, and request funding for speed and reliability projects. Once the budget is approved, project planning, construction, and delivery can take up to 3 years to complete a corridor project and up to 1 year to complete a spot improvement.

Note that if Metro and partners miss this project cycle, Metro can continue working with a local jurisdiction or agency while looking for other opportunities such as grant funding.



9 - 12 months | *12 - 18 months* | *submittal in April/May of even year*

Long Range/ Regional Planning and Metro Identification of Corridors

3 IDENTIFY THE ISSUE OR OPPORTUNITY

Metro and local jurisdictions both work to identify priority corridors and other areas for transit speed and reliability improvements.

4 DEFINE THE PROJECT, ITS BENEFITS, AND ITS TRADEOFFS

Metro and local jurisdictions work together to develop, evaluate, and prioritize potential corridor projects.

5 FUND THE PROJECT

Metro prepares budget submittal with prioritized speed and reliability projects.

Budget submittal

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4. TRANSIT SUPPORTIVE STRATEGIES

The *Transit Supportive Strategies* section describes the different types of issues that can be solved with transit supportive treatments, and provides guidance on each of the strategies, how they are implemented, and what types of barriers or side effects may be associated with each strategy.

4.1 PROBLEMS ADDRESSED BY SPEED AND RELIABILITY TOOLS

There are a number of different roadway, intersection, and/or built environment problems that can impact both transit speed and reliability. Identifying what those problems are is the first step in selecting which tool or combination of tools can be implemented to address those issues. The sections below summarize typical issues that can impact bus travel time and reliability.

4.1.1 CONGESTED INTERSECTION WITH GENERAL TRAFFIC DELAY

A congested intersection with general traffic delay can occur when:

- Inefficient signal timing plans create unnecessary bus delay, such as lead/lag phasing, unused green time, and uncoordinated corridors.
- Intersection demand is higher than the capacity provided, even with optimal signal timing.
- Transit operators must respond to riders' questions on where the bus is going or what is the fare policy.

4.1.2 DELAY TURNING RIGHT

Delay for buses turning right can occur when:

- High pedestrian demand in the crosswalk of the receiving lane prevents a bus from turning right.
- The bus is behind a queue of vehicles attempting to turn right caused by a congested receiving lane.
- There is a tight turning radius of intersection that requires slower turning speeds for the bus.

4.1.3 DELAY TURNING LEFT

Buses can experience delay turning left when:

- A short protected left-turn phase results in the bus waiting for a majority of the signal cycle.
- The demand of left-turning vehicles is higher than the length of the protected left-turn signal phase, which causes a bus to miss a protected left-turn signal phase.
- The demand of left-turning vehicles is higher than the left-turn storage length, or the receiving lane may be over capacity, causing delay for the bus before the movement is completed.
- High opposing vehicle demand limits the number of gaps available to turn at an intersection with a permissive left-turn phase.
- High pedestrian demand in the crosswalk of the receiving lane restricts permitted left-turn movements.

4.1.4 CONGESTED FREEWAY ON-RAMP

Delay for buses on a congested freeway on-ramp can occur when:

- Excess demand along access ramps to a freeway causes delay for buses attempting to enter the freeway.
- Upstream intersections are affected by the congested on-ramp because queues restrict turning or through movements.

4.1.5 PEDESTRIAN TRAFFIC CONFLICTS

Pedestrian traffic conflicts can cause delay for buses when:

- High pedestrian demand in the crosswalk of the receiving lane prevents a bus from turning.

4.1.6 BICYCLE TRAFFIC CONFLICTS

Bicycle traffic conflicts can cause delay for buses when:

- High bicycle demand in the crosswalk of the receiving lane prevents a bus from turning.
- High bicycle use in a bus-only lane that requires buses to slow down.

4.1.7 BUS ZONE DWELL TIME

Buses can experience delay from increased dwell time at bus zones when:

- Higher ridership increases the amount of time it takes to complete all boarding and alighting at a bus zone.
- Congested aisles on the bus constrict the efficient boarding and alighting of passengers.
- Higher demand for a bus zone causes a bus to wait for a prior bus to board and alight its passengers.

4.1.8 DELAYS LEAVING A STOP

Buses can experience delay when attempting to reenter the traffic stream after serving a stop when:

- Stops are provided out of the travel lane on higher traffic streets, which can make merging back into the travel lane difficult because gaps in traffic may be minimal.

4.1.9 GROWTH IN RIDERSHIP

Although ridership growth benefits the transit agency and regional mobility, it can create delays when:

- Dwell time increases due to additional boarding delay and congested aisles that constrict the efficient boarding and alighting of passengers.

4.1.10 INEFFICIENT ROUTE DESIGN

Route design can impact bus speed and reliability when:

- A higher frequency of stops increases the dwell time due to additional acceleration, deceleration, and time required to open and close the doors.
- Inefficient route design that incorporates unnecessary turns creates turning delay.

4.1.11 SIGNAL DELAY

Buses can experience delay at signals when:

- Inefficient signal timing plans create unnecessary bus delay, such as lead/lag phasing, unused green time, uncoordinated corridors, and a disconnect between where the stop is and how the timing serves that stop.
- Buses cannot take advantage of signal coordination due to a bus stop being located between signals.

4.1.12 CONGESTED ROADWAYS

Congested roadways can reduce transit speed and reliability when:

- A roadway operates above its capacity, either due to intersection capacity constraints or physical roadway constraints. Traffic queues are common through these bottlenecks.

4.1.13 OTHER TRAFFIC-RELATED DELAYS

Other traffic-related issues can increase bus delay when:

- A lack of turn-only lanes impede through movement of buses.
- Speed humps or other traffic calming improvements cause additional deceleration and acceleration for buses.
- Bicycle lanes require buses to yield through movements or turning movements on heavily used bicycle corridors.

4.1.14 INADEQUATE BUS ZONE CAPACITY

Buses can experience delay at bus zones when:

- Lack of rear door bus pads requires passengers to use the front door to board and deboard, increasing dwell times.

4.2 STRATEGIES TO OVERCOME BARRIERS AND SIDE EFFECTS

SOURCES: TCRP 183 | NACTO URBAN DESIGN GUIDE | TCRP 118 | TCQSM 3RD EDITION

LOCAL JURISDICTION PRIORITY FOR TRANSIT

Occasionally, transit mode share is not a high priority in a local jurisdiction. With METRO CONNECTS, Metro is expanding its partnership with local jurisdictions to benefit more communities with its transit service and capital investments. In forming or renewing a partnership with a local jurisdiction, the following approaches may be applied:

- Provide education to the public and partner agencies on the costs and benefits of speed and reliability improvements
- Demonstrate a need for transit or improving other modes of transportation through discussions of capacity and right-of-way constraints
- Include traffic analysis in proposals for capital projects
- Review peer knowledge and case studies from similar regions
- Identify transit-funding opportunities that may align with non-transit investments
- Encourage partnerships with communities that are more open to working with transit agencies, and then use that experience to gain the trust of other jurisdictions

PARKING REMOVAL

Parking removal is one method to leverage existing right-of-way to implement a bus lane as well as bus facilities such as bus bulbs, bus pull outs, bus islands, and bus stops. This is done in order to reduce the overall cost by limiting or eliminating the need to purchase right-of-way for speed and reliability investments.

However, Metro with a local jurisdiction partner will need to engage stakeholders who will be affected due to the parking removal. The removed parking could be relocated to side streets while incorporating a time limit to the parking space to improve parking turn-over. Documentation of the existing and future on-street parking demand and supply can assess the feasibility of relocating parking within a transit corridor. Additional strategies include relocating the parking to another location by converting a general purpose lane to parking.

Additionally, if the data are available, both the local jurisdiction and Metro may conduct a study demonstrating that transit may bring more pedestrians to a storefront than drivers parking in front of the store. Consideration should be given to the need for freight deliveries by assessing alternative locations, such as alleyways, side streets, and parking lots. If needed, a parking utilization and turnover study could be completed by the local jurisdiction or jointly with Metro.

TRAFFIC OPERATIONS

Balancing the needs of other roadway users with speed and reliability benefits for transit will need to be considered when implementing many of the tools. Local jurisdictions implementing transit-supportive strategies will need to determine how local streets and roadways can best accommodate all modes of travel. Acceptable changes in general purpose traffic operations will need to be determined by the local jurisdiction and communicated with Metro. The local jurisdiction and Metro can work together to develop strategies to provide transit benefits while maintaining operations for other roadway users at an acceptable level.

For example, transit signal strategies at intersections can be modified in a number of ways to balance general purpose traffic operations while providing improvements to transit speed and reliability. Modifications can include, but are not limited to, different prioritization schemes depending on peak direction of travel and/or passenger load and on-time performance of different routes. Local jurisdictions may also want to consider using different metrics to evaluate intersection operations, such as using person delay instead of vehicle delay.

Boarding and alighting at bus stops also cause delays to general purpose travel. To reduce the delay, several strategies can be incorporated to mitigate delays that include:

- Platform level boarding and alighting
- Off-board fare payment
- Bus islands or bus pull outs to separate buses from general purpose travel

STREETSCAPE REMOVAL/ALTERATION

Similar to the removal of parking, streetscape removal is done to leverage existing right-of-way to implement a bus lane as well as bus facilities, such as bus bulbs, bus pull outs, bus islands, and bus stops. This is done in order to reduce cost and remove the need to widen an existing roadway.

However, removal of streetscape comes into conflict with other modes, such as bicyclists and pedestrians, and also removes the aesthetic element of a street. If streetscape needs to be removed or altered, some elements could be kept to provide a similar level of comfort for bicyclists and pedestrians on a roadway:

- Accessible paths and slopes
- Lighting
- Availability of shade
- Active ground floor uses
- Street furniture (i.e., street poles can be used to create a visual and physical buffer between vehicles and pedestrians)

BALANCING PEDESTRIAN COMFORT VERSUS TRANSIT MOBILITY

Transit speed and reliability improvements may at times conflict with pedestrian needs. This can occur when roadway widths are widened to accommodate queue jump lanes and bus-only lanes, and when signal priority extends the waiting time for pedestrians looking to cross the main transit corridor. Wider roadway widths that necessitate longer pedestrian crossing times may be mitigated by updating signal timing plans that seek to balance both pedestrian and transit needs. This may involve specifying that a pedestrian crossing phase occurs at a time immediately after a transit signal priority call or by providing a safe median pedestrian refuge in order to balance the competing timing requests for both transit route directions.

DESIRE FOR BICYCLISTS AND BICYCLE FACILITIES TO SHARE SPACE WITH TRANSIT

Bicycle facilities that are parallel or near transit facilities can enhance their effectiveness. Bicycle lanes can be incorporated into transit infrastructure to provide access to both modes of transportation. The preferred design strategies would include separated bikeways or bicycle routes along the roadway or along a nearby parallel street. However, when no space is available for dedicated bikeways, a shared bus-bicycle lane strategy can be implemented. This strategy can be implemented when buses are traveling at relatively low speeds with medium headways. Co-location of transit stops with bicycle racks, bicycle storage facilities, and bicycle sharing stations can improve both modes of transportation as it allows for better connectivity and integration between modes.

LACK OF ADEQUATE FUNDING

With constrained funding for speed and reliability improvements, local jurisdictions should focus on operational modifications and changes to existing equipment rather than capital improvements. Transit signal priority would require additional investment when compared to signal timing strategies for improving traffic flow. Lower cost signal timing strategies include:

- Retiming the signal to reduce delay to through traffic (and thereby the bus movement)
- Reducing intersection cycle lengths
- Allocating more green time to approaches used by buses

Converting a general purpose lane to a bus-only lane at certain times of the day would not require substantial capital investment. Loss of traffic capacity may be accepted as long as there is support from the local jurisdiction politically.

PUBLIC SUPPORT

Public support for transit speed and reliability improvements varies from project to project. More education can be provided so the public can better understand the benefits of the improvements and recognize that there will be trade-offs.

ENFORCEMENT

Some transit improvements are more successful if there is adequate enforcement. For bus lanes, enforcement helps prevent use by general-purpose vehicles and improves transit travel speeds and reliability.

4.3 TOOLBOX

The *Toolbox* section is organized into four major categories:

- Bus Operations tools,
- Traffic Control tools,
- Infrastructure tools, and
- Transit Lane tools.

The Speed and Reliability Toolbox provides a high level introduction to each of the tools. More in-depth information can be found in the Transit Cooperative Research Program (TCRP) *Report 183* and National Association of City Transportation Officials (NACTO) *Transit Street Design Guide*. The tools are shown in order of the least complex to the most complex to implement. Each tool is summarized individually and includes implementation guidance and examples that have been completed throughout the county (the list of examples included is not exhaustive). The matrix shown on the adjacent page can be used to identify which tools can be used to address each of the issues discussed in SECTION 4.1. The estimated level of cost (low, medium, high) and level of coordination with Metro (low, medium, high) are summarized in the matrix as well. Many of the tools can and should be used in combination with others to improve their effectiveness.

When prioritizing speed and reliability projects for investment, Metro will work in coordination with local jurisdictions to evaluate projects using metrics including but not limited to:

- Person throughput: the number of people that can be moved through a roadway segment
- Person delay: the amount of delay per person at an intersection
- Intersection level of service: the amount of delay vehicles experience at an intersection (on a scale of A-F)
- Vehicle queues: the length of vehicles waiting at an intersection due to the roadway use exceeding capacity
- Project cost: the cost to construct the project
- Ease of construction: the complexity to construct the project
- Consistency with local and regional policy: how well the project fits within local and regional policy
- Travel time reduction: changes in transit travel time in corridor
- Reduction in potential collisions and conflicts with other modes of transportation: how the improvement may reduce potential conflicts
- Community support: the level of community support for the improvement
- Consistency with local transit master plans: how well improvements align with local jurisdiction transit master plans, if applicable

PROBLEM

1. CONGESTED INTERSECTION
2. DELAY TURNING RIGHT
3. DELAY TURNING LEFT
4. CONGESTED FREEWAY ON-RAMP
5. PEDESTRIAN TRAFFIC CONFLICTS
6. BUS ZONE DWELL TIME
7. DELAYS LEAVING A STOP
8. GROWTH IN RIDERSHIP
9. INEFFICIENT ROUTE DESIGN
10. SIGNAL DELAY
11. CONGESTED ROADWAYS
12. OTHER TRAFFIC-RELATED DELAYS

COSTS KEY

$: LESS THAN $50, 000

$$: $50,000 - $100, 000

$$$: $100,00 - $250,000

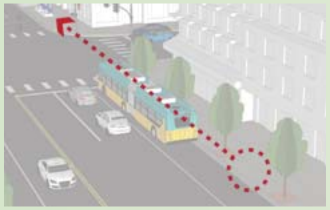
$$$$: $250,000 OR MORE

* requires striping only
** requires right-of-way acquisition

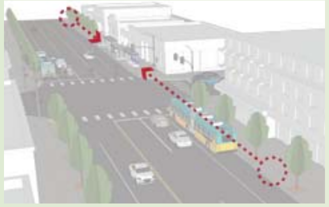
PROBLEM	1	2	3	4	5	6	7	8	9	10	11	12	LEVEL OF COST		LEVEL OF COORDINATION
BUS OPERATIONS TOOLS															
Stop Relocation	X						X		X	X			$		High
Stop Consolidation							X		X				$ - $$		High
Route Design									X	X	X		$		High
TRAFFIC CONTROL TOOLS															
Movement Restriction Exemption									X	X			$		Low
Turn Restrictions	X				X					X		X	$		Low
Yield to Bus							X						$ - $$		Low
Passive Traffic Signal Timing Adjustments	X	X			X					X			$ - $$		Medium
Phase Reservice										X			$ - $$		Low
Reverse Queue Jump							X						$$		Low
Transit Signal Priority	X		X							X	X		$$ - $$$		High
Transit Signal Faces		X	X		X								$		Low
Bus-Only Signal Phase		X	X		X					X			$ - $$		Low
Queue Jumps	X	X	X	X	X		X				X		$ - $$		Medium
Pre-Signals	X	X	X		X						X		$$ - $$$		Low
Traffic Signal Installed for Buses Only												X	$$$		Medium
Signal Phase Modification	X	X			X					X			$ - $$		Low
INFRASTRUCTURE TOOLS															
Speed Hump Modifications												X	$ - $$		Low
Bus Stop Lengthening						X		X					$ - $$		High
Bus Bulbs							X						$$ - $$$		High
Boarding Islands						X	X						$ - $$$		High
Roadway Channelization and Signage		X									X		$		Low
Parking Removal/ Alterations											X		$		Low
Turn Radius Improvements		X											$ - $$		Low
TRANSIT LANE TOOLS													Low*	High**	
Bus Lane, General	X	X	X	X			X				X	X	$	$$$$	High
Curbside Bus Lane	X	X		X			X				X	X	$	$$$$	High
Interior (Offset) Bus Lane	X	X		X			X				X	X	$	$$$$	High
Left-Side Bus Lane	X		X	X			X				X	X	$	$$$$	High
Queue Bypass (Short Bus Lane)	X	X	X	X	X		X				X	X	$	$$$$	High
Median Bus Lane	X			X			X				X	X	$	$$$$	High
Contraflow Bus Lane	X			X			X				X	X	$	$$$$	High
Reversible Bus Lane	X			X			X				X	X	$	$$$$	High

4.3.1 BUS OPERATIONS

This section describes the tools that improve speed and reliability through stop location and spacing and/or changes to route design.



4.3.1.1 STOP RELOCATION



4.3.1.2 STOP CONSOLIDATION

4.3.1.3 ROUTE DESIGN

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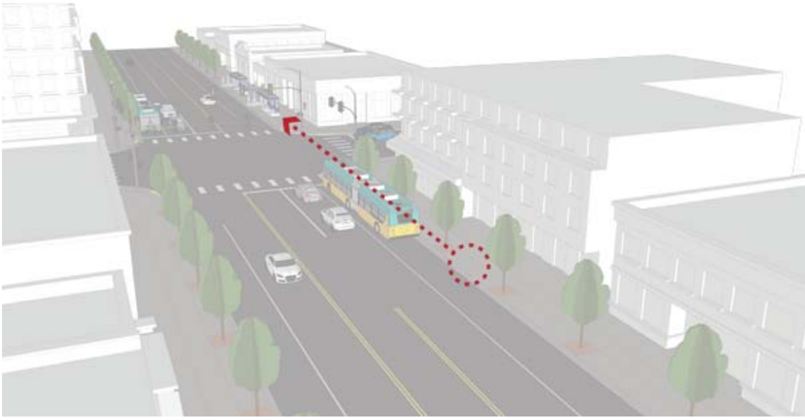
4.3.1.1 STOP RELOCATION



OVERVIEW OF STRATEGY

Bus stop relocation involves moving a stop from its existing location at an intersection (e.g., near side) to a different location (e.g., far side). In general, far-side stops at signalized intersections produce better bus travel time reliability than near-side stops located at the intersection stop bar.

BENEFITS

Relocating a bus stop to another location can reduce delay and travel time variability near that location. However, the delay saved at one stop can sometimes be lost when considering delay reductions along an entire route or corridor because delay can be experienced at other points. The benefits of relocating a stop to the far side versus the near side are different. Additional information is included in Section 5.1 of the TCRP *Report 183*.

OPERATIONAL CONSIDERATIONS

Moving a bus stop to a location between two intersections within close proximity may result in bus delay when attempting to reenter the traffic stream. While far-side stops are generally preferred, far-side placement may not be ideal when there is only one lane of traffic because this can cause traffic backups into the intersection, creating potential safety and operational issues.

IMPLEMENTATION GUIDANCE

Consider Roadway and Built Environment Constraints: Any existing barriers to relocating the bus stop should be considered as well as how existing land uses might be impacted in the location that the bus stop is being moved. Relocation of stops that are near community centers, hospitals, senior housing, or other similar uses will be more difficult to relocate.

Customer Access Concerns: Consider customer access needs to relocated bus stop, including compliance with ADA access requirements and ease of transfers between bus routes.

Coordination with Metro: Coordination with district planner in Metro's Transit Route Facilities group should occur to understand the impact of bus stop relocation on bus operations.

Guidance: Consult Metro's *Transit Route Facilities Guidelines* for additional information on stop spacing standards.

COST CONSIDERATIONS

Planning and Coordination

Low: This will vary depending on whether an individual stop or multiple stops are being affected. Stop relocations should be coordinated with Metro. Adjacent property owners should also be engaged in advance so that any potential negative impacts of a stop relocation (e.g., loss of parking, waiting passengers congregating in front of buildings) can be communicated.

Capital Costs

Low on a per-stop basis. This consists of removing infrastructure (e.g., bus stop poles, shelter) from the old site, installing infrastructure at the new site, and making any required Americans with Disabilities Act (ADA) improvements, such as a landing pad. The need for concrete paving at the bus stop to reduce bus-caused pavement damage may also be considered. Capital costs could be higher if more civil work is needed to provide new sidewalks and access to the nearest intersection, for example.

Maintenance Costs

There would be no additional maintenance costs.

Bus Operations Costs

There would be some savings from reductions in bus travel time and travel time variability.

Other User Costs

There could be reduced delay for general purpose vehicles on the intersection approach and for the intersection as a whole. If the stop is relocated farther from pedestrian activity centers, there could be some additional travel delay for pedestrians.

BARRIERS AND SIDE EFFECTS

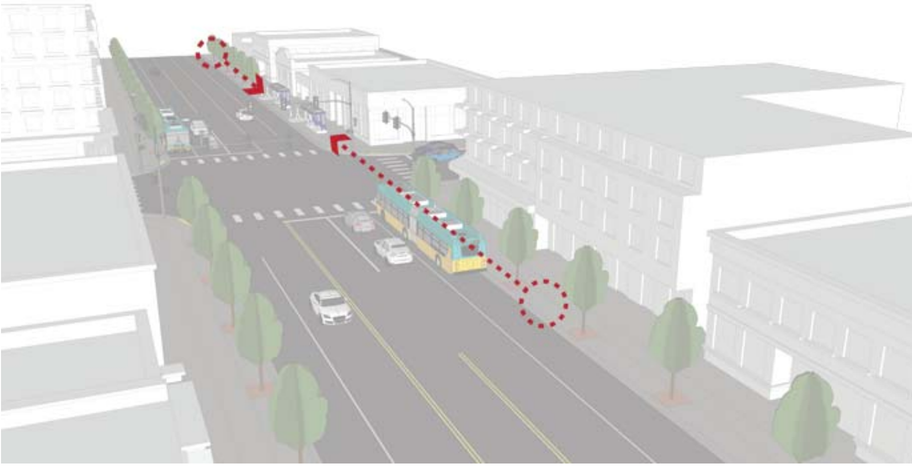
Stop relocation can have the potential to affect surrounding features of the built environment by being moved farther away from passenger generators, transfer points, and/or supportive land uses. Other existing features of the built environment can also be affected, such as sidewalk space, which can be reduced to provide the stop along with passenger amenities, and/or impacts to existing physical obstructions, such as street trees, fire hydrants, lamp posts, etc.

Stop relocation can also have the potential to affect traffic operations by creating queues at the stop that could back up into a nearby intersection. Conflicts with right-turning traffic should also be considered during stop relocations. The location of existing bicycle facilities and ADA-compliant facilities should also be considered when relocating a stop. There could also be impacts to access if parking and loading zones are removed, or if driveways, alleys, or other access points are blocked.

ALTERNATIVES AND COMPANION STRATEGIES

Stop relocations are often implemented as part of a package of improvements for an intersection, route, or street, including stop consolidation, route design changes, transit signal priority, bus-only signal phases, queue jumps, bus bulbs, and bus lanes.

4.3.1.2 STOP CONSOLIDATION



OVERVIEW OF STRATEGY

Bus stop spacing is optimized—typically by increasing the spacing—so that buses make fewer stops along the route while minimally affecting the area served by transit. The average bus stop spacing included in METRO CONNECTS for RapidRide routes is 1/2 mile; for frequent non-RapidRide routes it is 1/4 to 1/2 mile; for express routes it is 1 to 2 miles; and for local routes it is 1/4 mile.

BENEFITS

Every time a bus stops to serve passengers it can experience delay above the amount of time it takes to serve those passengers. Reducing the number of stops along a route can reduce the amount of delay associated with acceleration/deceleration, door opening and closing, traffic signal delay, and reentry delay. Travel time reliability can also be improved because bus-stopping patterns along a route would likely be more consistent from trip to trip. Additional information is included in Section 5.2 of the TCRP *Report 183*.

OPERATIONAL CONSIDERATIONS

Bus stop consolidation sometimes requires a new bus stop to be created. If a new stop is being created, it is preferable to not site it between two busy intersections within close proximity.

IMPLEMENTATION GUIDANCE

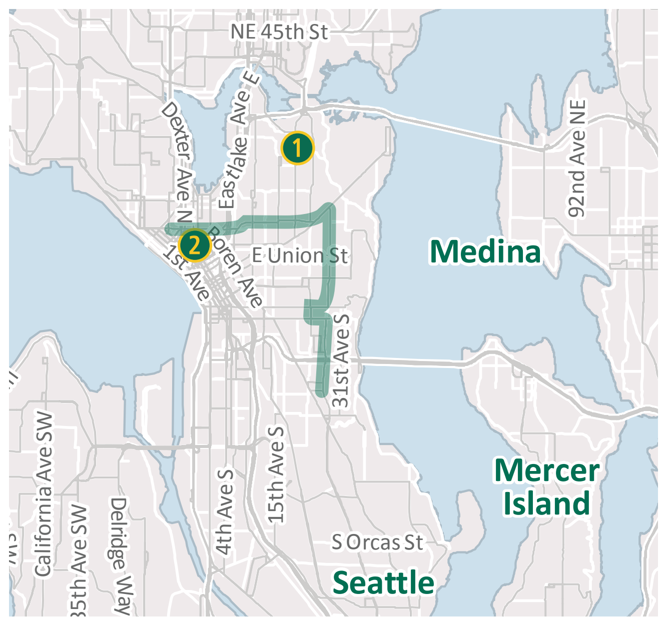
Coordination with Metro: Coordination with Metro should occur if stop consolidation is a tool that could be implemented. One route with relatively high ridership can be implemented first to demonstrate the benefits of stop consolidation.

Outreach: Public outreach to the community may need to be completed prior to consolidating stops in order to communicate the benefits. Outreach efforts should be coordinated with Metro to determine the appropriate level of outreach.

Guidance: Consult Metro's *Transit Route Facilities Guidelines* for additional information on stop spacing standards.

LOCAL APPLICATIONS

1. **Routes 7 and 8**: Metro is working with the City of Seattle to consolidate stops to improve speed and reliability along these routes.
2. **3rd Avenue and Lenora Street**: Metro consolidated the bus stop.



COST CONSIDERATIONS

Planning and Coordination

Moderate to high: This depends on the size of the effort. Passenger volumes, stop spacing, and pedestrian infrastructure would need to be analyzed for each stop included in the study. A significant amount of public outreach may be required to educate the public and other stakeholders about the benefits of stop consolidation.

Capital Costs

Low on a per-stop basis: Capital costs consist of removing infrastructure (e.g., bus stop poles, shelter) from stops that are to be closed.

Maintenance Costs

Maintenance costs will be eliminated for closed stops.

Bus Operations Costs

Bus travel time and travel time variability would likely be reduced. If elderly and disabled passengers cannot or will not access the next-closest stop, they may switch to more costly paratransit service.

Other User Costs

Motorists will experience fewer instances of having to stop and wait for a bus to serve passengers if stop consolidation occurs on roadways without passing space. Pavement damage due to bus stopping activity will cease at the closed stops. Current passengers whose stops are closed could have to walk farther to access a stop.

BARRIERS AND SIDE EFFECTS

Bus stop closures would likely result in longer walking routes for at least some passengers. The presence of safe and accessible walking routes and crossings could also be affected.

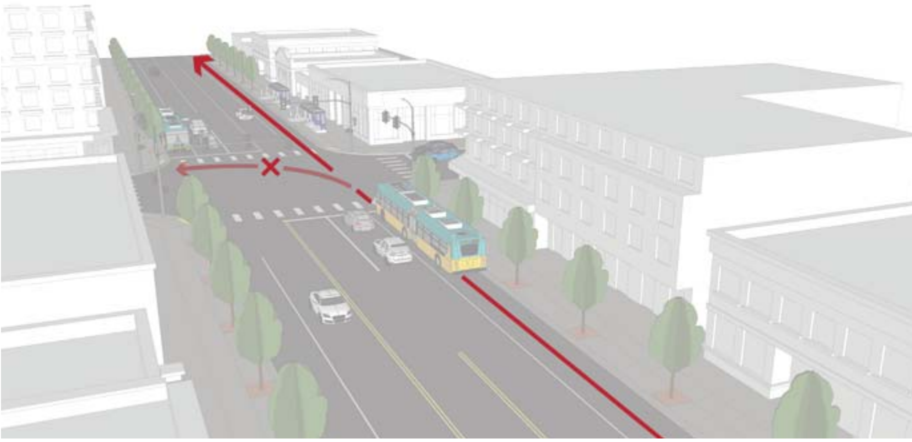
Implementation of route-wide or city-wide stop consolidation can be met with resistance from the public.

Stop consolidation can also affect operations at bus zones by consolidating passengers into fewer bus stops. This can reduce the stop's capacity to serve buses and can increase passenger congestion, potentially increasing the amount of time it takes for a bus to serve the stop.

ALTERNATIVES AND COMPANION STRATEGIES

Stop consolidations are often implemented in conjunction with stop relocations.

4.3.1.3 ROUTE DESIGN



OVERVIEW OF STRATEGY

A route's alignment is changed to provide a faster or more reliable trip for passengers. Routing that made sense in the past may not meet the needs of current passengers due to changes in land use, development, traffic volumes, passenger demands, or other changes. Route design adjustments could include changes such as straightening a route to avoid a difficult left turn, rerouting around a major chokepoint or source of delay such as a freeway on-ramp, or routing to take advantage of a faster pathway nearby. Additional information is included in Section 5.3 of the TCRP *Report 183*.

BENEFITS

The main benefit of route design changes is faster, more reliable service for riders. The time saved by more efficient route design can be used to offset travel time increases due to traffic congestion or increased ridership. Operating costs for Metro can also be reduced with route design.

OPERATIONAL CONSIDERATIONS

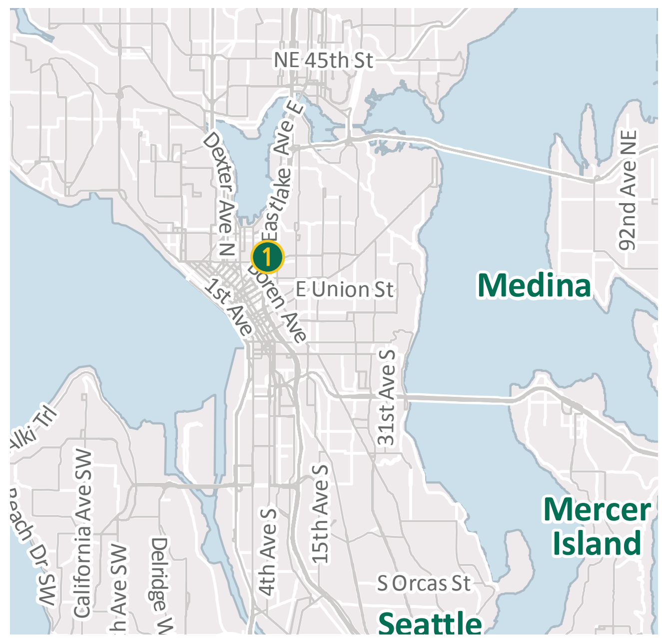
Any rerouting would need to consider the impacts to existing riders who may be getting on or off the bus at affected bus stops or whose trips would be different. The ability of the bus to make the required turning movements should also be considered (i.e., turning radii along the route should be sufficient for buses). Impacts to safety from introducing buses to a different street or for riders accessing rerouted services should also be considered.

IMPLEMENTATION GUIDANCE

Coordination with Metro: Routing change ideas need to be closely coordinated with Metro staff with input from the Service Planning, Safety, Speed and Reliability, and Operations groups. Routing changes may require public outreach and approval by the King County Council, depending on the scope of the changes.

LOCAL APPLICATIONS

1. **8th Avenue and Seneca Street**: Metro worked with the City of Seattle to make route design improvements at 8th Avenue and Seneca Street.



COST CONSIDERATIONS

Planning and Coordination

Moderate: Studying new routing options requires consideration of impacts to passengers from proposed changes. This includes comparing the number of passengers who might benefit from a faster or more reliable trip with the number of passengers who would have to change their trip, get on or off the bus at a new stop, or walk a longer distance to access a route. Detailed data analysis may be needed to closely review the magnitude of existing delay and traffic analysis to determine potential time savings from alternative routes. Metro may need to conduct outreach to riders and other stakeholders who would be affected by a change.

Capital Costs

Low: Capital costs consist of removing infrastructure (e.g., bus stop poles, shelter) from stops that are to be closed and installing infrastructure at any new stops that are created.

Maintenance Costs

Bus stop maintenance costs may go up or down, depending on the net change in the number of stops resulting from the route realignment and any upgrades in stop amenities that are installed in conjunction with developing new bus stops.

Bus Operations Costs

Low: Strategy may reduce route mileage and the number of stops made at intersections, which could lower bus expenses related to these factors (e.g., fuel costs).

Other User Costs

Passengers using stops that will be closed would have to walk farther to access the bus, but passengers would experience shorter travel times.

The net effect on pavement damage would depend on the net change in the number of bus stops and the type of pavement provided at the stops.

BARRIERS AND SIDE EFFECTS

Routing changes can have an impact on the daily lives of riders, neighbors along routes, and other stakeholders. This is particularly the case when a routing change would result in bus stops being closed, where transit would operate on streets that have no buses today, or where there is large actual or perceived impact to a community. Often, opinion can be divided between people who support a change and those who are opposed. For example, there may be significant negative feedback on a change from riders who would have to walk farther to access bus stops. Other riders may like a proposed change because they want a faster trip. Neighbors or stakeholders along an existing or proposed routing may have strong opinions about wanting a bus route to serve or not serve certain streets. If community support for a route change is not achieved, route re-designs could be needed after citizen complaints.

Another potential barrier to change is the need to ensure that people continue to have adequate access to transit. This means that pedestrian infrastructure must exist to allow people to access other nearby bus stops if other stops are closed as a result of a route realignment. A routing change may not be possible if there are not viable options for people to access service along proposed new pathways.

ALTERNATIVES AND COMPANION STRATEGIES

Route alignment changes may require stop relocations, particularly at locations where the route currently turns. When it is not possible to relocate a turn, other strategies can be considered to minimize the delay at the turn. These include bus-only turn lanes, passive signal timing changes, phase reservice, reverse queue jump, transit signal priority, bus-only signal phases, and pre-signals.

4.3.2 TRAFFIC CONTROL

This section describes tools that modify signal timing, phasing, and indications. Traffic control tools can also include changes to existing traffic control regulations to prioritize bus movements and enforce traffic regulations.

4.3.2.1 MOVEMENT RESTRICTION EXEMPTION/ TURN RESTRICTION

4.3.2.2 YIELD TO BUS

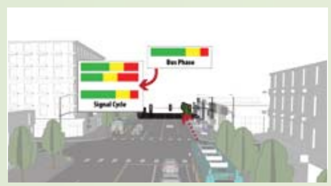
4.3.2.3 PASSIVE TRAFFIC SIGNAL TIMING ADJUSTMENTS

4.3.2.4 PHASE RESERVICE

4.3.2.5 REVERSE QUEUE JUMP

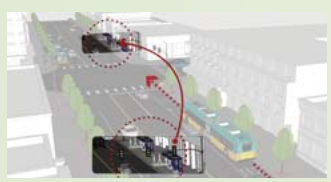
4.3.2.6 TRANSIT SIGNAL PRIORITY

4.3.2.7 TRANSIT SIGNAL FACES

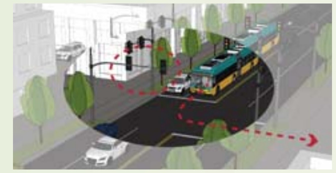


4.3.2.8 BUS-ONLY SIGNAL PHASE

4.3.2.9 QUEUE JUMPS



4.3.2.10 PRE-SIGNALS



4.3.2.11 TRAFFIC SIGNAL INSTALLED FOR BUSES ONLY

4.3.2.12 SIGNAL PHASE MODIFICATION

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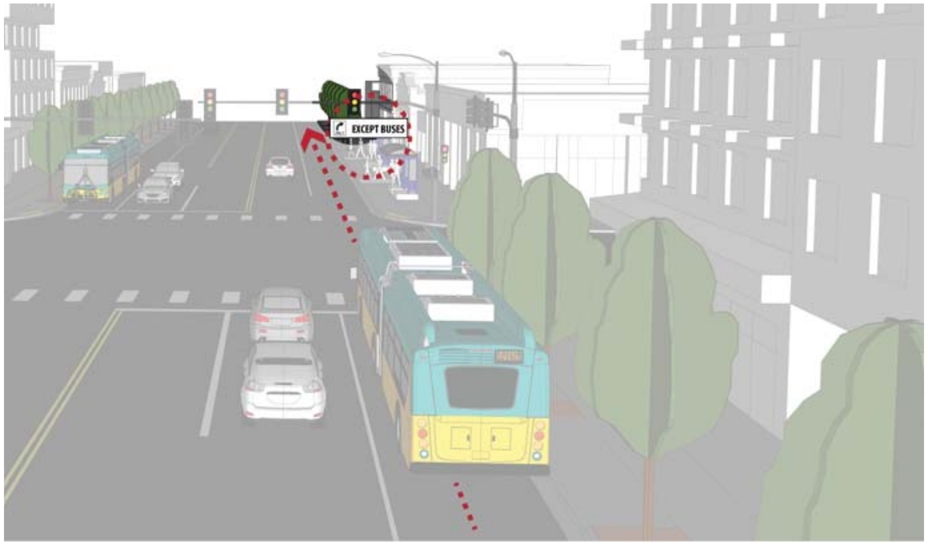
4.3.2.1 MOVEMENT RESTRICTION EXEMPTION/TURN RESTRICTION



OVERVIEW OF STRATEGY

One or more existing general purpose traffic turning movements at an intersection are prohibited. Buses may be allowed to make movements that have been prohibited for other vehicles. Turning restrictions and exemptions can be implemented full time or only during peak periods. For more information, see Sections 6.1 and 6.2 of the TCRP *Report 183.*

BENEFITS

Allowing buses to make turning movements that are prohibited for other vehicles can allow for more direct routing that can save travel time or provide bus service closer to the passengers' origins and destinations. Prohibiting turning movements can free up time or roadway space for both buses and general purpose traffic by prohibiting turning movements that cause high levels of delay.

OPERATIONAL CONSIDERATIONS

There are no operational considerations for turn restrictions. For movement restriction exemptions, potential operational considerations include the ability of the bus to make the turn that is being allowed. This can be problematic for tight right turn movements, which could require the bus to travel into another lane to make the movement. Some training for operators may also be needed to ensure there is no confusion on routing.

IMPLEMENTATION GUIDANCE

Analysis Approach: Collect traffic data and run intersection level of service to understand outcome of the proposed operational changes to both transit and general purpose traffic as needed.

Coordinate with Metro: For movement restriction exemptions, discuss the reason(s) behind the existing turn prohibition. Determine the appropriate implementation strategy and if needed, focus the scope for any traffic impact analysis.

Outreach to neighborhood: The need for neighborhood outreach is considered on a case-by-case basis. Outreach may be completed as part of a package of larger corridor improvements.

LOCAL APPLICATIONS

1. **NE 45th Street and 15th Avenue NE**: Turning movements are restricted except for buses.
2. **3rd Avenue and Lenora Street**: Left-turning movements are restricted except for buses during the AM and PM peak periods.
3. **Westlake Avenue N and Mercer Street**: Metro worked with the City of Seattle to implement a turn restriction.
4. **Westlake Avenue N and Harrison Street**: A turn restriction was implemented at Harrison Street and Westlake Avenue N.

COST CONSIDERATIONS

Planning and Coordination

Moderate: A traffic impact analysis could be required to evaluate the traffic and bus operations impacts of the proposed change and to evaluate potential safety issues. If infrastructure needs to be modified to allow the turning movement (e.g. removing a median barrier to allow a bus-only turn lane), design plans would need to be developed.

Capital Costs

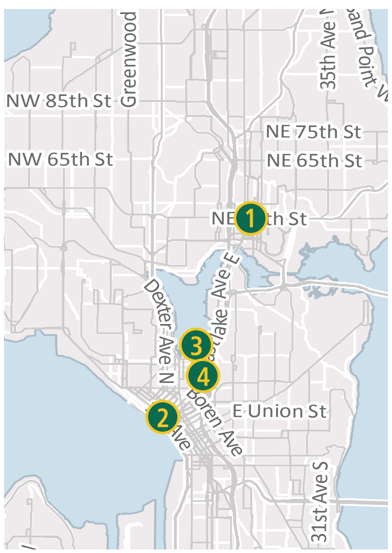
Low to moderate: These costs depend on the specific site characteristics. In some locations, only new or replacement signs may be needed; other locations may require modifications to pavement markings, traffic signal heads, or curb lines and medians.

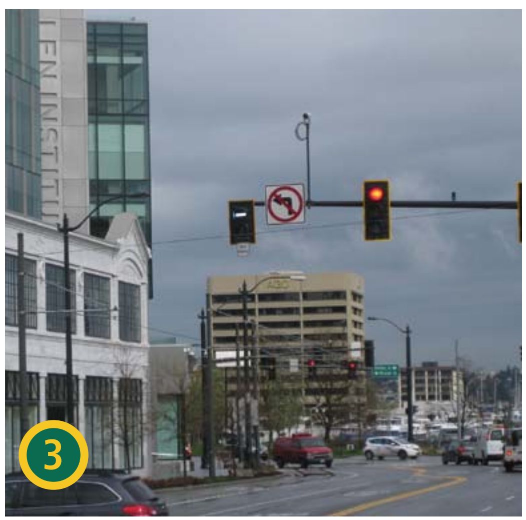
Maintenance Costs

Low: Maintenance needs would depend on the type of modification made, but could include maintenance of signals or signs and pavement markings.

Bus Operations Costs

Reduces travel time and in some cases travel distances.





Other User Costs:

Depending on the method of implementation of a movement restriction exemption, there could be additional travel delay for other vehicles. For turn restrictions, there would likely be potential cost savings to other roadway users. This tool would likely reduce delay to through traffic at the intersection and depending on specific implementation, it could also benefit other traffic movements at the intersection. The reduced delay would typically offset any additional travel time experienced by diverted traffic in locations where through traffic volumes are high relative to the diverted traffic volumes.

Collisions associated with the prohibited turning movement could be reduced, although collisions along the diversion route may increase due to the increased traffic volumes. In addition, intersection delays along the diversion route may increase as a result of the increased traffic volume caused by diverted traffic.

BARRIERS AND SIDE EFFECTS

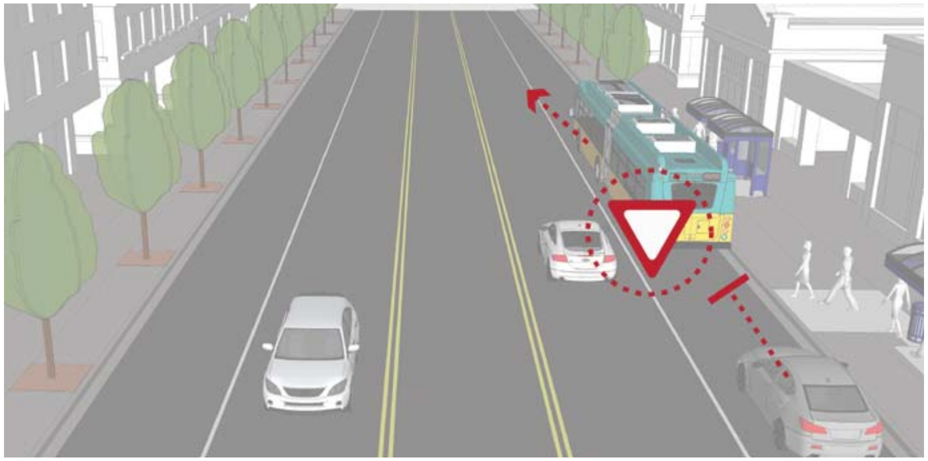
Safety considerations may be needed if the turning movement was prohibited for specific safety concerns. Traffic impacts to other vehicles may be an issue if bus service is frequent. Impacts to pedestrian or bicycle movements could be a concern if the intersection is located in a pedestrian- or bicycle-heavy corridor. A formal exception to a roadway agency's access management policy may be required.

ALTERNATIVES AND COMPANION STRATEGIES

At unsignalized intersections, if the turn prohibition is due to a lack of gaps in the opposing traffic, and a traffic signal exists a relatively short distance downstream of the intersection, reverse queue jump may be an option for creating a gap. When a turn lane is provided for bus use only, red-colored pavement markings may be considered to help reinforce the bus-only message. Enforcement may be required to maintain motorist respect for the traffic control.

At signalized intersections, bus-only signal phases are suggested to be considered in conjunction with a turn exemption, potentially supplemented with transit signal priority, transit signal faces, or both. Exemptions from right-turn requirements are commonly used with queue jump and queue bypass strategies.

4.3.2.2 YIELD TO BUS



OVERVIEW OF STRATEGY

General purpose vehicles are required by law, or are encouraged through bus-mounted signs, to let buses back into traffic when they are signaling to exit a bus stop. Actuated yield-to-bus traffic signals could also be used that display a yield-to-bus flashing light once the bus travels over a loop installed at the bus stop. Additional information is included in Section 6.3 of the TCRP *Report 183*.

BENEFITS

Reduces merging delay: This tool reduces the reentry delay experienced by buses that have finished serving a stop but need to wait to reenter traffic.

Improves schedule reliability: Encouraging traffic to allow buses to merge from out of lane stops can create more gaps in traffic for buses and reduce schedule variability.

OPERATIONAL CONSIDERATIONS

There would be minimal operational considerations. If bus-mounted signs are used, these would need to be installed on the buses. If the actuated yield-to-bus traffic signal was implemented, training on how to actuate the yield-to-bus traffic signal could be required for operators.

IMPLEMENTATION GUIDANCE

Identify the type of yield-to-bus strategy to use: Evaluate which type of yield-to-bus strategy will provide the greatest benefit.

Evaluate Whether to Implement Public Awareness Campaign: A public awareness campaign could be implemented to encourage a friendlier and more courteous environment between bus operators and motorists.

COST CONSIDERATIONS

Planning and Coordination Costs

Moderate to high: A yield-to-bus strategy could be more effective when accompanied by a public awareness campaign.

Capital Costs

Low to high: Depending on the type of signage used on the fleet (e.g. stickers versus electronic yield signs) and whether an entire fleet is equipped. If an activated yield-to-bus signal is installed, capital costs would be higher and would include installing the light and related infrastructure, including the signal loop.

Maintenance Costs

Low to medium: Maintenance costs depend on what type of signage is chosen or if a signal is installed. Electronic yield signs would require more maintenance.

Bus Operations Costs

There would likely be savings from travel time reductions. Although not easily quantifiable, travel time variability may decrease once general purpose traffic begins to yield to buses leaving a stop.

Other User Costs

Drivers in general purpose vehicles and those behind them would experience small delays as they allow buses back into traffic. The amount of delay could increase depending on the number of buses and stops along a corridor.

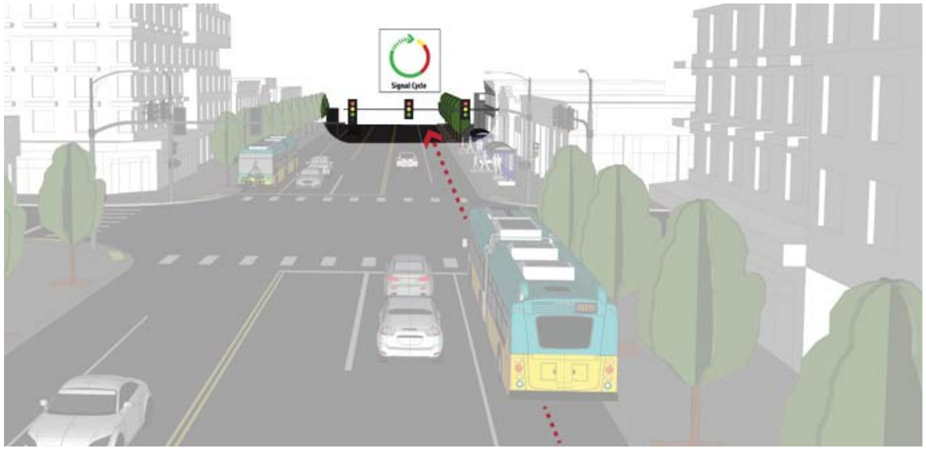
BARRIERS AND SIDE EFFECTS

To be enforceable, state legislation needs to be passed to require motorists to yield to buses leaving a stop.

ALTERNATIVES AND COMPANION STRATEGIES

Installing bus bulbs can be used as an alternative strategy because it provides the same benefits. Reverse queue jumps can also be used to provide a similar benefit. Roadway channelization can be used to complement a yield-to-bus strategy by providing a straight path for buses leaving the bus stop while passing traffic has to weave around the bus.

4.3.2.3 PASSIVE TRAFFIC SIGNAL TIMING ADJUSTMENTS



OVERVIEW OF STRATEGY

Existing signal timing plans can be optimized to reduce delay for traffic in general on intersection approaches used by buses or for buses specifically. The signal timing is followed whether or not a bus is present; therefore, the adjustments are considered to be passive.

Reviewing existing signal timing is an activity that can be done on a periodic or ongoing basis. Optimizing traffic signal timing is done to minimize the number of stops or traffic signal delays experienced by vehicles traveling along a street. Changes that result in better operations for general purpose vehicles may also benefit buses, although good signal timing for general purpose vehicles is not necessarily good signal timing for buses.

Signal timing can also be adjusted specifically to benefit buses. Some of these changes, such as shorter cycle lengths or more green time for the approaches used by buses, will also improve operations for many other roadway users. Other changes, such as signal timing designed to allow buses to progress, may benefit some modes while increasing delay for others.

BENEFITS

Adjusting or optimizing signal timing plans to benefit buses in particular or the approaches where buses are traveling reduces the delay that buses experience at signalized intersections.

OPERATIONAL CONSIDERATIONS

When adjusting traffic signal timing plans, consideration of the locations of bus stops between intersections should be made to ensure that the timing plans account for buses serving the stop. Additional information is included in Section 6.4 of the TCRP *Report 183*.

IMPLEMENTATION GUIDANCE

Develop Internal Process for Identifying Candidate Signals: Both Metro and local jurisdictions can develop an internal process for identifying and reporting signal timing issues that affect bus operations. Local jurisdictions should also consider bus operations when retiming traffic signals. Signal progression for buses is a potential strategy for high-passenger-volume corridors where a net person-delay benefit may be feasible. It can also be considered in local jurisdictions that wish to prioritize non-automobile traffic.

Develop Signal Timing Plan: Collect data and model the changes to traffic operations of the signal timing modifications.

Implement and Adjust: Implement the signal timing modifications and monitor traffic operations. If further modifications to the signal timing plan are needed, adjustments of the signal timing plan can be made.

LOCAL APPLICATIONS

1. **NE 4th Street and 112th Avenue NE**: Signal timing was adjusted to extend the southbound left-turn phase, allowing coaches to effectively clear the intersection, resulting in less transit delay and mitigation of possible pedestrian/vehicle conflict.

2. **NE 29th Street and 148th Ave NE**: The green time for eastbound traffic was given additional time, allowing coaches to successfully complete the movement during periods of high traffic volumes. Maximum delay times observed at the location decreased by 27 percent.

COST CONSIDERATIONS

Planning and Coordination Costs

Between $9,000 and $70,000: Costs could include collection of traffic data (buses, bicyclists, pedestrians, and automobiles), and developing the traffic model to evaluate the initial timing plan and the effects of that plan. Planning and coordination costs would also include implementing and adjusting the final plan.

Capital Costs

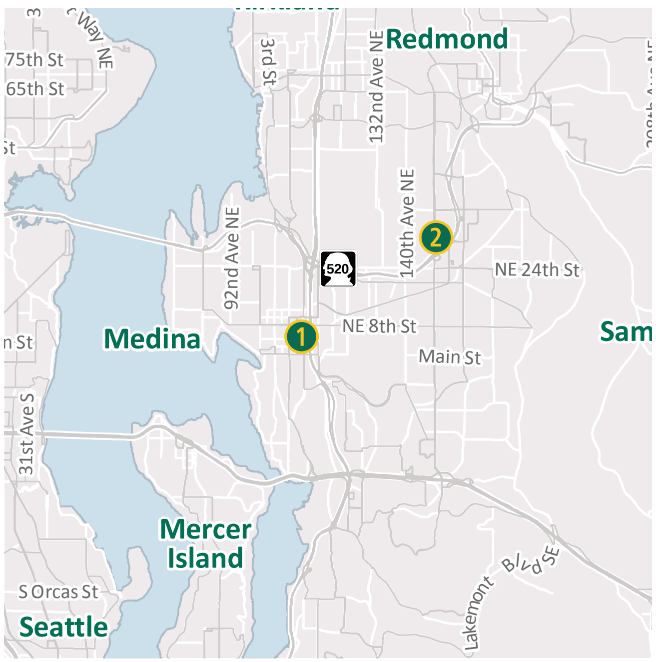
There would be no new capital costs to implement this tool, unless cabinet rewiring or a signal controller upgrade is required to facilitate the changes.

Maintenance Costs

There would be no new maintenance costs to implement this tool.

Bus Operations Costs

There would be potential savings from reductions in traffic signal delay. Timing signals to allow buses to progress can also help reduce bus travel time variability.



Other User Costs

Potential changes in delay (both up and down) for other intersection users, as discussed in the Benefits section; however, the outcome should be an overall improvement on a person-delay basis.

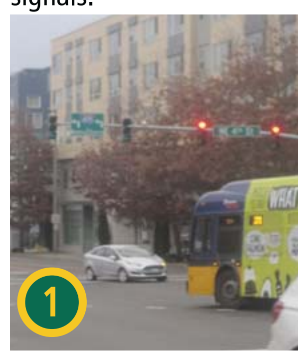
BARRIERS AND SIDE EFFECTS

Allocating more green time to intersection approaches used by buses would reduce delay for motorized vehicles, bicyclists, and (potentially) pedestrians on those approaches, but would increase delay to motorized vehicles and bicyclists on the approaches whose green time is shortened.

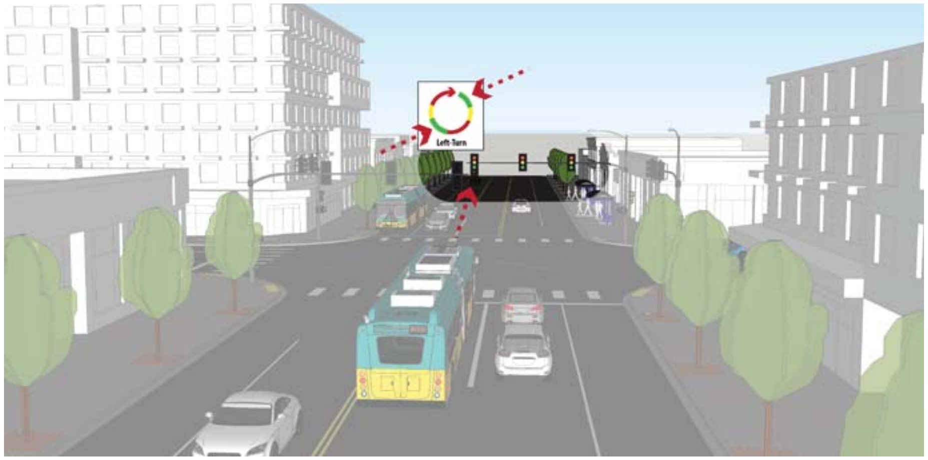
The amount of signal timing that can be reallocated to different approaches would be constrained by the amount of time required to serve vehicles on other approaches (dependent on traffic volumes and the number of lanes) and by the minimum time required to serve pedestrian movements (dependent on the crossing width and the minimum pedestrian walk times specified in the Manual on Uniform Traffic Control Devices [MUTCD]). Also, if all signals in a corridor are coordinated (i.e., operate as group, allowing traffic movements to be synchronized between intersections), a common cycle length must be used. Making a change to one intersection's cycle length would normally require all of the other intersections' cycle lengths to be changed identically.

ALTERNATIVES AND COMPANION STRATEGIES

Passive signal timing adjustments can be implemented in conjunction with other signal timing strategies that react to the presence of a bus, including phase reservice, transit signal priority, bus-only signal phases, queue jumps, and pre-signals.



4.3.2.4 PHASE RESERVICE



OVERVIEW OF STRATEGY

Modifying signal phasing so that a traffic signal phase is served twice during a traffic signal cycle; for example, a left-turn phase that is served both at the start and the end of the green phase for through traffic. Additional information is included in Section 6.5 of the TCRP *Report 183*.

BENEFITS

Bus delay will be reduced, as will the delay experienced by other vehicles sharing the intersection approach

Buses will experience additional green time at signals, which can reduce bus travel time variability.

OPERATIONAL CONSIDERATIONS

The adequate amount of cycle time must be available to allow for a signal reservice. During peak traffic periods, there may not be enough cycle time to allow a reservice while also maintaining an acceptable level of service at busier intersections.

IMPLEMENTATION GUIDANCE

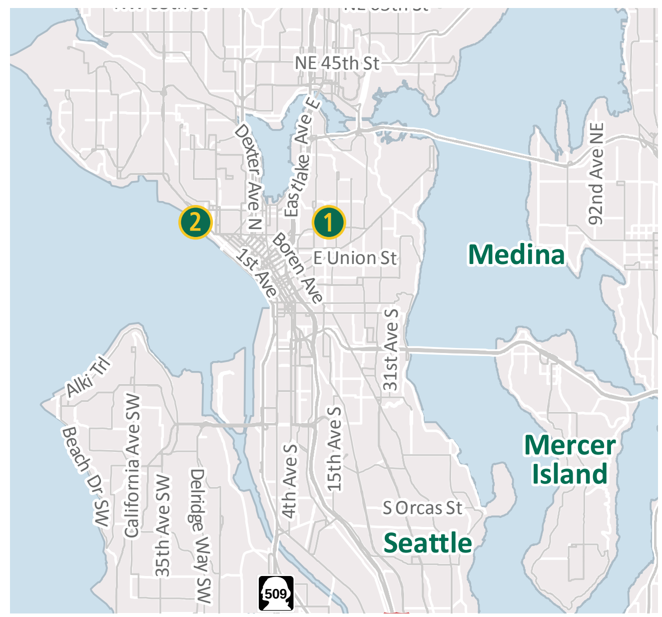
Identify Candidate Signals: Identify signals that would be good candidates for this tool, which has the greatest potential application to signalized intersections where buses turn left.

Analysis Approach: Collect traffic data and run intersection level of service to understand outcome of the proposed operational changes to both transit and general purpose traffic as needed.

Implement Signal Modification: Implement signal reservice strategy and monitor traffic operations.

LOCAL APPLICATIONS

1. **12th Avenue East and East John Street**: A signal reservice was implemented at 12th Avenue East and East John Street.
2. **Elliott Avenue West and West Mercer Place**: A signal reservice was implemented at Elliott Avenue West and West Mercer Place.



COST CONSIDERATIONS

Planning and Coordination Costs

Low to moderate: Costs would be lower for an intersection equipped with a suitable controller. Costs could also include collection of traffic demand data at each intersection (including for buses, bicyclists, and pedestrians), existing signal timing, and an evaluation of the effects of a phase reservice on intersection operations. Costs would be higher if a new signal controller is required.

Capital Costs

Low to moderate: There would be no new capital costs if a suitable controller already exists; if a new controller is needed, capital costs would be higher. Some additional vehicle detection capability may be required to implement phase reservice conditionally, which entails relatively low costs.

Maintenance Costs

No new maintenance costs would be needed unless a new controller is required and it is the first advanced controller, in which case staff training will be required.

Bus Operational Costs

There would be potential savings from reductions in traffic signal delay and bus travel time variability.

Other User Costs

Phases whose green times are shortened to provide phase reservice would experience greater vehicle delay. A net vehicle-delay benefit would be more likely to occur as traffic volumes served by the reserved phase increase and as traffic volumes served by the phase(s) with reduced green time decrease. Pedestrian crossing delay would increase on the crosswalk conflicting with a reserved left-turn phase if its walk time is reduced.

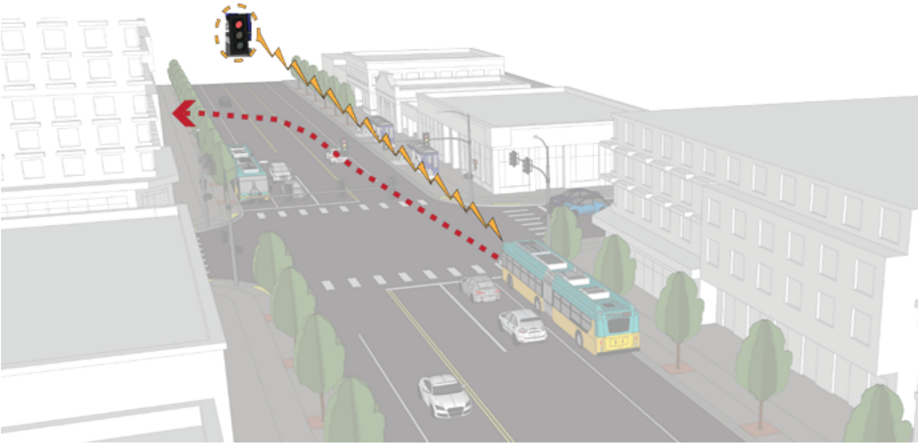
BARRIERS AND SIDE EFFECTS

Phase reservice is an advanced feature that may not be provided by the intersection's current traffic signal controller. This strategy requires that underutilized green time be available within the traffic signal cycle that can be used to reserve a phase (e.g., relatively low traffic volumes in the opposite direction of travel when reserving a left-turn phase).

ALTERNATIVES AND COMPANION STRATEGIES

Phase reservice can be considered in conjunction with special bus phases or queue jumps.

4.3.2.5 REVERSE QUEUE JUMP



OVERVIEW OF STRATEGY

This tool includes communication between nearby signals and the bus to create gaps in traffic to expedite a difficult movement. For example, a bus turning left at an unsignalized intersection would trigger a call for a left-turn phase at a nearby downstream intersection to create a gap in traffic that the bus can use to turn left. This strategy could also include a bus signaling an upstream intersection to turn red, creating a gap in traffic for a bus exiting an out-of-lane bus stop. Additional information is included in Section 6.6 of the TCRP *Report 183*.

BENEFITS

Delay and schedule variability can be reduced for buses by creating gaps in traffic for difficult merging or turn movements. The delay benefit to buses is site-specific but may be higher on high traffic volume corridors.

OPERATIONAL CONSIDERATIONS

There are no major operational considerations for this tool.

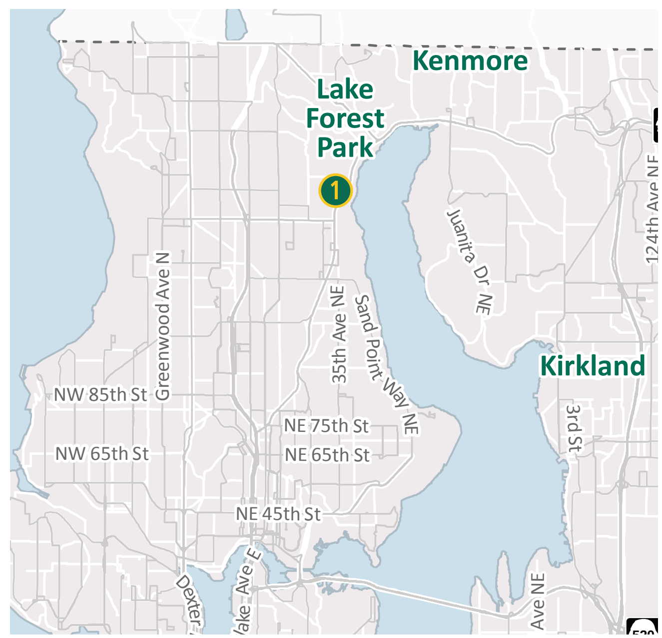
IMPLEMENTATION GUIDANCE

Evaluate Potential for Other Solutions: Other possible solutions could be considered before implementing a reverse queue jump for certain scenarios, such as when a left turn movement at an unsignalized intersection is difficult. In these scenarios, the need for installing a traffic signal could be evaluated to address general traffic concerns.

Develop Design Plans: If reverse queue jump is selected for implementation, design plans will be needed to implement the needed infrastructure, such as the detection connection to the traffic signal.

LOCAL APPLICATIONS

1 **Bothell Way and NE 153rd Street:** A loop installed at the end of the bus stop pullout activates a signal phase that stops northbound traffic on Bothell Way and creates a gap for the bus.



COST CONSIDERATIONS

Planning and Coordination

Moderate: A traffic impacts analysis could be needed to determine whether shadowing is the most appropriate strategy and what the impacts would be. If the strategy is determined to be feasible, design plans would need to be developed for the detection connection to the downstream traffic signal.

Capital Costs

Moderate: These costs are for implementing the infrastructure to detect the bus and communicate with the signal controller at the downstream or upstream traffic signal.

Maintenance Costs

There would be a small increase in costs related to the detection system.

Bus Operations Costs

There would be potential savings from reductions in traffic signal delay and bus travel time variability.

Other User Costs

Delay may be increased for traffic from the opposite direction if no left-turning vehicles need to be served or when the left-turn phase is served earlier than normal. Prohibiting right turns on red may increase delay for that movement if gaps in traffic and pedestrian crosswalk activity would have otherwise permitted right turns on red to occur. Calling a left-turn phase early may increase pedestrian delay on the conflicting crosswalk if the crosswalk's walk time is reduced as a result.

BARRIERS AND SIDE EFFECTS

This strategy requires a nearby traffic signal that can provide the needed phase to create a gap (i.e., a protected left-turn phase), the ability to prohibit right turns on red from the cross street at that traffic signal, no or few driveways between the traffic signal and the unsignalized intersection, and a means of detecting buses. The ability to serve the left-turn phase or red light early is constrained by the requirement to provide a minimum pedestrian crossing time on the conflicting crosswalk.

ALTERNATIVES AND COMPANION STRATEGIES

This strategy can be paired with a turn restriction to prevent vehicles turning right on red and filling the gap in traffic. This strategy can also be paired with transit signal priority to serve the left-turn phase sooner than usual.

4.3.2.6 TRANSIT SIGNAL PRIORITY

OVERVIEW OF STRATEGY

Traffic signal timing is altered in response to a request from a bus so that the bus experiences no delay or reduced delay passing through an intersection.

Transit signal priority can be implemented in a number of ways, including green extension, red truncation (early green), phase insertion, sequence change, and phase skipping. Additional information about the specific types of transit signal priority is described in the National Cooperative Highway Research Program (NCHRP) *Report 812: Signal Timing Manual* and Section 6.7 of the TCRP *Report 183*.

BENEFITS

Transit signal priority can be used to reduce the amount of delay that buses experience at traffic signals. When implemented along corridors, transit signal priority can improve travel time variability.

OPERATIONAL CONSIDERATIONS

Transit signal priority can be applied to intersections with level of service C or worse. All Metro buses have equipment necessary to operate on the King County Transit Signal Priority system. King County is currently developing a next-generation transit signal priority system that will leverage center-to-center (C2C) connections and existing city-owned communications networks. A Center-to-Infrastructure (C2I) option will also be available, which will rely on King-County owned roadside and communication equipment.

IMPLEMENTATION GUIDANCE

Consider Other Tools: Evaluate the possibility of implementing other lower-cost, quicker-to-implement strategies such as stop relocation, stop consolidation, and passive traffic signal timing adjustments.

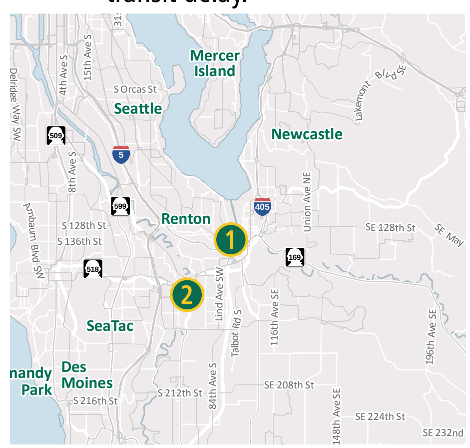
Evaluate Transit Signal Priority Feasibility: Collect traffic demand data (buses, automobiles, bicyclists, and pedestrians) and existing signal timing to develop and evaluate an initial transit signal priority timing plan. A simulation study can be completed to evaluate corridor operations with and without transit signal priority. If transit signal priority is a new strategy, the required infrastructure will need to be planned and designed.

Monitor Traffic Operations: After a signal timing plan has been implemented in the field, monitor traffic operations for both general purpose traffic and transit and determine if modifications are needed.

LOCAL APPLICATIONS

1. **Burnett Avenue S and S 2nd Street**: Metro implemented transit signal priority improvements, which reduced transit delay and alleviated queuing of general purpose traffic.

2. **Longacres Way and W Valley Highway**: Transit signal priority settings were adjusted to better reflect actual transit operations and to allow transit signal priority to request service more aggressively, which resulted in less transit delay.



COST CONSIDERATIONS

Planning and Coordination

Moderate to high: This is for collecting traffic demand data and existing signal timing, and to model and evaluate the initial timing plan. Costs would be higher if transit signal priority is a new strategy and the required infrastructure needs to be planned and designed.

Capital Costs

Costs are $30,000 to $100,000 per intersection, depending on how transit signal priority is to be implemented and how much of the required infrastructure already exists.

Maintenance Costs

Variable: Like capital costs, maintenance costs will be higher if transit signal priority infrastructure does not already exist. There would likely be some staff training if transit signal priority is being introduced for the first time.

Bus Operations Costs

Bus travel time variability is typically reduced and depending on corridor specific conditions and the method of implementation, travel times may also be reduced.

Other User Costs

Vehicular traffic on the approaches served by transit signal priority would typically experience a small average delay reduction due to transit signal priority, while vehicular traffic on the approaches not served by transit signal priority would typically experience a negligible-to-small delay increase. If the cycle time and pedestrian walk times are not changed, pedestrian delay would be unchanged. Phase skipping can significantly increase vehicular and pedestrian delay for those approaches that are skipped.

BARRIERS AND SIDE EFFECTS

Transit signal priority infrastructure can be a significant capital investment because traffic signal controllers may need to be upgraded, and bus detection capabilities at intersections may need to be improved.

A key requirement for transit signal priority to be successful is that buses actually be able to reach the intersection to take advantage of it. If an intersection approach operates over capacity, it may make matters worse to adjust the signal timing when the bus is blocked by other vehicles because the bus cannot get to the intersection and may not be granted priority again until the signal recovers from the first granting of priority.

ALTERNATIVES AND COMPANION STRATEGIES

The potential need for stop relocations should be considered when implementing transit signal priority because some applications work better with some stop locations than with others (e.g., green extension with far-side stops). Transit signal priority can also be combined with most signal-related strategies, including passive signal timing adjustments, traffic signals, bus-only signal phases, turn lanes serving buses only, queue jumps, and pre-signals.

4.3.2.7 TRANSIT SIGNAL FACES

OVERVIEW OF STRATEGY

Special transit signal faces are used for controlling bus, streetcar, or light rail operations. Transit signal faces help to distinguish transit priority at intersections. Additional information is included in Section 6.8 of the TCRP *Report 183*.

BENEFITS

Transit signal faces can help reduce the possibility of road users misinterpreting regular traffic signals used to control transit vehicles as applying to them, leading to potential conflicts. This can reduce the potential for collisions that can occur when motorists or other road users misinterpret a standard signal display meant only for buses as being a green indication for them.

OPERATIONAL CONSIDERATIONS

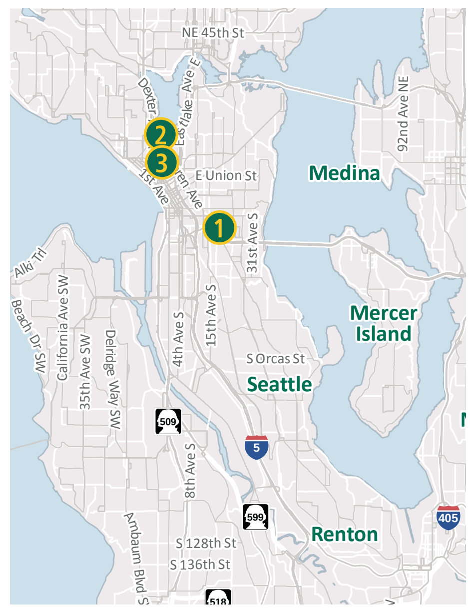
There are no operational considerations for the fleet, but training could be required for operators to ensure they are familiar with the transit signal faces. Transit signal faces may require a bus-only lane.

IMPLEMENTATION GUIDANCE

Consider Coordination with Other Tools: Transit signal faces are suggested for consideration in conjunction with other tools that support the provision of transit priority, described in the *Companion Strategies* section.

LOCAL APPLICATIONS

1. **Rainier Avenue South and South Dearborn Street**: transit signal faces were installed along with other speed and reliability improvements, including turn restrictions, a queue jump, and a bus lane.
2. **Westlake Avenue North and Mercer Street**: transit signal faces were installed along with other improvements, including a turn restriction, a bus lane, and bus-only signal phase.
3. **Fairview Avenue North and Mercer Street**: transit signal faces were installed.



COST CONSIDERATIONS

Planning and Coordination

Low to moderate: Coordination with Metro would likely be needed, especially if signal upgrades are needed to support the bus phase and signal faces. Outreach to police and the public may be necessary to ensure that there is understanding of what the signal faces mean.

Capital Costs

Moderate: The capital costs would vary depending on the amount of signal faces installed and if signal controller upgrades are needed.

Maintenance Costs

Low: These are additional costs to maintain the extra signal equipment.

Bus Operations Costs

None: There would be no direct impact to bus operations but transit signal faces do support other strategies designed to provide benefits. To the extent that they reduce road user confusion, the signals may provide a safety benefit relative to using shielded standard signal heads.

Other User Costs

None: However, costs used in conjunction with other strategies, may produce other user costs or benefits.

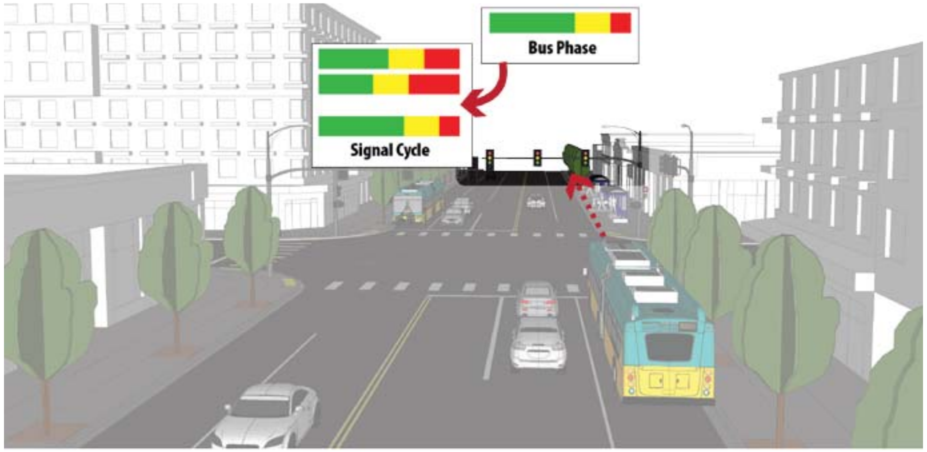
BARRIERS AND SIDE EFFECTS

There are no major barriers or side effects to implement this tool.

ALTERNATIVES AND COMPANION STRATEGIES

Transit signal faces can be considered when implementing bus-only signal phases, queue jumps, pre-signals, transit signals installed specifically for buses, queue bypasses, median bus lanes, contraflow bus lanes, and reversible bus lanes to help distinguish the phase/movement designated for transit vehicles only from other general purpose vehicle phases/movements.

4.3.2.8 BUS-ONLY SIGNAL PHASE



OVERVIEW OF STRATEGY

A traffic signal phase included in the traffic signal cycle to serve bus movements that cannot be served, or are not desired to be served, concurrently with other traffic. Bus-only signal phases help support other tools by allowing buses to make nonstandard movements at an intersection. Without bus-only signal phases, some tools might not be feasible while others would be less effective.

BENEFITS

Bus-only signal phases are typically a support strategy and make another strategy feasible or allow another strategy to be used to maximum effectiveness. When used to serve turning movements from unconventional locations, they may reduce travel time or travel time variability, depending on the level of traffic congestion and challenges faced by buses to weave through traffic to position themselves to make a turn from a conventional location. The potential benefit is highly site-specific and would need to be determined by a traffic analysis.

OPERATIONAL CONSIDERATIONS

There could be some training needed for operators on routes with bus-only signal phases if they are making unconventional movements. This would help to reduce any confusion for operators so that speed and reliability benefits could be maximized. A bus-only signal phase may require a bus-only lane.

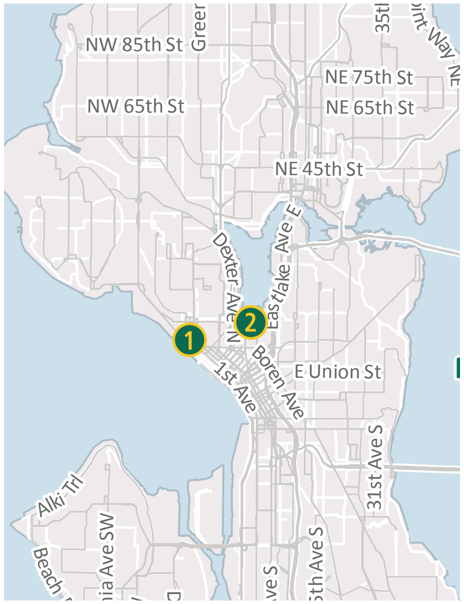
IMPLEMENTATION GUIDANCE

Understand the need and consider other users: Bus-only signal phases are a potential option when bus turning movements need to be made from unconventional locations. Designs may need to take into consideration conditions where other intersection users need to be warned about the unconventional movement (e.g., "Bus Signal" signs, accessible pedestrian signals, a special sign depicting the bus maneuver, dotted pavement markings), and the conditions listed in the BARRIERS AND SIDE EFFECTS section will need to be checked and potentially addressed prior to proceeding. Guidance for implementing this tool with median bus lanes, right-side bus lanes, and left-side bus lanes is provided in Section 6.9 of the TCRP *Report 183*.

LOCAL APPLICATIONS

1 **1st Avenue and Denny Way**: A bus-only signal phase was implemented in coordination with the City of Seattle along with a bus lane.

2 **Westlake Avenue North and Mercer Street**: a bus-only signal phase was implemented along with other improvements, including a bus lane, a turn restriction, and transit signal face.



COST CONSIDERATIONS

Planning and Coordination

Between $10,000 and $25,000. A higher level of coordination with Metro would be required for the first implementation, particularly if a signal controller upgrade is needed to support the bus signal phase and signal heads. Public outreach may also be needed to minimize the risk of collisions resulting from unfamiliarity with the new signals from other roadway users.

Capital Costs

Between $75,000 and $100,000. These costs depend on whether bus detection infrastructure would need to be installed and whether a signal controller upgrade would be needed. Accessible pedestrian signals may also be required.

Maintenance Costs

There would be no direct impact to maintenance costs.

Bus Operations Costs

When used to serve unconventional turning movements, the strategy may reduce delays associated with buses weaving across traffic lanes to a location where a conventional turning movement can be made.

Other User Costs

The time required to serve a bus-only signal phase would likely increase delay for at least some other vehicles using the intersection.

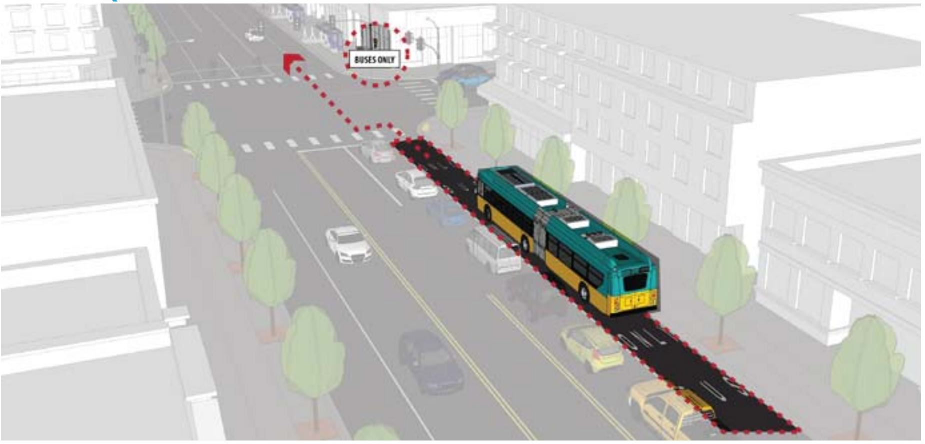
BARRIERS AND SIDE EFFECTS

The signal controller would need to have an unused signal phase available to serve the bus-only phase. Turn radii would need to be sufficient to allow the movement for the bus, which could result in the need to set the stop bar for general purpose vehicles back from the intersection. There could be traffic impacts to other vehicles at the intersection, which could be evaluated through a traffic impacts analysis.

ALTERNATIVES AND COMPANION STRATEGIES

Bus-only signal phases could be implemented in conjunction with transit signal faces, movement restriction exemptions, transit signal priority, queue jumps, pre-signals, bus-specific signals, queue bypasses, median bus lanes, contraflow bus lanes, and single-lane reversible bus lanes.

4.3.2.9 QUEUE JUMPS



OVERVIEW OF STRATEGY

Buses are given an opportunity to move ahead of queued vehicles at a signalized intersection and, in many cases, to proceed into the intersection in advance of the through traffic. Queue jumps are a combination of roadway infrastructure and traffic control strategy. Queue jumps can be provided in a number of ways, including shared right-turn lanes, short bus lanes, and shoulder bus lanes.

BENEFITS

Queue jumps can potentially save buses significant amounts of time at intersections where through-traffic queues are long by allowing the bus to bypass the queue and/or serve a bus stop sooner (if provided near a transit stop). Pedestrians can also benefit from queue jumps if right turns are controlled with a restricted turn phase, which reduces the number of interactions with right-turning traffic, or if right turns are restricted, which reduces delay by allowing pedestrians to begin crossing earlier along with the bus.

OPERATIONAL CONSIDERATIONS

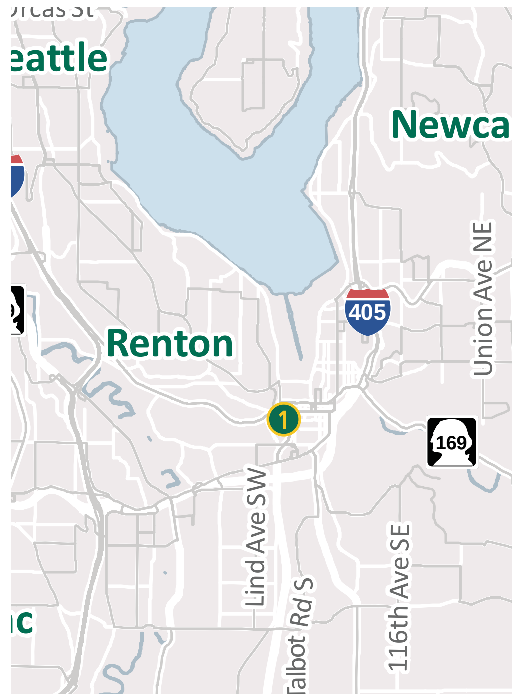
Detection equipment could be required for vehicles that operate on routes with queue jumps. Queue jumps generally do not provide a benefit when there is a far-side stop. Receiving lanes are preferred but not required. Queue jumps can be provided on either the left or right side. Queue jumps can operate as its own phase or as an overlap with an adjacent phase.

IMPLEMENTATION GUIDANCE

Consider Roadway and Built Environment Constraints: There are some characteristics that should be considered when implementing a queue bypass, which include bus stop location, queue jump lane length, and existing traffic and nonmotorized operations at the intersection (right-turning vehicles, pedestrian usage of parallel crosswalk, and throughput). Detailed information on implementation is included in Section 6.10 of the TCRP *Report 183* and AASHTO's *Guide for Geometric Design of Transit Facilities on Highways and Streets* (Section 4.3.2.3).

LOCAL APPLICATIONS

1. **Rainier Avenue S and S 3rd Place**: a queue jump was installed at the intersection with a curbside bus lane. The queue jump allows the bus to enter the intersection ahead of general purpose traffic and begin to merge left to facilitate a left-turn at the next signal.



COST CONSIDERATIONS

Planning and Coordination

Between $15,000 and $20,000. A traffic impacts analysis could be conducted to understand the effect of the queue jump on intersection operations. If this is the first implementation of a queue jump, a higher level of coordination with Metro would likely be needed. Some outreach to the public could be required if this is the first queue jump to be implemented.

Capital Costs

Between $15,000 and $75,000 without right-of-way; $100,000 to $250,000 when combined with a queue bypass lane. Costs for signage are low, but construction and potential right-of- way acquisition costs to construct the queue jump lane could be high. There could also be signal-related costs if other tools are used in combination with the queue jump lane, such as a bus-only signal phase or transit signal priority. Accessible pedestrian signals may be required.

Maintenance Costs

Low to moderate to maintain extra signs, extra pavement, and any detection equipment needed.

Bus Operations Costs

The travel time savings benefits for buses increases the closer the intersection operates at capacity.

Other User Costs

There could be a small increase in average delay to parallel through traffic if time is taken from its phase to provide an advanced green for buses. There would likely be more substantial increase in delay to right-turning traffic if right turns are restricted to a protected right-turn phase only or if right turns are relocated to another intersection.

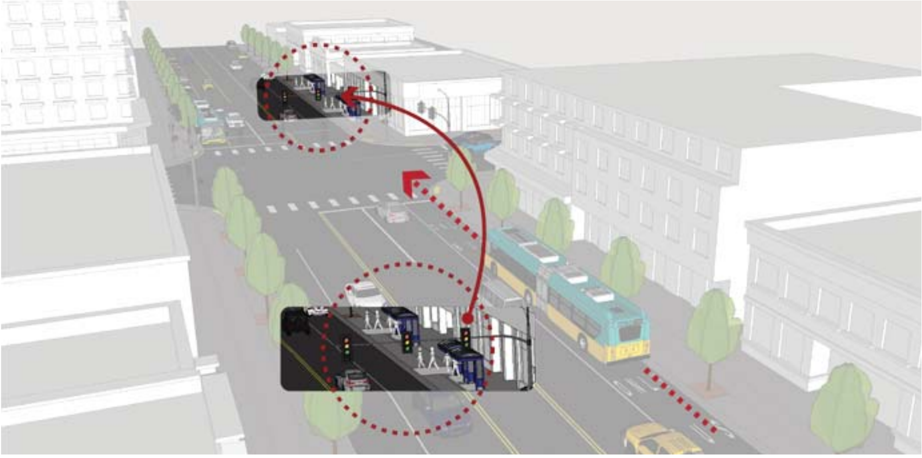
BARRIERS AND SIDE EFFECTS

The need to provide a sufficiently long queue lane is a potential barrier to implementation because this space is often reallocated from general purpose traffic. Sufficient space could also require right-of-way acquisition if it is not currently available within the roadway. Also, sufficient time during the traffic signal cycle must be reallocated to the queue jump, which becomes more difficult as traffic volumes at the intersection increase.

ALTERNATIVES AND COMPANION STRATEGIES

Queue jumps can be implemented in combination with bus stop relocations, movement restriction exemptions, right-turn restrictions, phase reservice, and transit signal priority. A bus-only signal phase is also often used as part of the queue jump and may be paired with transit signal faces. Red colored paint to indicate 'bus only' can also be used with queue jumps. Pre-signals and queue bypasses are related strategies.

4.3.2.10 PRE-SIGNALS



OVERVIEW OF STRATEGY

A traffic signal for one direction of a street, coordinated with a traffic signal at a downstream intersection that is used to control the times when particular vehicles may approach the intersection. Pre-signals are used at the end of a bus lane to give buses priority access to the intersection when constraints make it infeasible to continue the bus lane all the way to the intersection. They can also be used to manage queues on the intersection approach; for example, when a side street or driveway is regularly blocked by queues extending back from the traffic signal.

BENEFITS

Pre-signals can result in significant potential time savings when the pre-signal allows buses to bypass the queue of an over-capacity intersection. The magnitude of time savings depends on the level of congestion. Pre-signals can also be used primarily to facilitate bus movements into or across general purpose traffic lanes. Travel time variability is also reduced by pre-signals.

OPERATIONAL CONSIDERATIONS

There are no major operational considerations for this tool.

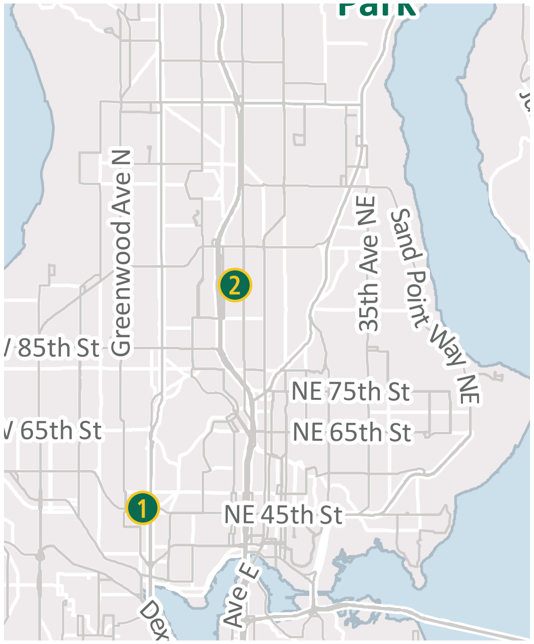
IMPLEMENTATION GUIDANCE

Ensure Appropriate Supporting Infrastructure is in Place: The presence of a bus lane or an extended bus pullout is a prerequisite for considering a pre-signal.

Design and Implement: The pre-signal should operate full time unless there are overriding reasons not to do so. To obtain maximum benefit for buses, locate bus stops either immediately prior to the pre-signal or on the far side of the intersection. Additional guidance is provided in Chapter 6.11 of the TCRP *Report 183*.

LOCAL APPLICATIONS

1. **Aurora Avenue North and North 46th Street Southbound On-Ramp**: a pre-signal was provided at the SR 99 on-ramp and North 46th Street.
2. **Northgate Transit Center and NE 100th Street**: a pre-signal was provided at the entrance/exit of the transit center and NE 100th Street.



COST CONSIDERATIONS

Planning and Coordination

Moderate: A traffic impacts analysis could be needed to identify the optimal location for the pre-signal. A signal timing plan would need to be developed for the pre-signal and coordinated with the downstream signal. Planning and coordination costs associated with transit signal faces and special bus phases would also be applicable.

Capital Costs

Moderate to high to obtain and install traffic signal equipment for the pre-signal. Depending on how close the pre-signal is to the downstream signal, the signal faces for the approach at the downstream signal may need to be replaced with visibility-limited signal faces that are only visible once motorists pass the pre-signal.

Maintenance Costs

Moderate: These costs are to maintain and operate the pre-signal.

Bus Operations Costs

There would be potential savings from travel time and variability reductions.

Other User Costs

There would be no change in general traffic delay as long as the presence of driveways and side streets do not require that the pre-signal be moved to a less-optimal location.

BARRIERS AND SIDE EFFECTS

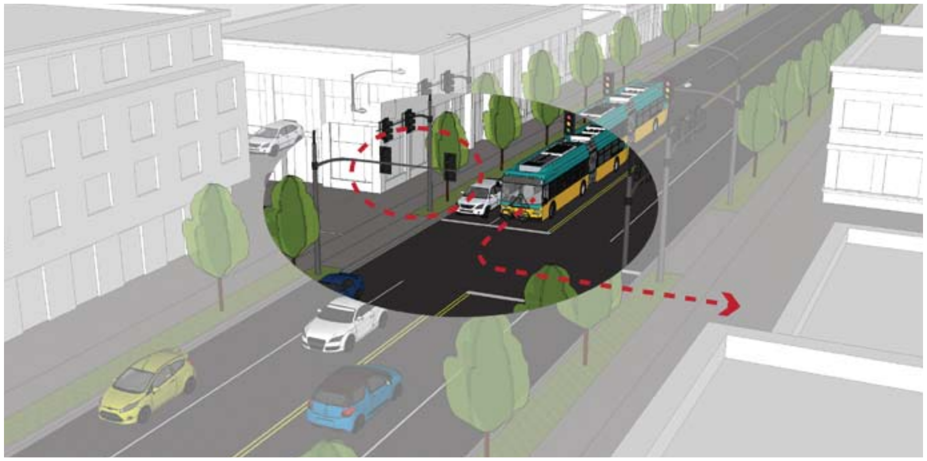
Pre-signals have similar barriers and side effects as bus lanes because pre-signals are a support strategy for bus lanes. Pre-signal placement can be impacted by the presence of side streets and/or driveways that could affect intersection throughput because pre-signals relocated the queue from the intersection to farther upstream from the intersection. If the pre-signal facilitates the conversion of a general-purpose lane to a bus lane, the queue in the general-purpose lanes would become longer.

ALTERNATIVES AND COMPANION STRATEGIES

A bus lane is a prerequisite for employing a pre-signal. The bus lane can be controlled by transit signal faces providing a bus-only signal phase. Transit signal priority can potentially be applied both at the pre-signal and the downstream signal.

Queue jumps (priority is provided at the signalized intersection) and queue bypasses (priority provided without traffic signals) are related strategies.

4.3.2.11 TRAFFIC SIGNAL INSTALLED FOR BUSES ONLY



OVERVIEW OF STRATEGY

An intersection that is signalized primarily to serve bus movements rather than general traffic. This could be necessary in locations where buses experience significant delays when making turns at an unsignalized intersection along a major roadway, but the minor street-traffic volumes may not be sufficient to meet the MUTCD's volume-based traffic signal warrants. Additional information is included in Section 6.12 of the TCRP *Report 183*.

BENEFITS

Traffic signals specifically for buses are typically installed to reduce delay from buses turning left onto, turning left from, or crossing major streets. A traffic signal could reduce bus travel time and travel time variability; specific benefits are highly site-specific and would need to be determined by a traffic impacts analysis. Pedestrian mobility can also benefit because a traffic signal provides a new signalized crossing opportunity.

OPERATIONAL CONSIDERATIONS

There are no major operational considerations for this tool.

IMPLEMENTATION GUIDANCE

Consider Alternatives: Rerouting buses to avoid a problematic intersection should be considered prior to installing a traffic signal primarily for buses.

Analysis Approach: If necessary, conduct a traffic analysis to evaluate the need for a signal and benefit for transit and other roadway users.

Evaluate Policy Restrictions: An experimentation request to the FHWA could be required if the signal would not be warranted on the basis of MUTCD warrants.

COST CONSIDERATIONS

Planning and Coordination

Moderate to high: A traffic impacts analysis could be required to evaluate intersection operations before and after implementation of the signal. If an experimentation request is needed, additional study requirements could be necessary. Other traffic control measures could also be needed, such as signage; motorist outreach programs may also be necessary.

Capital Costs

High: These costs are to install a new traffic signal and potentially make ADA-related improvements such as curb ramps, if not already provided.

Maintenance Costs

Maintenance costs would include operating and maintaining the signal.

Bus Operations Costs

There could be potential savings from reductions in travel time and travel time variability.

Other User Costs

There would likely be increased delay for other roadway users.

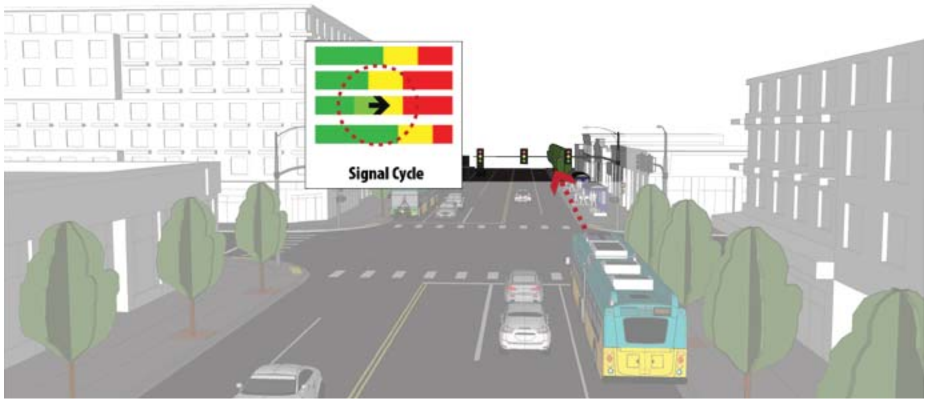
BARRIERS AND SIDE EFFECTS

Policy to support the implementation of a signal without meeting MUTCD warrants could be necessary. The new traffic signal could also affect roadway operations, particularly if the major roadway currently provides good traffic progression. There are also potential safety issues with implementing a new signal; an increase in bus-vehicle crashes could occur, particularly in the first year after implementation.

ALTERNATIVES AND COMPANION STRATEGIES

Traffic signals, specifically for buses, could be implemented using transit signal faces to control bus movements and would typically be used in conjunction with bus-only signal phases. Transit signal priority could also potentially be provided. Reverse queue jump may be an alternative strategy if a signal specifically for buses is not feasible.

4.3.2.12 SIGNAL PHASE MODIFICATION



OVERVIEW OF STRATEGY

Modifications to the signal phasing at an existing signalized intersection to facilitate difficult movements for buses. This could include modifying a signal to include a protected left-turn phase instead of a permissive turn phase.

BENEFITS

Signal phase modification can provide travel time savings and travel time variability benefits by making difficult movements at a signalized intersection easier for buses. Signal phase modifications can also have potential safety benefits when permissive phases are converted to protected phases. General purpose vehicles making the same movement would also experience a reduction in delay at the intersection.

OPERATIONAL CONSIDERATIONS

There are no major operational considerations for this tool.

IMPLEMENTATION GUIDANCE

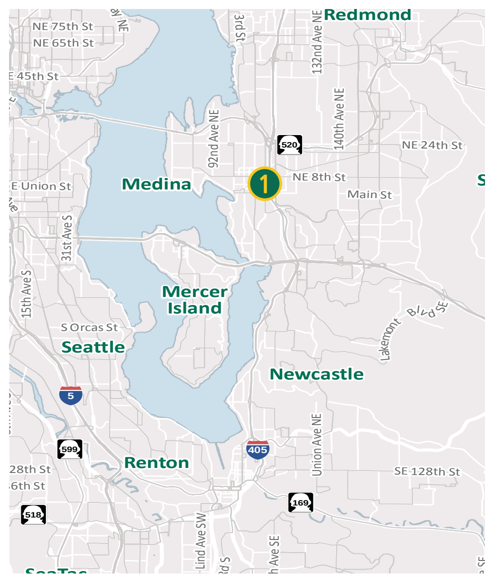
Coordination: Coordination with Metro would be required before implementing a signal phase modification.

Analysis Approach: Make adjustments to the signal phasing. A traffic analysis may be needed to monitor traffic operations for transit and other roadway users.

Implement and Adjust: Implement the signal phase modification and monitor operations for general purpose traffic and transit.

LOCAL APPLICATIONS

1 **NE 6th Street and 112th Avenue NE**: Metro coordinated with the City of Bellevue to add a protected left-turn movement to the signal cycle, which allows more buses through the intersection per cycle.



COST CONSIDERATIONS

Planning and Coordination

Low to moderate: A traffic impacts analysis could be required to evaluate intersection operations before and after implementation of the signal.

Capital Costs

Between $10,000 and $65,000. These costs are to install any new traffic signal heads using an existing signal pole.

Maintenance Costs

There would be some additional maintenance costs to operate and maintain any new signal heads.

Bus Operations Costs

There could be potential savings from reductions in travel time and travel time variability.

Other User Costs

There could be some minor increased delay to other roadway users.

BARRIERS AND SIDE EFFECTS

Modifying the signal phasing could result in additional delay to other roadway users at other intersection approaches. It may be necessary to develop clear policy guidance that identifies which mode gets priority because reallocating signal time to transit may impact the delay of another mode.

There would need to be adequate time in the existing signal cycle to reallocate to a new phase. The amount of time that can be reallocated to the modified phase would be constrained by the amount of time required to serve vehicles and pedestrians on other approaches.

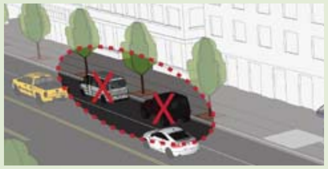
ALTERNATIVES AND COMPANION STRATEGIES

Companion strategies include passive traffic signal timing adjustments, phase reservice, and transit signal priority. Transit signal faces and bus-only signal phases could be used as an alternative if the volumes of vehicles making the same movement cause bus delay.

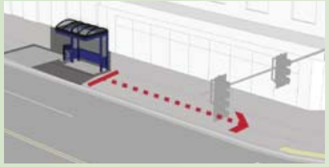
4.3.3 INFRASTRUCTURE

This section describes the types of improvements that focus on physical changes to the roadway to improve speed and reliability.

4.3.3.1 SPEED HUMP MODIFICATION

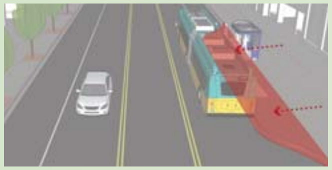


4.3.3.6 PARKING REMOVAL/ ALTERATIONS



4.3.3.2 BUS STOP LENGTHENING

4.3.3.7 TURN RADIUS MODIFICATIONS



4.3.3.3 BUS BULBS

4.3.3.4 BOARDING ISLANDS

4.3.3.5 ROADWAY CHANNELIZATION AND SIGNAGE

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4.3.3.1 SPEED HUMP MODIFICATIONS

OVERVIEW OF STRATEGY

Speed bumps and humps along bus routes are replaced with bus-friendlier versions to reduce the amount of deceleration needed as noted in the *Implementation Guidance* section. Additional information is included in Section 7.1 of the TCRP *Report 183*.

BENEFITS

Speed bumps and humps that are relatively short force buses to slow to speeds that are much slower than the street's posted speed to avoid jolting passengers and damaging the bus's suspension. Buses accelerate more slowly than automobiles; therefore, they experience more delay from speed bumps. Replacing speed humps with bus-friendlier designs can retain the desired traffic-calming effect while improving bus passengers' comfort, improving bus fuel economy (by avoiding the need to accelerate after the hump), and reducing noise impacts in the vicinity of the speed hump. Emergency vehicles will also benefit from bus-friendly speed hump designs.

OPERATIONAL CONSIDERATIONS

Speed hump modifications would have a positive impact on bus operations by reducing damage to the suspension and the amount of deceleration/acceleration that is required.

IMPLEMENTATION GUIDANCE

Coordination: Coordinate with Metro to develop an approach to removing or replacing non-transit-friendly speed humps.

Local Jurisdiction: Develop policies discouraging or preventing speed hump use on bus routes or designated transit streets. Alternative traffic-calming strategies should be investigated first in coordination with Metro.

Implementation: Design speed bumps that are transit-supportive:

- Not installed near bus stops since passengers may be moving to or from their seats,
- Provide as long a distance as possible (e.g., 22 ft) between the slope up and the slope down or be designed such that buses avoid the bump (e.g., a speed cushion),
- Provide at least 600 ft between successive bumps, and
- Be located so that buses can traverse them at a 90-degree angle (e.g., not near bus stops).

LOCAL APPLICATIONS

1. **Bellevue College**: Metro coordinated with Bellevue College to modify the speed humps within campus, improving bus travel time and operations.
2. **University of Washington**: Buses are able to straddle speed bumps entirely throughout the campus.

COST CONSIDERATIONS

Planning and Coordination

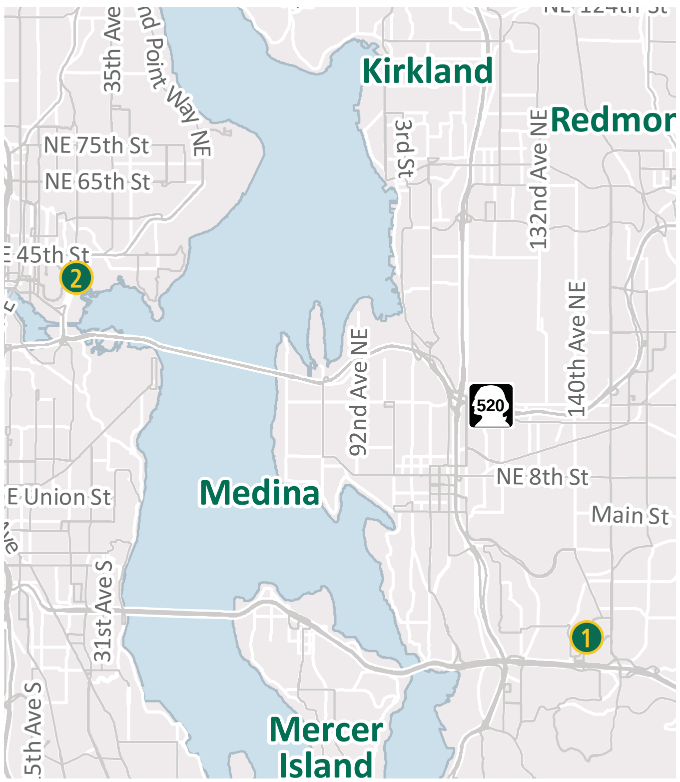
Moderate: Neighborhood outreach could be needed when changing an existing speed hump to a bus-friendlier design. Emergency responders may be supportive of speed hump changes that allow faster emergency vehicle response times.

Capital Costs

Low to moderate: These costs are to remove or replace the speed hump.

Maintenance Costs

A bus-friendlier design may reduce pavement damage caused by buses decelerating and traveling over a speed hump.



Bus Operations Costs

There could be savings from reductions in travel time and improved fuel economy.

Other User Costs

Removing an existing speed hump may result in higher traffic speeds along the street before and after where the hump was located, which has potential safety impacts.

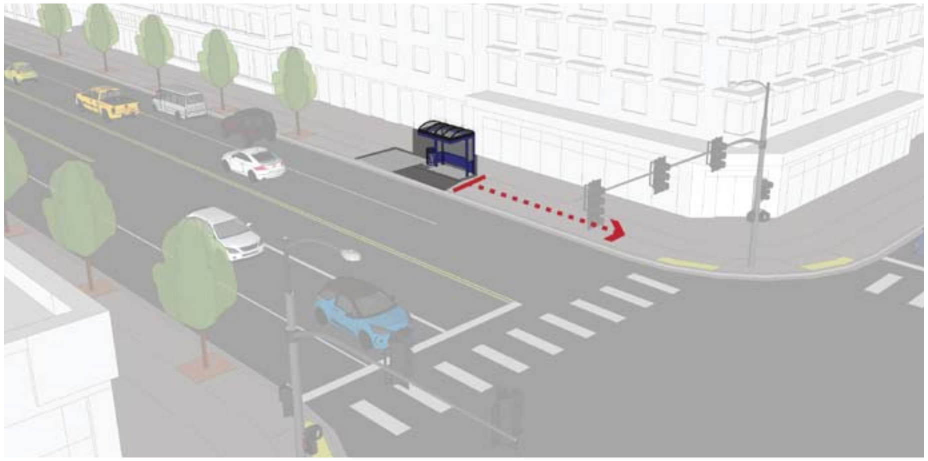
BARRIERS AND SIDE EFFECTS

Existing roadway design manuals may use standards for speed humps that are not bus-friendly.

ALTERNATIVES AND COMPANION STRATEGIES

Speed hump alterations can be implemented as a stand-alone improvement or as part of a package of speed and reliability improvements along a road or route.

4.3.3.2 BUS STOP LENGTHENING



OVERVIEW OF STRATEGY

A bus stop's length is increased to allow it to serve more (or longer) buses simultaneously. Additional information is included in Section 7.2 of the TCRP *Report 183*.

BENEFITS

If more buses want to use a stop at one time than space exists, the other buses have to wait in the street until space opens up at the stop. This delays both buses and general traffic. Increasing the bus stop length to provide the appropriate capacity can reduce travel time variability.

OPERATIONAL CONSIDERATIONS

There are no major operational considerations for this tool.

IMPLEMENTATION GUIDANCE

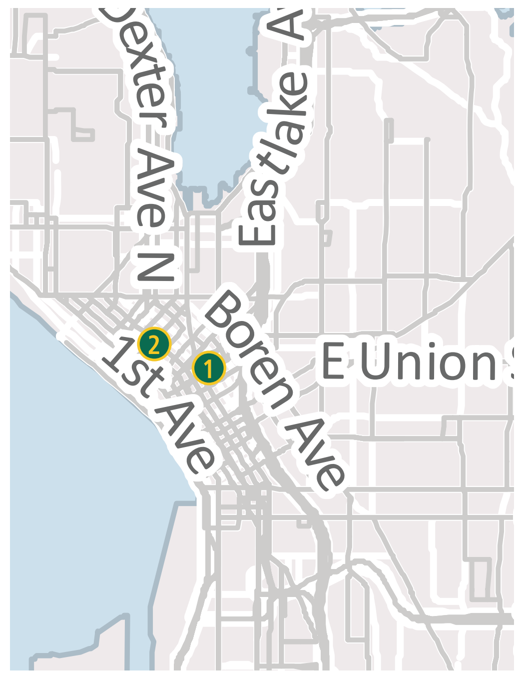
Coordination: Coordinate with Metro to estimate hourly bus stop capacity and existing and future bus frequencies using this stop in order to determine appropriate level of bus stop capacity and develop strategy for addressing bus capacity issues.

Determine Feasibility: Determine if lengthening a stop is physically or politically feasible by reviewing nearby access points and other barriers.

LOCAL APPLICATIONS

1. **6th Avenue and Pike Street**: Metro coordinated with the City of Seattle to lengthen the bus stop at 6th and Pike Street.

2. **3rd Avenue and Virginia Street**: Metro coordinated with the City of Seattle to lengthen the bus stop to allow more space for buses to serve the stop.



COST CONSIDERATIONS

Planning and Coordination

Low: Lengthening a stop will need to be coordinated with Metro. It may also be desirable to engage adjacent property owners in advance about potential negative impacts to them (e.g., loss of parking).

Capital Costs

Between $10,000 to $30,000. These costs consist of moving parking signs and making any required ADA improvements such as a landing pad. The need for concrete paving at the bus stop to reduce bus-caused pavement damage may also be considered. Costs will be higher when curb lines or parking meters need to be moved to accommodate a longer stop.

Maintenance Costs

No significant change in costs.

Bus Operations Costs

There could be savings from reductions in bus travel time variability.

Other User Costs

For in-lane bus stops, there could be reduced delay for motor vehicles that would otherwise be blocked by buses waiting to serve a stop. There is also the potential for on-street parking loss.

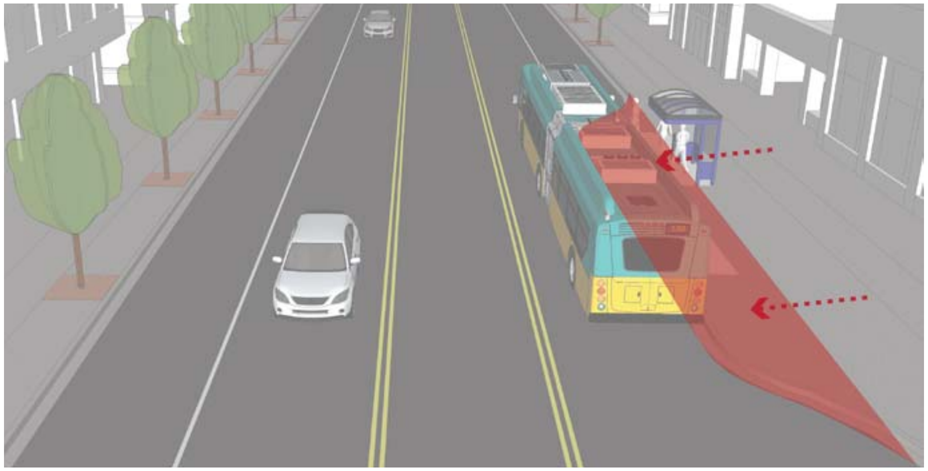
BARRIERS AND SIDE EFFECTS

Bus stop lengthening may result in a loss of on-street parking. It may not be feasible if driveways, alleys, or intersections are located close to the stop. If one stop requires lengthening, other stops with similar boarding/alighting operations may also require lengthening.

ALTERNATIVES AND COMPANION STRATEGIES

Bus stop lengthening may need to be considered when stops are consolidated because the increased passenger activity at the remaining stops will increase bus dwell times and thus reduce the number of buses that a bus stop can accommodate during an hour. Bus stops may also need to be lengthened if longer buses are used on a route. If a bus stop cannot be lengthened at its current location, it may need to be relocated.

4.3.3.3 BUS BULBS



OVERVIEW OF STRATEGY

Bus bulbs extend the curb and sidewalk out to the edge of the parking lane to allow buses to stop in the travel lane and avoid delay from reentry into traffic when leaving the stop. Additional information is included in Section 7.5 of the TCRP *Report 183*.

BENEFITS

Bus bulbs can be used to reduce the reentry delay that buses experience when leaving a stop. Bus bulbs can increase bus travel speeds within the block where the bus bulb was implemented and can also make bus stopping patterns more predictable for other roadway users. When implemented at intersections, bus bulbs shorten the pedestrian crossing distance, thus reducing the amount of time pedestrians are exposed to conflicts with other road users and, potentially, the amount of time that other road users are delayed by pedestrians crossing. Bus bulbs can provide both a better bus stop waiting environment (in terms of the space available per waiting passenger and space to install bus stop amenities) and better adjacent sidewalk flow by giving bus passengers a place to wait other than the sidewalk. Bus bulbs can also increase the amount of on-street parking that can be provided by allowing parking lanes to be continued up to the start of the bus bulb.

OPERATIONAL CONSIDERATIONS

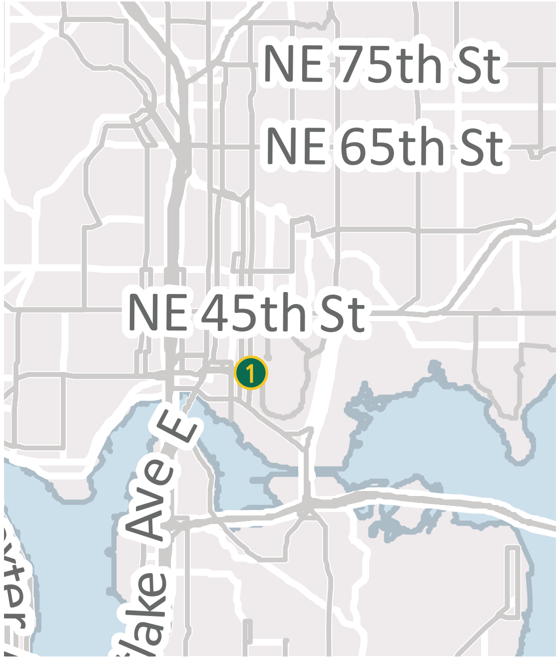
Consider whether median treatments (c-curbing, posts, or small islands) are needed to prevent vehicles from using a two-way left turn lane or opposing lane for passing.

IMPLEMENTATION GUIDANCE

Determine Feasibility: conditions supportive of bus bulbs should be present, such as the presence of full-time curbside parking, near-side or midblock stop locations, relatively low traffic speeds, low to moderate traffic volumes, two or more travel lanes in the direction of travel (desirable), relatively high sidewalk or crosswalk usage or relatively high passenger volumes at the stop, relatively low right-turning vehicles volumes.

LOCAL APPLICATIONS

1 **15th Avenue NE and NE 40th Street**: A bus bulb was constructed in coordination with the City of Seattle.



COST CONSIDERATIONS

Planning and Coordination

Moderate: A traffic impact study may be needed to evaluate the impact of the bus bulb on other roadway users. Civil engineering plans will need to be developed to address street drainage modifications. Outreach to adjacent businesses may be needed, particularly when installing shelters that may block views of businesses' signs from the street.

Capital Costs

Up to $200,000: The largest portion of these costs involve drainage changes and, potentially, utility relocations. There will be added costs if bicycle facilities need to be relocated around the bus stop.

Maintenance Costs

No significant changes are expected.

Bus Operations Costs

There would be savings from reductions in bus travel time and travel time variability.

Other User Costs

On streets with one lane of travel per direction, bus bulbs would likely increase vehicular delay, with the extent of the delay dependent on bus frequencies, dwell times, traffic volumes, and whether the stop is located at a signalized intersection (because traffic might need to stop anyway).

BARRIERS AND SIDE EFFECTS

Bus bulbs affect street drainage patterns, and drainage may need to be reworked to prevent water ponding issues. When used at intersections, they reduce the turning radius available for larger vehicles, which may require restrictions on right turns or moving the side-street stop bar away from the intersection to provide more room for larger turning vehicles. If bicycle facilities exist, consideration will need to be given to how to route bicycles around stopped buses. The ability to match the roadway and sidewalk cross slopes so that a low-floor bus's wheelchair ramps can deploy at an ADA-acceptable slope should also be considered. Parking removal may also be needed when installing a bus bulb.

ALTERNATIVES AND COMPANION STRATEGIES

Bus bulbs can be used in combination with interior bus lanes. Alternatively, yield-to-bus tools can be used to address reentry delay.

4.3.3.4 BOARDING ISLANDS

OVERVIEW OF STRATEGY

Bus stops on raised concrete islands within the roadway that allows bus stops to remain at intersections to support other tools. Additional information is included in Section 7.6 of the TCRP *Report 183*.

BENEFITS

Boarding islands make it possible to place bus stops in locations that are ideal for serving passengers but where suitable space may not be available, such as an intersection where a right turn is provided. Boarding islands also allow for protected bicycle lanes to coexist with transit stops. Bus islands are necessary along bus lanes provided on the left side of the street except when coaches with left-side doors are used (Madison BRT). Boarding islands make other tools feasible while maintaining good access to bus service.

OPERATIONAL CONSIDERATIONS

Boarding islands installed near intersections may constrain bus turning movements at the intersection; consider future routing plans, and probable construction/event/emergency reroutes.

IMPLEMENTATION GUIDANCE

Determine if Supportive Conditions Exist: conditions supportive of installing a boarding island should be present, such as sufficient space, passenger generator or transfer point nearby, other speed and reliability tools (queue jump, bus lanes, etc), and ability to accommodate bicycle.

Consider Design and Amenities: Determine which supporting infrastructure is necessary and whether ADA improvements are needed.

LOCAL APPLICATIONS

1. **4th Avenue South and South Jackson Street**: Metro worked with the City of Seattle to install a boarding island.

2. **Dexter Avenue**: Metro worked with the City of Seattle to install boarding islands along Dexter Avenue.

COST CONSIDERATIONS

Planning and Coordination

Low to moderate: Right-turn channelizing islands would require less planning and coordination, depending on how much modification the island would require; sight distances should be evaluated. Channelizing islands elsewhere in the roadway could require higher costs due to the need to realign other travel lanes, but may be incorporated as part of a larger bus lane or roadway improvement project.

Capital Costs

Low to high: These costs depend on the necessary modifications to implement the boarding island. Pedestrian fencing, bollards, and MUTCD object markers may be required. Concrete paving at the bus stop to reduce bus-caused pavement damage may also be needed. Costs can be significantly reduced if boarding island construction can be incorporated into a larger roadway overlay or reconstruction project.

Maintenance Costs

There would be no additional maintenance costs unless items such as pedestrian fencing, bollards, etc. are needed.

Bus Operations Costs

There would be no direct bus operations costs.

Other User Costs

Boarding islands may reduce delays to right-turning traffic from buses when used in combination with a channelizing island.

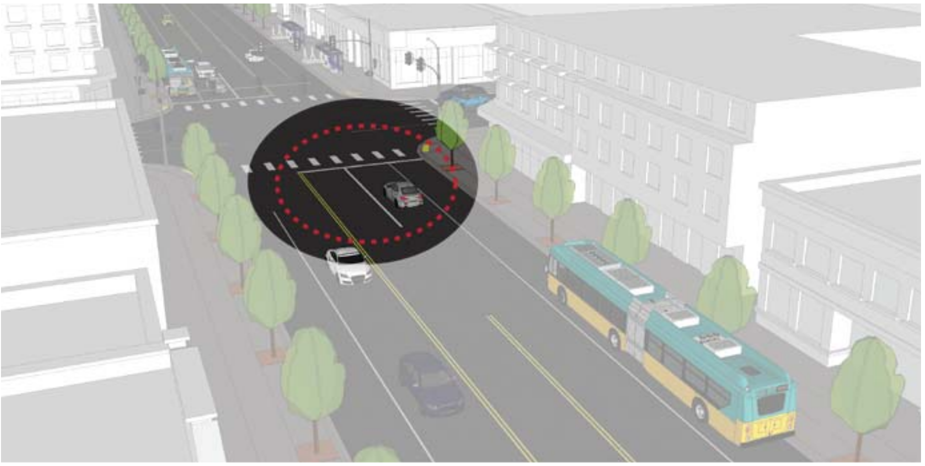
BARRIERS AND SIDE EFFECTS

Sufficient space needs to be available on the island to provide the minimum required ADA clear area for each bus loading area provided at the stop. Potential sight-distance issues created by a bus shelter or stopped buses should be considered when placing bus stops on right-turn channelization islands. Right-turn channelization islands large enough to accommodate a bus stop are more likely to be found in suburban areas where rights-of-way may be less constrained and where roadway designs provide larger vehicle turning radii.

ALTERNATIVES AND COMPANION STRATEGIES

This strategy supports bus-only signal phases (for example, a bus left turn from a right-side lane), queue jumps, most forms of bus lanes, and other strategies that can be used in combination with queue jumps and bus lanes. For example, a short bus lane could be highlighted with red-colored pavement.

4.3.3.5 ROADWAY CHANNELIZATION AND SIGNAGE



OVERVIEW OF STRATEGY

Modification of roadway channelization or signage in support of bus operating characteristics. This could include rechannelization to delineate travel lanes, relocating the stop bar, and/or installing signage, such as “Do Not Block Intersection” sign.

BENEFITS

Rechannelization and signage improvements can improve travel speeds along roadway segments and reduce intersection delay where they are employed by reducing delay associated with turning movements, clarifying lane operations, and improving intersection operations.

OPERATIONAL CONSIDERATIONS

There are no major operational considerations for this tool.

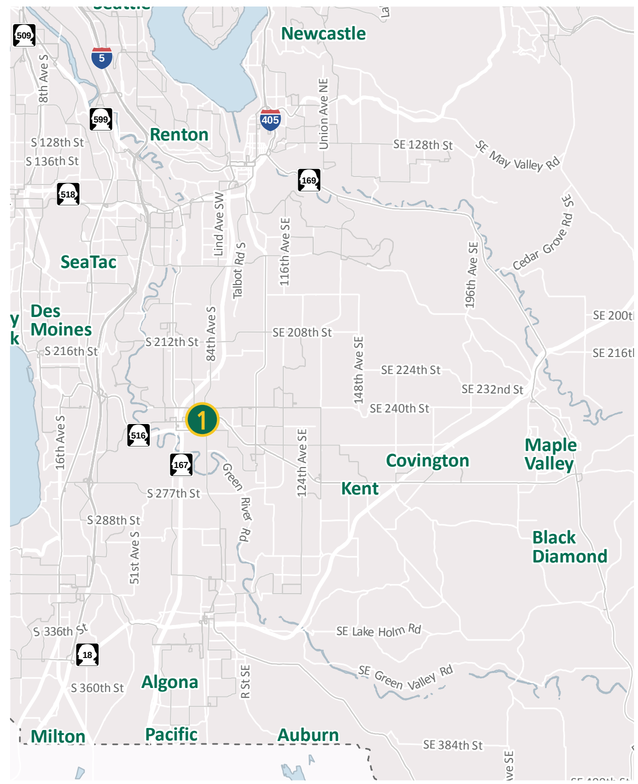
IMPLEMENTATION GUIDANCE

Identify the Condition Causing Delay: identify the condition or conditions causing delay and determine if a channelization or signage improvement would address the concern.

Coordinate with Metro: coordinate with Metro to develop a solution to the condition impacting speed and reliability. Solutions will likely be highly site-specific.

LOCAL APPLICATIONS

1 **Railroad Avenue N and E Pioneer Street**: New signage was installed to limit pedestrian crossing zones, parking stalls were removed to improve visibility, and striping was installed to better define vehicle paths.



COST CONSIDERATIONS

Planning and Coordination

$5,000 to $10,000: These costs would vary based on the amount of study needed to determine the appropriate solution.

Capital Costs

Between $5,000 and $25,000: These costs depend on the type of improvement. Capital costs would include new signage and/or restriping the roadway.

Maintenance Costs

There would likely be minimal added maintenance costs associated with any additional signage or pavement markings.

Bus Operations Costs

There would be savings in travel time and travel time variability.

Other User Costs

There would be minimal costs to other roadway users.

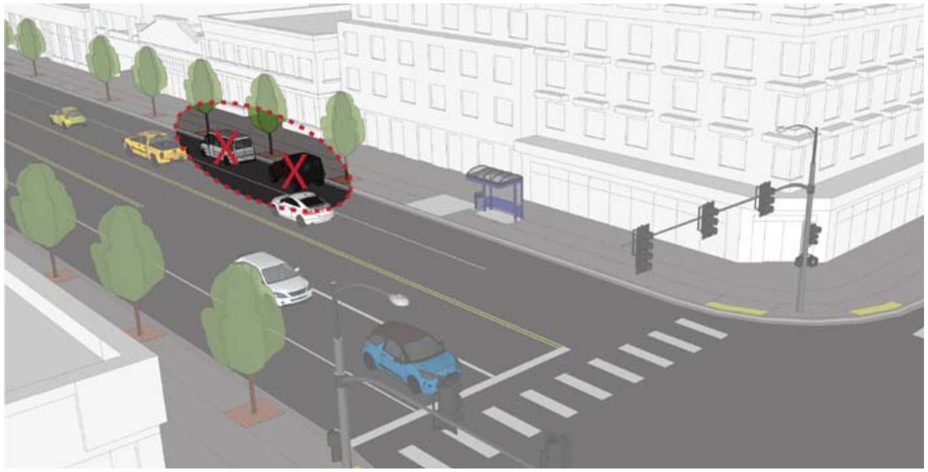
BARRIERS AND SIDE EFFECTS

Changes in roadway channelization will need to consider the availability of roadway space, which could restrict the improvements that could be made.

ALTERNATIVES AND COMPANION STRATEGIES

Many of the traffic control tools could be paired channelization and signage improvements, but improvements to channelization and signage can be used as stand-alone improvements to reduce projects costs while achieving improvements in speed and reliability. Roadway channelization is also often used to improve turn radius.

4.3.3.6 PARKING REMOVAL/ALTERATIONS



OVERVIEW OF STRATEGY

Removal or alteration of parking in targeted areas to provide additional roadway space for buses. This can include providing additional space to increase lane widths, to install a bus lane, or to expand a bus zone.

BENEFITS

Parking removal can permit wider lanes or reduce parking encroachment for transit use. This can reduce travel times and delay near the improvement. Parking can be rearranged or altered (replaced by loading zones) to reduce the loss of parking. Parking removal or alterations can also improve safety for buses and other roadway users.

OPERATIONAL CONSIDERATIONS

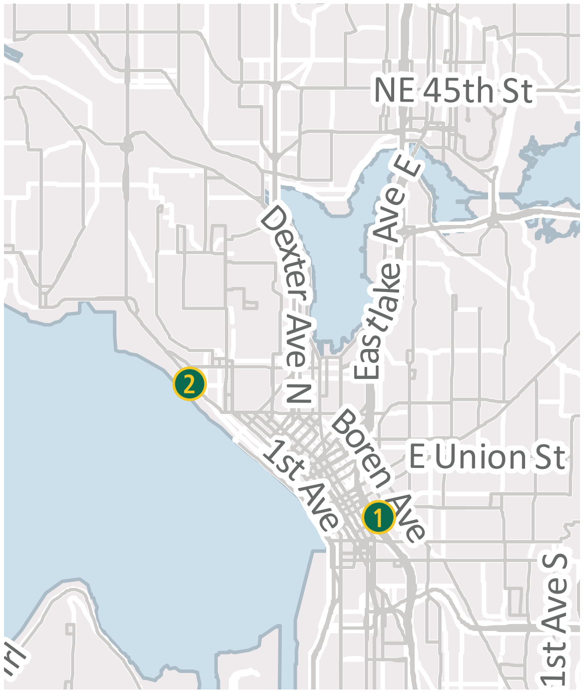
There are no major operational considerations for this tool.

IMPLEMENTATION GUIDANCE

Coordinate with Metro: coordinate with Metro to develop parking alterations or removal concepts that could reduce conflicts with transit. Solutions will likely be site-specific.

LOCAL APPLICATIONS

1. **9th Avenue and Seneca Street**: Parking on the southern curb of 9th Avenue conflicted with new routing of Route 193; therefore parking was restricted in the AM period.
2. **Elliott Avenue**: Parking was restricted during the AM and PM peak periods to provide a curbside bus lane.



COST CONSIDERATIONS

Planning and Coordination

Low to moderate: This is to develop concepts for parking changes or removal. Outreach to nearby property owners may also be necessary. Also, implementing policy guidance on how parking is provided within the street network may be needed.

Capital Costs

Between $1,250 and $25,000: There would be some capital costs associated with removal or restriping of parking. Some new signage may also be necessary.

Maintenance Costs

There would be minimal added maintenance costs.

Bus Operations Costs

There would likely be some savings in travel time and delay for buses.

Other User Costs

There could be some loss or reductions in parking. If paid parking is removed or altered, there could be some of loss of parking meter revenue. Other roadway users could benefit from increased safety.

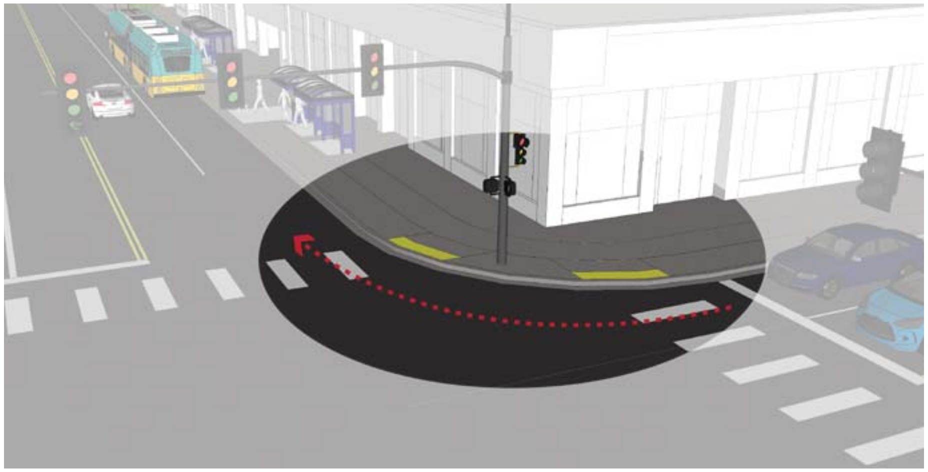
BARRIERS AND SIDE EFFECTS

It can be difficult to remove or reduce parking, particularly in locations where parking is already minimally provided or in residential areas. Public perception to parking removal can be negative, making it difficult to implement projects that involve changes to parking. Support from the community for parking removal is often difficult to obtain. Policy measures that describe how parking is prioritized among other competing needs for roadway space can help provide guidance when implementing this type of project (i.e., policy stating that parking needs are prioritized after adequate space has been provided for transit, nonmotorized users, freight, and general purpose traffic). Extending outreach to the neighboring local jurisdiction where parking changes are proposed is important. Implementation can be easier, if possible, to only modify parking (i.e., restrict parking during peak periods only) and/or replace it in another location rather than removing it completely.

ALTERNATIVES AND COMPANION STRATEGIES

Parking removal or changes can be paired with many of the speed and reliability tools (in some cases, parking removal may be considered as a side effect of making a speed and reliability improvement). Parking removal/alteration is also often used to improve turn radius.

4.3.3.7 TURN RADIUS MODIFICATIONS



OVERVIEW OF STRATEGY

Modifying the turn radius of intersections to make turning movements easier for buses and to reduce delay.

BENEFITS

Intersections that make turning movements difficult for buses can increase delay and travel times for buses. Turn radius modifications can improve travel delay for buses near the intersection where the improvement is made. Turn radius modifications can also improve safety at the intersection if the bus was riding over the curb in order to make the turn movement.

OPERATIONAL CONSIDERATIONS

Modifying the turn radius of an intersection can reduce bus maintenance needs if the bus was riding over the curb frequently in order to make the turn. On-vehicle bicycle racks will need to be considered when analyzing the turn movement radius.

IMPLEMENTATION GUIDANCE

Identify the Condition Causing Delay: identify the specific intersection or turn radius concerns causing delay and determine if minor restriping or parking removal/alteration is sufficient or if the curb needs to be physically altered.

Coordinate with Metro: coordinate with Metro to develop a solution to the turn radius concern impacting speed and reliability. Solutions will be highly site-specific. Conduct an Autoturn analysis or coach test in the field. Consult Metro for appropriate selection of design vehicle and other Autoturn parameters.

LOCAL APPLICATIONS

1 **Seward Park Boulevard and South Othello Street**: modifications were made to the turn radius of the curb to make turning movements easier for Route 50.

COST CONSIDERATIONS

Planning and Coordination

Low to moderate: This is to develop a concept to address the turn radius challenge.

Capital Costs

Low to moderate: These costs depend on the type of solution. Costs for pavement markings will be lower while intersection modifications will have higher capital costs.

Maintenance Costs

There would be minimal added maintenance costs.

Bus Operations Costs

There would likely be savings from reductions in delay at the intersection.

Other User Costs

Improved turn radius for coaches can increase vehicle speeds, which could create safety concerns.

BARRIERS AND SIDE EFFECTS

Pedestrian crossings could become longer at intersections where the curb radius is increased. Improvements to crossings could help mitigate this impact.

ALTERNATIVES AND COMPANION STRATEGIES

This can be a stand-alone tool or can be implemented as part of a package of speed and reliability improvements.

4.3.4 TRANSIT LANES

This section summarizes the different types of bus lanes strategies that can be used. The considerations that apply to all types of bus lanes are described first, followed by information specific to individual types of bus lanes.

4.3.4.1 BUS LANE, GENERAL

4.3.4.2 CURBSIDE BUS LANE

4.3.4.3 INTERIOR (OFFSET) BUS LANE

4.3.4.4 LEFT-SIDE BUS LANE

4.3.4.5 QUEUE BYPASS (SHORT BUS LANE)

4.3.4.6 MEDIAN BUS LANE

4.3.4.7 CONTRAFLOW BUS LANE

4.3.4.8 REVERSIBLE BUS LANE

4.3.4.9 BUS AND BICYCLE LANES (SEPARATED AND SHARED)

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4.3.4.1 BUS LANE, GENERAL

OVERVIEW OF STRATEGY

A roadway lane dedicated exclusively or primarily to the use of buses. Bus lanes are typically considered in the following situations:

- On urban streets with relatively high bus and general traffic volumes, where many buses and their passengers are subject to delay;
- In corridors with BRT or other premium bus service, where maximizing bus speeds and reliability is a priority; and
- On shorter stretches of roadway, allowing buses to bypass a bottleneck or to move to the front of a queue.

Bus lanes may operate full time or only during peak periods. Additional information is included in Section 8.1 of the TCRP *Report 183*.

BENEFITS

Bus lanes can improve bus travel times and bus travel time variability. The magnitude of the benefit depends on a number of factors, including the ability of buses to avoid delays from right-turning traffic, illegal stopping and parking activity in the lanes by other vehicles, and the level of congestion that existed on the roadway prior to the implementation of the bus lanes.

OPERATIONAL CONSIDERATIONS

Specific operational considerations are discussed for each type of bus lane. A queue jump may be added at the end of the bus lane when the lane is constricted. A continuous bus lane is more effective when compared to intermittent bus lanes along a corridor. Metro requires a minimum lane width of 11 feet in order to operate its fleet on public streets.

IMPLEMENTATION GUIDANCE

Balance Operations of All Roadway Users: When converting a lane to bus use only, there should be considerations of how to balance transit speed and reliability benefits with operations of other roadway users and whether there could be some traffic diversion to other parallel streets.

Determine Bus Lane Operating Characteristics: Operating characteristics, such as full-time versus part-time lanes, right-turn prohibitions, shared use, and visibility, should be determined to improve overall support and success of the bus lane.

LOCAL APPLICATIONS

See the specific bus lane sections for local applications.

COST CONSIDERATIONS

Planning and Coordination

Between $15,000 and $115,000: Because bus lane projects are implemented over relatively long lengths of roadway in comparison to the intersection focus of most other types of tools, stakeholder engagement, traffic analysis, and similar efforts will be needed to address a corresponding large area.

Capital Costs

Between $2,000 and $30,000 per 100 feet of bus lane: These costs range from installing new striping and pole-mounted signing, to providing overhead signing, to widening the roadway or reconstructing the roadway median.

Maintenance Costs

Maintenance costs would be relatively low if the bus lane is created by restriping an existing lane, in which case there may be some added costs to maintain the striping and new signs. If the bus lane is created by widening the roadway or creating a new facility in the roadway median, then the costs would be high relative to other strategies due to the new pavement area requiring maintenance.

Bus Operations Costs

Bus lanes can provide a significant time savings for buses, which can be more substantial when used on corridors with high-frequency routes. Note that there is a difference between one route operating on a bus lane at high frequency versus several low-frequency routes that combine to provide a high frequency. The former situation is more likely to result in substantial time savings. However, lesser time savings can still provide benefits to transit agencies and their passengers. Bus lanes typically require some degree of enforcement to operate effectively, which entails added operating costs.

Other User Costs

These costs depend on the type of bus lane developed; see the following sections on specific bus lane types for details.

BARRIERS AND SIDE EFFECTS

Specific barriers and side effects are described for each type of bus lane. For all types of transit lanes, enforcement and conflicting use of transit lanes by bicyclists can be a barrier to implementation.

ALTERNATIVES AND COMPANION STRATEGIES

All of the Bus Operations tools can be paired with bus lanes. Prohibiting right turns by general traffic results in better bus lane operations (as buses avoid waiting behind right-turning vehicles queued at a red light or waiting for pedestrians to clear the crosswalk) and gives Metro considerable flexibility in where bus stops are located.

Passive traffic signal timing adjustments can be considered with bus lane applications to keep buses progressing in the peak direction of travel. Transit signal priority can also be applied where bus volumes are lower (to prevent priority requests at nearly every traffic signal cycle). Bus-only signal phases may be required to serve bus turning movements that would conflict with through traffic if made from the bus lane. Pre-signals can be used to mimic the benefits of a bus lane in locations where constraints make it infeasible to continue a physical bus lane.

It may be beneficial to shift routes serving parallel streets onto the street with a bus lane to use the lane more efficiently; in these cases, bus stops may need to be lengthened to accommodate the increased bus volumes. Red-colored pavement markings can be used on bus lanes to improve their conspicuity, which helps reduce inadvertent violations of the bus lane by other vehicles. However, red-colored pavement markings are expensive and may not be appropriate for peak-only bus lanes.

4.3.4.2 CURBSIDE BUS LANE

OVERVIEW OF STRATEGY

A bus lane located in the rightmost lane of the roadway and adjacent to the right curb. This type of bus lane provides speed and reliability benefits without the need for extensive capital improvements beyond signing and pavement markings. Additional information is included in Section 8.2 of the TCRP *Report 183*.

BENEFITS

See SECTION 4.3.4.1 for a general discussion of benefits. Because of the interference caused by right-turning traffic stopped for pedestrians in crosswalks, curbside bus lanes will produce smaller benefits for buses than other bus lane types when right turns need to be accommodated at intersections. There will also typically be some degree of illegal driving, parking, or stopping activity in the lane.

OPERATIONAL CONSIDERATIONS

There are no specific operational considerations for this type of bus lane. The effectiveness of a curbside bus lane is reduced when approaching an intersection with a high right-turn volume.

IMPLEMENTATION GUIDANCE

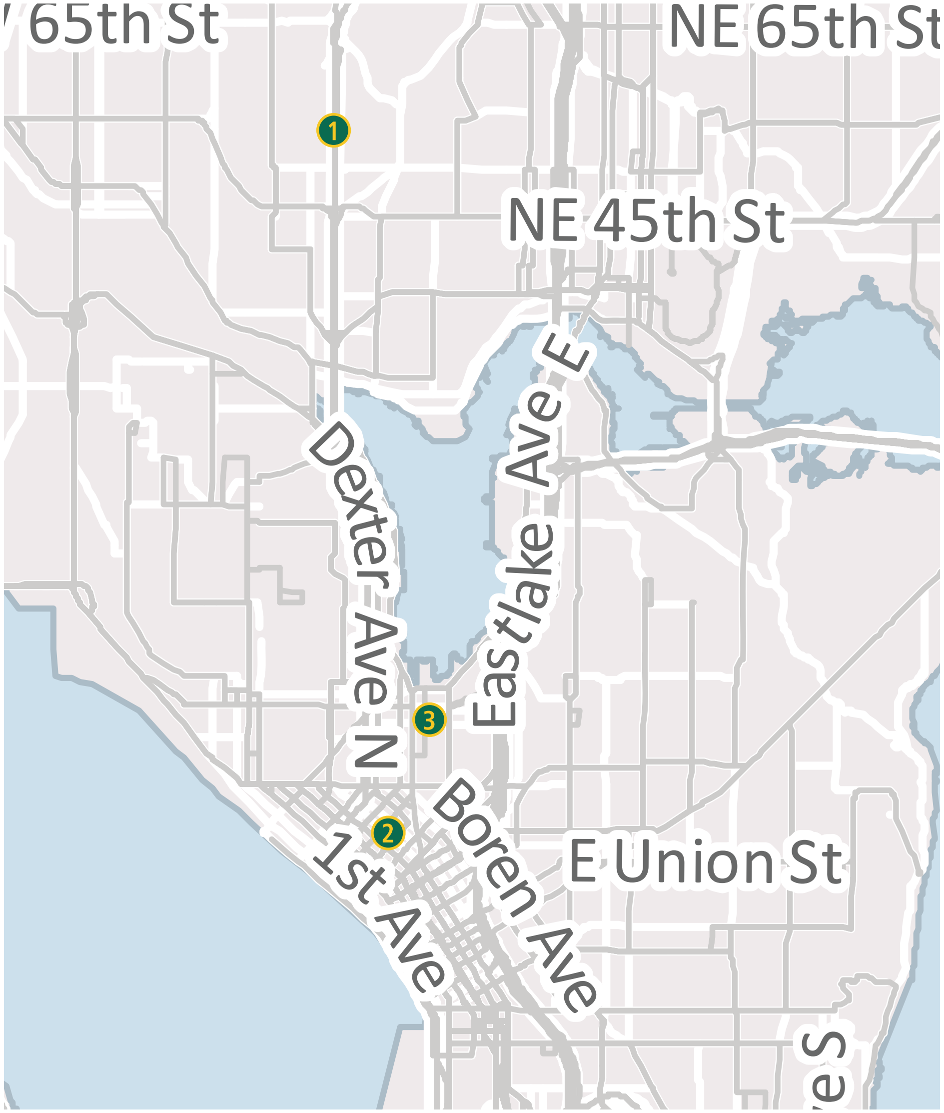
Determine Design Characteristics: Consider key design characteristics and how they fit within the roadway needs. Curbside bus lanes are most susceptible to pressure to allow other road users at specific times or places. See SECTION 4.3.4.1 for a general discussion of implementation guidance.

LOCAL APPLICATIONS

1. **Aurora Avenue N**: a curbside lane is provided on Aurora Avenue North during the AM and PM peak periods.
2. **4th Avenue between Pike Street and Olive Way**: an all-day curbside lane is provided on 4th Avenue between Pike Street and Olive Way.
3. **Westlake Avenue North**: a curbside lane is provided all-day for buses on Westlake Avenue North.

COST CONSIDERATIONS

See SECTION 4.3.4.1 for a discussion of costs. If an existing lane is being converted to a bus lane, the capital costs are typically lower for this type of bus lane because only signing and pavement marking changes would be needed.



BARRIERS AND SIDE EFFECTS

A key constraint is the potentially large number of competing users that also have a stake in how the curb space is used. Competing uses include bus stops, right-turning traffic, parking, deliveries, passenger pickup and drop-off, bicycles, service and maintenance vehicles, and usage as a temporary sidewalk when an adjacent building is under construction. Some of these competing uses may be able to be accommodated from other locations—for example, on the opposite side of the street, on side streets, or off the street.

ALTERNATIVES AND COMPANION STRATEGIES

See the discussion in SECTION 4.3.4.1. Enforcement may be necessary to deter the use of the curbside lane for unauthorized parking, deliveries, and passenger pick-ups and drop-offs. Queue jumps and pre-signals are options for creating a virtual bus lane when a physical curbside bus lane needs to end due to downstream constraints on the use of the curb space.

4.3.4.3 INTERIOR (OFFSET) BUS LANE

OVERVIEW OF STRATEGY

A bus lane in the interior of the roadway that is typically located to the left of the curb (parking) lane but can also be in another non-curb lane. This type of bus lane is typically used to preserve curb space for other uses, such as parking, deliveries, or right-turning traffic. Additional information is included in Section 8.4 of the TCRP *Report 183*.

BENEFITS

See SECTION 4.3.4.1. Interior bus lanes provide the option for using the curb lane as a right-turn lane at intersections (with any bus stop located on a far-side bus bulb), which provides more flexibility for accommodating right turns without significantly affecting bus operations. Thus, interior bus lanes with curb-lane right-turn lanes will operate similarly to curbside bus lanes that prohibit right turns in terms of the impact of turning traffic on buses. Buses traveling in interior bus lanes may experience brief delays associated with vehicle parking maneuvers that buses in curbside bus lanes would not experience, but they are less likely to experience the need to leave the lane to go around vehicles illegally stopped in the lane. General traffic flow benefits from interior bus lanes because parking movements occur from the bus lane rather than a general traffic lane, resulting in smoother general traffic flow between intersections.

OPERATIONAL CONSIDERATIONS

There are no specific operational considerations for this type of bus lane.

IMPLEMENTATION GUIDANCE

Determine Design Characteristics: Consider key design characteristics and how they fit within the roadway needs. Implementing interior bus lanes on relatively narrow roadways (e.g., four- or five-lane two-way roadways) will likely require a combination of creative transit and traffic engineering strategies. As a result, this strategy is one where it is essential to coordinate with Metro to develop mutually satisfactory solutions. See the general bus lane discussion in SECTION 4.3.4.1.

LOCAL APPLICATIONS

1 **Columbia Street**: an interior bus lane is provided on Columbia Street between 2nd and 1st Avenues.

COST CONSIDERATIONS

See the general discussion in SECTION 4.3.4.1. Interior bus lanes may require higher capital and maintenance costs than curbside bus lanes due to the potential need for overhead signs to make the bus lane more visible to other roadway users.

BARRIERS AND SIDE EFFECTS

The main potential constraint for interior bus lanes is the loss of roadway capacity; thus, this is primarily a strategy to be considered in locations where policy environments permit some degradation of roadway operations. It may be necessary to use a combination of traffic control strategies (e.g., turn restrictions and other traffic pattern changes) at busy intersections and short sections of curbside bus lanes to provide two through lanes or dual turn lanes where needed to serve traffic operations requirements

ALTERNATIVES AND COMPANION STRATEGIES

See the list of generally applicable companion strategies in SECTION 4.3.4.1. Interior bus lanes work well in combination with bus bulbs, which can also help increase the amount of available on-street parking because parking does not need to be removed before or after a stop to give buses access to a curbside stop. Traffic control strategies such as left-turn restrictions at key intersections can help improve traffic flow in the remaining general-purpose lanes.

4.3.4.4 LEFT-SIDE BUS LANE

OVERVIEW OF STRATEGY

A bus lane on the left side of the roadway that is adjacent to the left curb on one-way streets or adjacent to the median on two-way streets. This type of bus lane is typically applied in special-purpose situations where a more conventional location is infeasible. Additional information is included in Section 8.5 of the TCRP *Report 183*.

BENEFITS

See SECTION 4.3.4.1. Left-side bus lanes avoid right-turning traffic interferences that can be encountered with more conventional bus lanes. Typically, left turns are prohibited from left-side bus lanes, or left-turning traffic is allowed to cross the bus lane into a left-turn bay; therefore, buses do not experience significant interference with left turning traffic.

OPERATIONAL CONSIDERATIONS

Buses used on routes with left-side bus lanes may require doors on both sides of the vehicle depending on routing and the location of bus stops. Buses may require a queue jump to return to the curb lane. Bus stops may need to be closed or relocated to accommodate a left-side bus lane.

IMPLEMENTATION GUIDANCE

Determine Design Characteristics: Consider key design characteristics and how they fit within the roadway needs. Motorists turning onto a street with a left-side bus lane will likely need special signs to indicate which lane(s) they should turn into. See also the general bus lane discussion in SECTION 4.3.4.1.

LOCAL APPLICATIONS

1 **Rainier Avenue South and South Dearborn Street**: a left-side bus lane is provided along Rainier Avenue South, along with other speed and reliability improvements.

COST CONSIDERATIONS

See the general bus lane discussion in SECTION 4.3.4.1. Left-side bus lanes will experience slightly higher capital and maintenance costs than curbside bus lanes due to the need for signs to inform motorists on side streets about the presence of the left-side lane.

BARRIERS AND SIDE EFFECTS

Depending on how the bus lane is developed—by taking parking from the left curb or by converting a general traffic lane to bus use—the same constraints faced by curbside bus lanes or interior bus lanes will apply. When conventional buses will be serving bus stops along a left-side bus lane, sufficient roadway space needs to be available to provide an ADA-compliant boarding island.

ALTERNATIVES AND COMPANION STRATEGIES

See SECTION 4.3.4.1 for a list of applicable companion tools. Median bus lanes are a related strategy. If bus stops are to be provided along a left-side bus lane, boarding islands could be required.

4.3.4.5 QUEUE BYPASS (SHORT BUS LANE)

OVERVIEW OF STRATEGY

A relatively short bus lane that allows buses to move to the front of the line at a bottleneck, where they then merge into the adjacent general traffic lane. Additional information is included in Section 8.6 of the TCRP *Report 183*.

BENEFITS

The magnitude of the benefit depends on how much delay general traffic experiences at a bottleneck, which in turn depends on the degree to which roadway demand exceeds capacity. The benefit might be a time savings on the order of 1 minute at a freeway ramp meter to 10 minutes or more in the case of a severe capacity constraint on an arterial roadway. Travel time variability would also be expected to improve.

OPERATIONAL CONSIDERATIONS

Merging back into traffic after the intersection can be difficult, especially if a queue jump is not implemented along with the queue bypass.

IMPLEMENTATION GUIDANCE

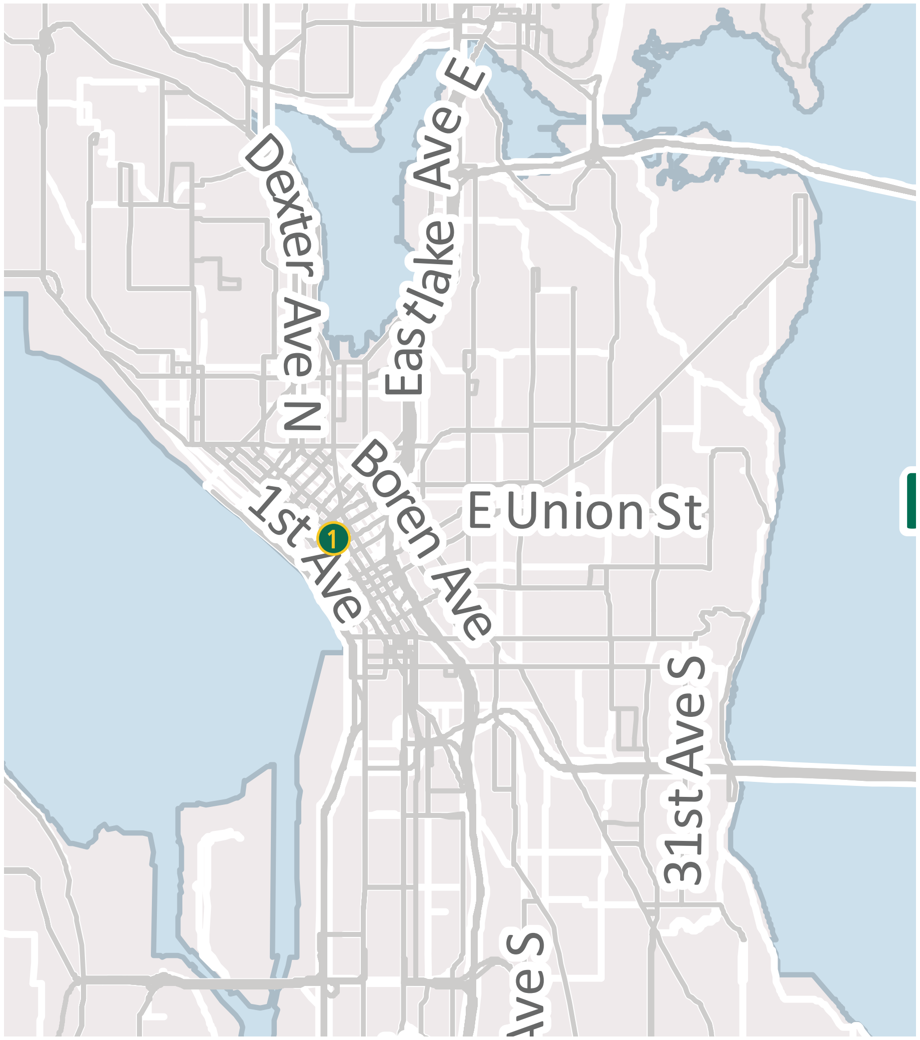
Determine Design Characteristics: Consider key design characteristics and how they fit within the roadway needs. The main implementation criterion is that the queue bypass lane should start before the point that buses reach the back of the general traffic queue to allow buses to proceed without delay. See the general bus lane discussion in SECTION 4.3.4.1.

LOCAL APPLICATIONS

1 **2nd Avenue and Columbia Street:** A queue bypass is provided at 2nd Avenue on Columbia Street.

COST CONSIDERATIONS

See the discussion of costs in SECTION 4.3.4.1. The overall project cost will often be lower than for other kinds of bus lanes because queue bypass projects tend to be shorter, but the cost will be similar to other types of bus lanes when calculated on a per-mile basis. Capital and maintenance costs will depend on whether new pavement is required to create the lane or whether an existing lane is converted to bus use only.



BARRIERS AND SIDE EFFECTS

When the bottleneck is created intentionally, such as at a ramp meter, there needs to be sufficient right-of-way available to provide a bypass lane long enough for buses to avoid the queue in most circumstances. When the bottleneck is created by a roadway capacity constraint, it might be possible to take a general traffic lane to create the queue bypass lane because this has the effect of moving the general traffic merge point upstream, but typically does not affect general traffic delay (the time spent waiting in the queue simply occurs at a different point on the roadway). However, as the back of the queue also moves upstream, there needs to be sufficient space to store the queue without it spilling back into upstream intersections.

ALTERNATIVES AND COMPANION STRATEGIES

The alternative and companion strategies included in SECTION 4.3.4.1 also apply. Queue jumps and pre-signals are related strategies, but these rely on traffic signal control to merge buses into the general traffic lane.

4.3.4.6 MEDIAN BUS LANE

OVERVIEW OF STRATEGY

Lanes reserved for the exclusive use of buses. These lanes are located in the middle of a roadway and are often separated from other traffic by curbs or landscaped islands. These types of bus lanes remove interference from other roadway users. Additional information is included in Section 8.7 of the TCRP *Report 183*.

BENEFITS

Median bus lanes remove interference from other roadway users (e.g., right-turning traffic, parking, delivery activity) that other types of bus lanes can experience. When physically separated from general traffic by curbs or islands, the potential for unauthorized use is very low, except for the possibility of vehicles accidentally turning left into the bus lanes at a signalized intersection. As a result, median bus lanes provide improvements in bus travel time reliability and remove most potential sources of bus delay other than traffic signal delays.

OPERATIONAL CONSIDERATIONS

Buses would need to merge back with traffic when it needs to make a right turn and/or when the bus lane ends. If boarding islands are not provided, the bus would also need to move across travel lanes to serve stops.

IMPLEMENTATION GUIDANCE

Determine Design Characteristics: Consider key design characteristics and how they fit within the roadway needs. Key design characteristics include degree of separation, station location, general traffic left-turn accommodations, bus turning accommodations, pedestrian access and crossing movements. See AASHTO's *Guide for Geometric Design of Transit Facilities on Highways and Streets* for more detailed design guidance.

Consider Feasibility: determine potential roadway and traffic impacts using modeling software to understand potential trade-offs and implementation feasibility.

LOCAL APPLICATIONS

There are currently no local applications of median bus lanes.

COST CONSIDERATIONS

See the general bus lane discussion in SECTION 4.2.4.1. Median bus lanes are typically the most expensive bus lane option due to the extensive street reconstruction required to adequately separate the bus facility from general traffic and the need to provide stations and pedestrian access to those stations within the street median.

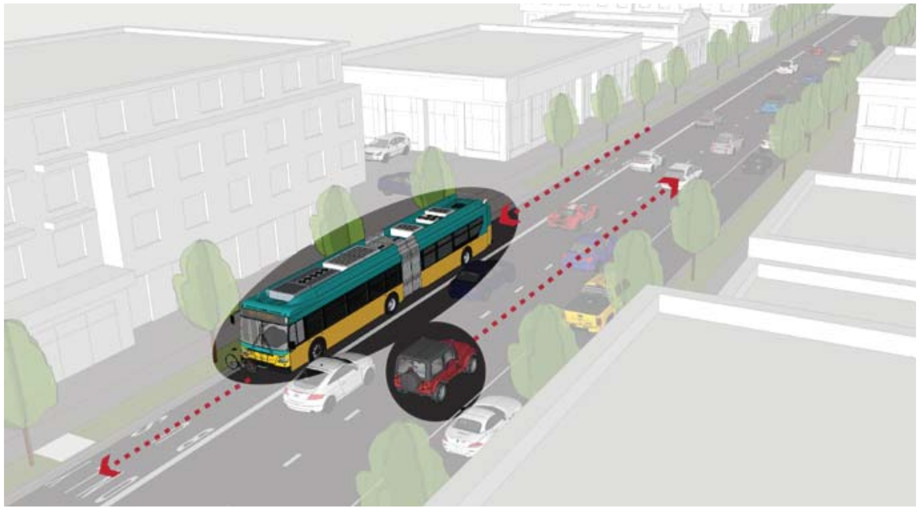
BARRIERS AND SIDE EFFECTS

After cost, the primary constraint is the availability of right-of-way to accommodate both median bus lanes and stations along the bus lanes. Depending on the degree of separation of the bus lanes from other traffic and the need to accommodate bus turns from the bus lanes, median bus lanes typically require three to four lanes of total right-of-way width. In addition, a sufficient number of through and turning general traffic lanes need to be maintained at intersections, and width may also be required for bicycle facilities, on-street parking, or other design features. General traffic left turns would also need to be maintained (unless a turn restriction is implemented), which can have impacts on bus delay because additional time in the signal cycle would likely be used to provide this turning movement. This in turn may reduce the amount of green time available for bus movements compared to bus operations in a curbside or interior bus lane, resulting in more bus delay at signals. The degree to which bus signal delay is increased will depend on a combination of the traffic signal timing and phasing, the bus stop location at the intersection, and the location of the left-turn lane relative to the bus lanes; it is best determined through simulation. The constraints associated with bus-only signal phases will also be applicable.

ALTERNATIVES AND COMPANION STRATEGIES

The discussion of companion strategies described in SECTION 4.3.4.1 also applies. Turning movements from a median bus lane at a signalized intersection require a bus-only signal phase, and through movements will often require one, depending on how general traffic left turns are accommodated.

4.3.4.7 CONTRAFLOW BUS LANE



OVERVIEW OF STRATEGY

A bus lane provided in the opposite direction of normal traffic flow on a one-way or divided street. This allows buses to use more direct routing through a one-way street grid, to keep both directions of a route on the same street, to take advantage of available capacity in the opposite direction of travel, or a combination of these. Additional information is included in Section 8.8 of the TCRP *Report 183*.

BENEFITS

The benefits described in SECTION 4.3.4.1 also apply. Contraflow bus lanes on one-way streets typically operate free of turning-traffic, parking, and delivery conflicts and tend to be self-enforcing. Part-time contraflow lanes allow buses to avoid traffic congestion in the normal-flow lanes.

OPERATIONAL CONSIDERATIONS

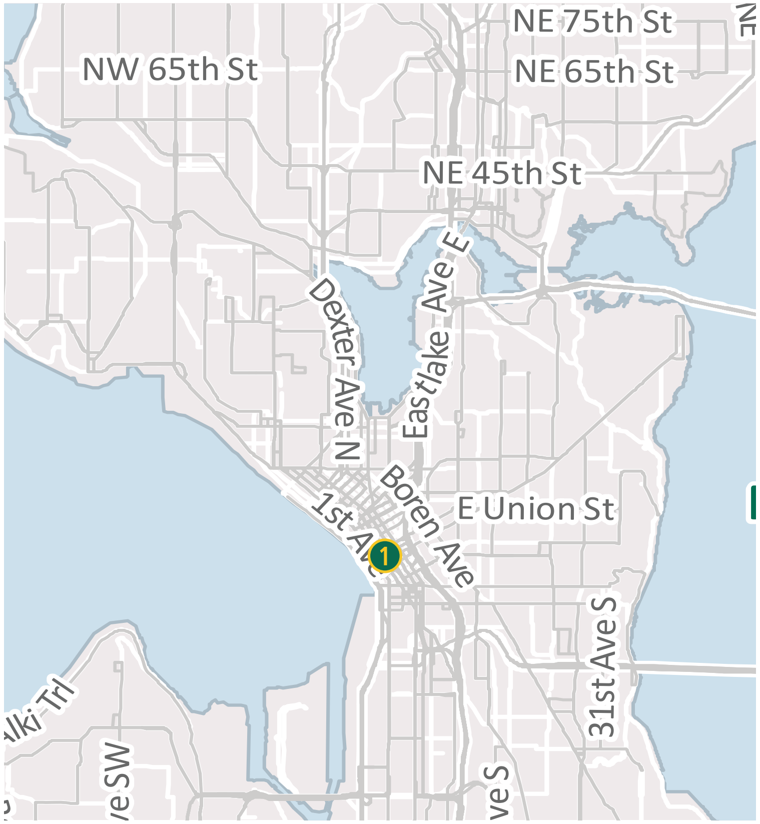
There could be a need for additional training for operators on safety concerns that could arise with contraflow bus lanes.

IMPLEMENTATION GUIDANCE

Determine Design Characteristics: Consider key design characteristics and how they fit within the roadway needs. Key design characteristics include location of the lane within the roadway and use of signage and pavement markings to delineate the lane from other roadway users. See AASHTO's *Guide for Geometric Design of Transit Facilities on Highways and Streets* for more detailed design guidance.

LOCAL APPLICATIONS

1 **Seneca Street and 2nd Avenue**: a contraflow lane is provided on Seneca Street between 2nd Avenue and 3rd Avenue.



COST CONSIDERATIONS

See SECTION 4.3.4.1 for a general discussion of costs. Contraflow bus lanes to the right of opposing traffic would have costs similar to curbside bus lanes. Contraflow lanes where buses operate on the left side of the street may require greater separation from traffic (e.g., pylons, curbing) to keep traffic from inadvertently entering the lane and will require extra measures to draw pedestrians' attention to buses approaching from an unexpected direction. Part-time contraflow lanes may require overhead lane control signals (an additional capital and maintenance cost relative to other bus lane types) or daily installation and removal of pylons (an additional operating cost relative to other bus lane types).

Contraflow lanes developed on streets as part of a conversion from two-way to one-way operation have experienced a drop in collisions, while contraflow lanes developed on existing one-way streets have sometimes experienced an increase in crashes.

BARRIERS AND SIDE EFFECTS

Contraflow lanes require the conversion of general traffic lanes to bus-only use, which could be infeasible on narrower roadways or could require the removal of parking. Contraflow bus lanes on one-way streets normally require prohibiting parking and deliveries on the side of the street used by buses and thus have similar potential issues as curbside bus lanes. Placement of a contraflow bus lane on the left side of a one-way street can be confusing for other roadway users.

Part-time contraflow lanes typically require a strong directional split of traffic (e.g., 2/3 or more of the roadway's traffic in the peak direction) and the ability to prohibit left turns during hours when the contraflow lane is in operation. Part-time contraflow or reversible operation on arterial streets is not common in the United States, and an extensive outreach effort to motorists may be required as part of the implementation.

ALTERNATIVES AND COMPANION STRATEGIES

The companion strategies described in SECTION 4.3.4.1 also apply. Depending on the way the contraflow bus lane is developed, turning movement restrictions may be required to prevent potential conflicts between buses and other motor vehicles. Red pavement markings may be desirable to improve the conspicuity of lanes for vehicles and pedestrians. Bus signal faces may be required to control contraflow buses at signalized intersections.

4.3.4.8 REVERSIBLE BUS LANE

OVERVIEW OF STRATEGY

A single bus lane that serves buses operating in both directions. This type of bus lane is provided on a roadway where right-of-way constraints prevent bus lanes being provided in both directions. Additional information is included in Section 8.9 of the TCRP *Report 183*.

BENEFITS

Turns from the bus lane are typically prohibited, which provide benefits similar to those of median bus lanes, interior bus lanes, or curbside bus lanes with right turns prohibited, depending on the design of the reversible lane. The benefits summarized in SECTION 4.3.4.1 also apply.

OPERATIONAL CONSIDERATIONS

Some operator training may be required to familiarize operators with how to use this type of bus lane. Also, considerations of route design would be necessary; routes with high numbers of turns would likely be poor candidates for reversible bus lanes.

IMPLEMENTATION GUIDANCE

Determine Design Characteristics: Consider key design characteristics and how they fit within the roadway needs. Reversible bus lanes may be an option where right-of-way constraints prevent the use of bus lanes for both directions of travel. Key design characteristics include the type and timing of lane control to be used, turning restrictions needed, and pedestrian signage and notifications. See Section 8.9 of the TCRP *Report 183* for additional guidance.

LOCAL APPLICATIONS

There are currently no local applications of reversible bus lanes.

COST CONSIDERATIONS

Reversible bus lanes are typically more expensive to construct than similar types of non-reversible bus lanes (i.e., median, interior, or curbside lanes), particularly when a signal system to control bus access to the lane is required. More signs are needed relative to other types of bus lanes to warn other road users of the unusual operation, and the use of red-colored pavement markings is suggested to improve the bus lane's conspicuity. Time-controlled reversible bus lanes may require two sets of bus stop infrastructure at each stop—one for when buses are using the bus lane and one for when buses are using the general traffic lane. See also the discussion of costs in SECTION 4.3.4.1.

BARRIERS AND SIDE EFFECTS

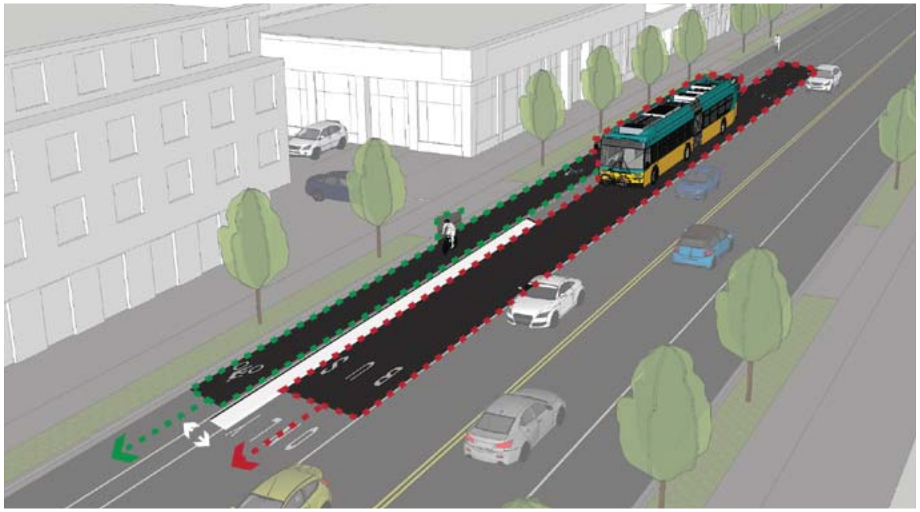
Restrictions to turning movements across the reversible bus lane may be needed to eliminate or reduce the potential for crashes between buses and turning motorists that did not expect a bus to come from either direction in the lane. Two-directional, single-lane operation that alternates back and forth can greatly reduce the bus frequency that can operate in the bus lane, with the impact increasing as the distance between passing opportunities increases. Converting a curb lane to a reversible bus lane may have impacts on adjacent land uses similar to those of a curbside bus lane (SECTION 4.3.4.2).

When protected turn phases are required to serve general traffic turns across the reversible lane, the amount of green time available for buses may be less than that available for general through traffic, resulting in longer bus signal delays. When the lane alternates direction through the use of signals, buses may experience delay waiting for a bus from the opposite direction to clear the reversible lane segment. Consequently, ensuring that buses arrive on schedule at the start of a reversible lane segment to use their designated time slot, and designing passing opportunities in appropriate locations for the planned headway to minimize potential waits, are critical factors to address for buses to gain a travel time benefit from the use of a reversible lane.

ALTERNATIVES AND COMPANION STRATEGIES

Reversible bus lanes separated from general traffic only by striping are preferably highlighted in some way, such as with red pavement markings. When signals are used to control bus access to the reversible bus lane, transit signal faces are typically used to indicate to buses when they may proceed. Transit signal faces and bus-only signal phases are frequently used at signalized intersections along the bus lane. Turn restrictions that prevent general traffic from crossing the bus lane may also need to be considered. ADA-compliant boarding islands will be required to serve stops along bus lanes in the center of the street. See also the generally applicable companion strategies described in SECTION 4.3.4.1.

4.3.4.9 BUS AND BICYCLE LANES (SEPARATED AND SHARED)



OVERVIEW OF STRATEGY

Corridors that accommodate both bus and bicycle lanes. Bus and bicycle lanes can be implemented as either separated facilities or combined in a shared bus and bicycle lane. Separated bus and bicycle lanes are preferred, but on corridors with lower bus volumes and limited right-of-way, shared bus and bicycle lanes can be provided to achieve a similar purpose. Design of bus and bicycle lanes needs to consider potential conflict points and interaction between the different modes to reduce the potential for collisions. Section 8.3 of the TCRP *Report 183* contains additional information on shared bus and bicycle lanes.

BENEFITS

Benefits to transit speed and reliability would be similar to those discussed in SECTION 4.3.4.1 and SECTION 4.3.4.2. Dedicated bicycle facilities in the same corridor as bus service enhances the effectiveness of the two modes because bicycling is supportive of transit ridership and access.

OPERATIONAL CONSIDERATIONS

Consideration of the type of buses operating on the corridor is necessary. Trolley overhead wire needs to be provided over the bus lane and for safety reasons cannot be placed over bicycle lanes, which could affect the placement of bicycle and bus lanes within the right-of-way. Design for bicycle lane barriers need to consider the turn radius of buses and the right-of-way into which they turn. Bus stop and layover access for buses can conflict with bicycle lanes. Bus stop islands are preferred, but if they cannot be provided, pavement markings and other physical delineation should denote the space required to allow buses to enter and depart from the bus zone. On one-way streets with bus and bicycle lanes, the preferred placement of the bicycle lane is the left curb.

IMPLEMENTATION GUIDANCE

Develop Cross Section: Determine whether facilities will be separated or shared. Review right-of-way constraints and bus volumes on corridor to plan appropriate facility type.

Determine Design Characteristics: Determine how bicycle and bus lanes will be provided within the right-of-way. Design of the facilities should consider the needed turn radius, trolley infrastructure and location of bus stops and layover. Other key design characteristics include safety considerations for conflict zones between modes, the type and timing of bus lane control to be used, turning restrictions needed, and pedestrian signage and notifications.

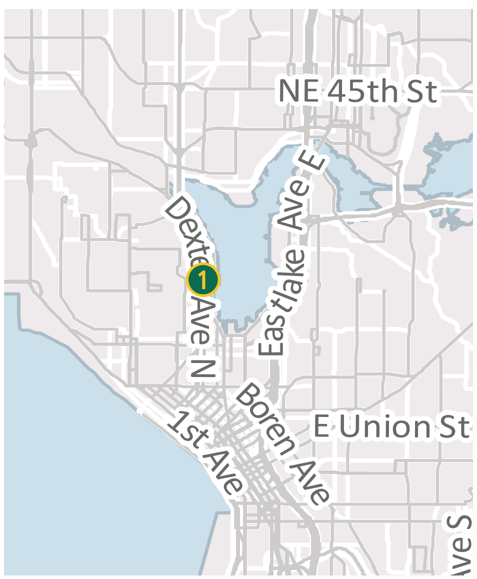
Coordinate with Metro: coordinate with Metro to ensure safety and operational considerations are made for the interaction between bus and bicycle traffic.

LOCAL APPLICATIONS

1 **Dexter Avenue**: Separated bus and bicycle facilities with bus boarding islands are provided on Dexter Avenue.

COST CONSIDERATIONS

Separated bus and bicycle lanes may be more expensive to design and install than standard curbside bus lanes because barriers and boarding islands may be needed. Boarding islands are cheaper and easier to install when included in a larger roadway paving project. Depending on available right-of-way, costs could be higher to provide enough space for bus and bicycle lanes in addition to sidewalks and general purpose lanes. Shared bus and bicycle lanes would have slightly higher costs compared to curbside bus lanes because additional pavement markings and signage would be required. See also the discussion of costs in SECTION 4.3.4.1.



BARRIERS AND SIDE EFFECTS

Separated bus and bicycle lanes require more right-of-way than other types of bus lanes and could require higher capital costs to modify bus stops or trolley infrastructure. Special consideration must be made to safely provide access to and from bus zones and layover.

For shared bus and bicycle lanes, roadways with a significant uphill grade are not desirable because the speed differential between buses and bicycles is greater compared to level or downhill roadways. Roads with high general purpose traffic volumes in the adjacent lane are also not desirable because buses would have to frequently slow behind bicyclists while waiting for a gap in traffic to move around the bicyclist. Also, bicyclists would need to pass stopped buses in the travel lane unless a boarding island was provided. Shared bus and bicycle lanes are also not desirable along routes with frequent headways and higher travel speeds.

The design needs to pay particular attention to potential conflict points, such as intersections, and consider interactions between bicycles and buses, as well as other modes. Consideration of the behaviors of all users is important to minimize the potential for conflicts.

ALTERNATIVES AND COMPANION STRATEGIES

See the generally applicable companion strategies described in SECTION 4.3.4.1. Some of the traffic signal-related tools described in SECTION 4.3.2 can also be used to benefit bicyclists, including bus-only signal phases that do not conflict with parallel bicycle traffic, queue jumps, and pre-signals. Bus-specific signals could also benefit bicycle turning movements, particularly when a well-used bicycle route follows the same alignment as the bus route. Bicycle signal heads can be considered to control bicycle movements when bicycle priority will be given in conjunction with bus priority. Boarding islands should be considered with separated bus and bicycle lanes.

5. CASE STUDY

The following case study describes the process of building a speed and reliability improvement partnership with Metro by walking through a successful project and calling out the steps identified in the FRAMEWORK FOR PARTNERSHIPS SECTION.

This case study describes the Route 150 Speed and Reliability Improvement Project that occurred in the cities of Tukwila and Kent. This work took place from 2015 to 2018 and was led by Metro with both partner agencies heavily involved throughout.

ROUTE 150 IMPROVEMENTS

WATCHING FOR OPPORTUNITIES

Route 150 is one of Southeast King County's primary transit routes and serves a diverse mix of residential, commercial, and industrial uses along its corridor. Connecting Downtown Kent, Kent's West Valley, Southcenter Mall in Tukwila, and Downtown Seattle together creates a route that serves a large population with multiple different trip patterns.

Route 150 provides frequent 15-minute service from 6 a.m. to 6 p.m. and then subsequent half-hourly service from 6 p.m. to midnight. Weekday ridership is between 1.75 and 2 million rides per year with the heaviest ridership occurring during the peak hours. Because of the numerous economic centers served along the route, it also has strong mid-day and evening ridership, especially for industries that have non-traditional hours, such as service and warehousing.

Because of the importance of this route, Metro and its city partners were concerned when reliability suffered due to increases in regional traffic congestion. Metro and each of the partner agencies agreed that providing competitive and consistent transit service to these important economic centers was critical. Metro and the cities began discussing potential improvements to the route to improve its performance. From these initial discussions, a Federal Transit Administration (FTA) grant was applied for and subsequently a $2.64 million grant was awarded to Metro.

CONNECTING

Using the FTA grant, Metro began working with its partner agencies to develop a planning study that would further determine the issues, needs, and solutions for the Route 150 corridor. The initial planning process happened jointly among the three parties. Additionally, Metro coordinated with the Washington State Department of Transportation (WSDOT) to understand its needs and requirements along a portion of the corridor that was designated a state route.

IDENTIFYING THE PROBLEM AND OPPORTUNITY

In order to move forward with the planning study, a consultant team was selected and tasked with developing an existing conditions analysis of the corridor. This existing conditions work identified where problems occurred on the corridor and where there was opportunity for improvement.

DEFINING THE PROJECT AND ITS BENEFITS AND TRADE-OFFS

Improving Route 150's speed and reliability was the primary objective of this effort. In turn, these improvements would boost the route's overall ridership and lead to continued ridership growth. While in general this corridor can be described as moderately congested with reasonable free-flow speeds, there were specific areas of concern that required careful consideration of modes and adjacent land uses.

SIGNAL TIMING

While the route primarily travels in a north/south direction, it does so along multiple corridors. When working with the jurisdictions to optimize signal timing along the route, it was Metro's desire to optimize the path Route 150 uses. This meant the prioritization of certain turning movements at locations along the corridor where those movements were competing with prioritization of through vehicles. By working with staff from each of the jurisdictions, Metro was able to successfully prioritize a number of key turning movements for transit while also minimizing impacts to the mainline flow. Metro worked with the partner agencies to identify the locations where transit could be prioritized, as well as the locations where Metro's optimization desires could not be accommodated due to the impacts to mainline traffic. Metro was able to successfully demonstrate both the benefits and trade-offs of the retiming approach to secure timings more favorable to transit than what would have been expected at first glance. By working with Tukwila, Kent, and WSDOT, the signal retiming effort was able to improve southbound PM peak travel time for general purpose traffic and transit

by more than 5 minutes. Queuing before and after the improvements are shown below.

QUEUE JUMPS AND QUEUE BYPASS LANES

This project proposed five potential locations for a queue jump during the initial planning. Based on the outcomes of the alternatives analysis it was determined that three of the locations would provide only a minimal benefit. Two of the locations were moved forward; the first was a straightforward implementation of a queue jump and channelization modification. (See SECTION 4.3.2.9 for a more in-depth discussion of queue jumps) The second location on West James Street near 4th Avenue North (pictured) required several iterations of its design in order to accommodate the City of Kent's requirements and to mitigate parking loss at the adjacent city community center. While a challenge, this queue jump will include approximately a 1/4 mile of queue bypass lane on completion, which will function similarly to a BAT lane. This location, in particular, was of significant importance because this treatment will enable significant bus priority when the frequently used adjacent downstream rail crossing is active.

PEDESTRIAN CROSSINGS

In partnership with Metro's Route Facilities group, this effort was also able to install two rapid rectangular flashing beacon (RRFB) pedestrian crossings. These crossings connect bus stop zone pairs, which currently do not have a marked crossing within a 1/4 mile. While this improvement does not benefit bus speed and reliability, it does make the customer experience of reaching these zones faster and more efficient. This is an example of how better access to transit is being provided along with speed and reliability improvements.

FUNDING THE PROJECT

Using the FTA grant, Metro was able to fund the improvements identified during the planning study. This effort did not require a contribution from the local jurisdiction partners outside of the significant time spent reviewing, working with Metro staff, and working with the consultant teams on the projects.

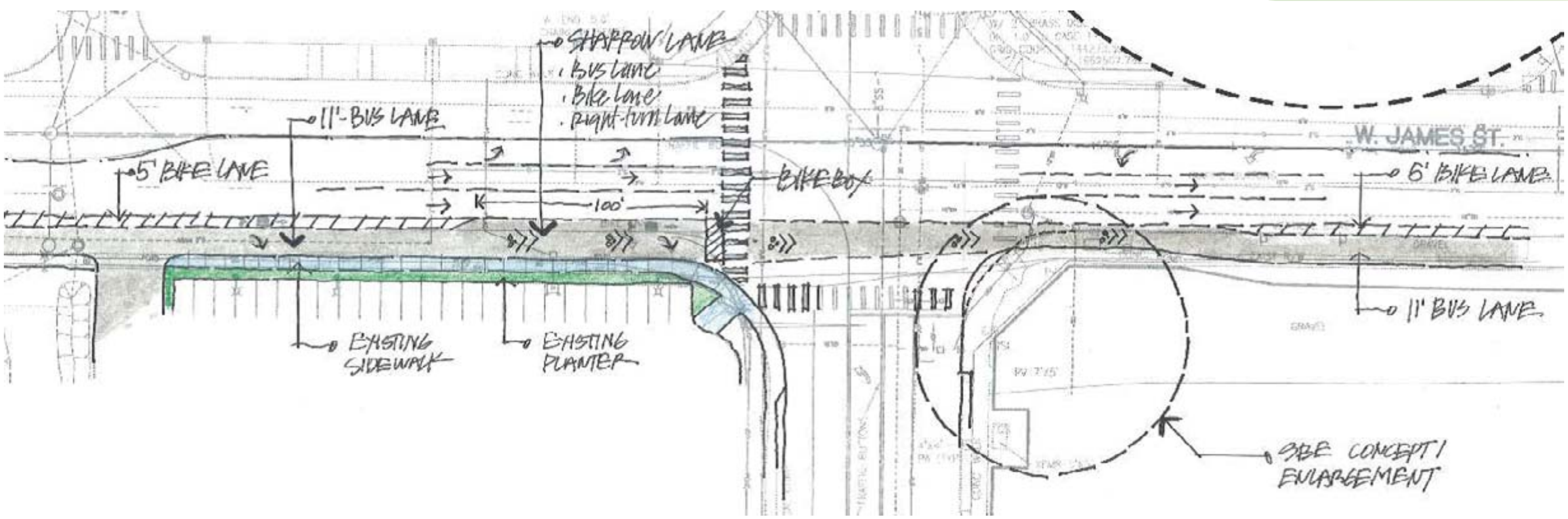
BUILDING THE PROJECT

Project construction is scheduled for 2017 to 2018 and will be constructed by Metro's Design and Construction group.

LESSONS LEARNED

Lessons learned from the Route 150 project included:

- Coordinate with partner local jurisdictions early
- Advocate to conceptualize, analyze and then decide when it comes to projects with trade-offs.
- Work to provide mutually beneficial improvements and when necessary, be prepared to provide reasonable cost-effective mitigations to impacts.



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5. GLOSSARY

This glossary contains King County Metro-specific terms that may be helpful for users of the Speed and Reliability Toolbox.

ALTERNATIVE SERVICES: Flexible, non-fixed route bus service

BAT LANES: Business Access and Transit Lanes

BUS ZONE: Bus Stop

CORRIDORS: A pathway that is often home to multiple bus routes

HIGH-FREQUENCY ROUTE: “Show-up-and-go” service that starts early and runs late in the day. Includes both RapidRide and non-RapidRide routes

HUBS: Centers of activity, such as a transportation center, a rail station, or a major destination

METRO CONNECTS: King County's vision for bringing more service, more choices, and one easy-to-use system over the next 25 years

RAPIDRIDE: King County Metro's bus rapid transit service that includes a unique fleet of vehicles, and corridor and system capital investments, such as transit signal priority and improved passenger facilities

RELIABILITY: The ability for transit vehicles to arrive at stops at predictable times

SPEED: The ability of transit vehicles to move along their routes in reasonable amounts of time

SPOT IMPROVEMENT: A transit improvement at a specific spot or segment along a route or corridor

TRANSIT-SUPPORTIVE STRATEGIES: Speed and reliability improvements

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