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ETC Capital and Operational Toolbox Memorandum

This Toolbox is a collection of potential capital and operational treatments that can be applied to improve transit performance or create safer, more predictable interactions with other travel modes. It was developed as part of the Enhanced Transit Corridors Plan.

Toolbox Organization

For ease of navigation, potential treatments are organized into categories that reflect the purpose and function of specific tools. Within the categories, treatments are organized in descending order from most to least capital intensive. Tools may be applied individually or in combination – including tools from multiple categories.

Individual toolbox sheets are intended to give an overview of each tool, including the type of problem it seeks to solve, key features, and typical context for application.

ETC Toolbox Purpose

As one component of the Enhanced Transit Corridors Plan, this Toolbox accompanies the ETC Existing Conditions & Methodology Memorandum, which describes criteria and performance measures to inform the evaluation and prioritization of ETC

Candidate Corridors. Transit operations criteria and performance measures address Reliability, Transit Speed, and Dwell Time. These measures help identify different types of delay along potential ETC corridors. Toolbox treatments can be used to address this delay and help improve transit operations.

Based on the Methodology evaluation, the consultant team will recommend Toolbox treatments for further consideration based on the type of delay measured in particular corridors. This high-level assessment will be based on indicator measures and a general understanding of the roadway context.

Toolbox Application

More detailed analysis is needed to assess which of the Toolbox treatments are likely to be feasible and effective in particular corridors. Appropriate application of individual tools will require additional corridor-level analysis regarding the specific existing conditions and context – as well as the needs of other travel modes. The Enhanced Transit Corridors project will conduct this detailed analysis on up to 3 corridors.

In addition to detailed corridor analysis on up to 3 corridors, the consultant team will develop a matrix that describes which tools are most appropriate

for which types of corridors – and which types of problems. This matrix will describe at a conceptual level which potential treatments merit additional study in other ETC corridors.

It is important to note that not all Toolbox treatments are possible in every street context. Some treatments can only be applied under specific conditions or with significant changes to the street and cross-section, which may not be feasible or practical. Therefore, some treatments may not be applicable in some corridors.

Finally, some treatments may involve trade-offs in the public right-of-way, or require acquisition of additional private property to widen the right-of-way. For example, widening can impact adjacent properties and buildings. Trade-offs could also impact vehicle access and space for parking or other modes. Where such trade-offs arise, additional stakeholder and public engagement is often necessary.



Dedicated Transit Lane

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Dedicated bus lanes are exclusive lanes allowing transit use only during all times of day. Dedicated lanes improve reliability and reduce travel time by providing separated space for buses, allowing free flow through otherwise congested traffic conditions.

Key Features

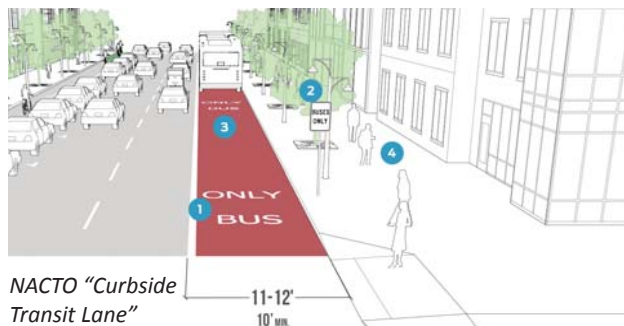
- All-day separation from mixed through traffic (physical barriers or pavement markings)
- May require or be accompanied by dedicated signal(s)/phases

Application

- High-volume, highly-congested corridors
- Can be center-running, curb tight, or floating lanes adjacent to parking/bike facilities

Cost Considerations

- Dedicated transit lane costs can vary considerably depending on context. The cost of moving curbs to accommodate a dedicated lane may be significant – especially if property acquisition is required. Simple roadway re-striping is less expensive, but may necessitate other tradeoffs.



NACTO "Curbside Transit Lane"

11-12'
10' min.

Local Example

Southbound 5th Avenue approaching I-405 (Portland, OR)





Business Access and Transit (BAT) Lane

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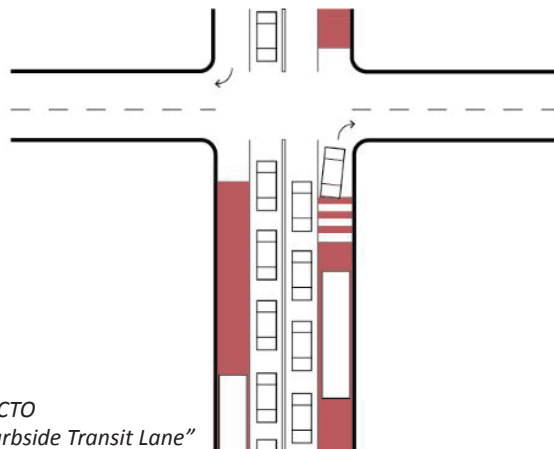
BAT lanes are primarily dedicated for transit use, but allow some general traffic circulation for turning into driveways or onto intersecting streets. Even limited separation from mixed traffic allows for more efficient transit movement through otherwise congested conditions. At the same time, BAT lanes lessen the impact of dedicated bus lanes by maintaining business and residence access.

Key Features

- Separation from mixed through traffic (pavement markings)
- Markings and signage that prohibit general traffic use except in limited locations for limited access purposes

Application

- High-volume, highly-congested corridor segments
- Can be right- or left-side running in a curb-tight lane depending on access requirements and context



NACTO
"Curbside Transit Lane"

Local Example

Southbound SW 11th Avenue approaching SW Columbia Street (Portland, OR)





Intersection Queue Jump/Right Turn Except Bus Lane

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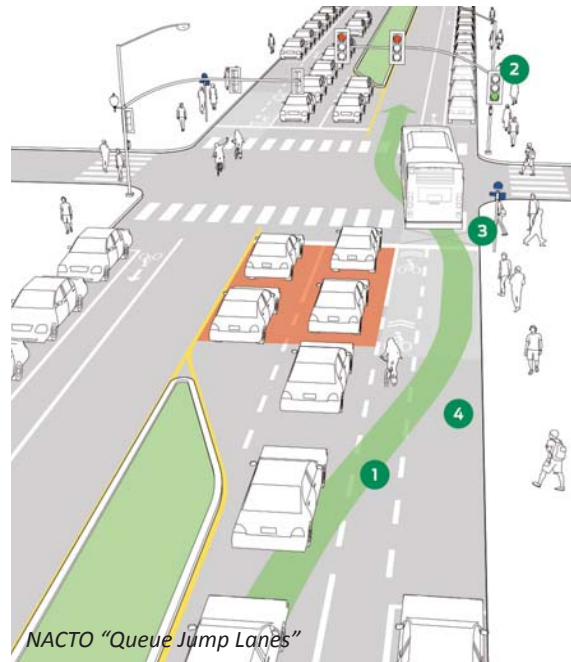
Intersection queue jumps are often applied in tandem with Right Turn Except Bus lanes. A short section of exclusive transit lane approaching a signalized intersection allows the bus to “jump the queue” of traffic waiting at a red light. In a queue jump, the bus may get a special “early green” signal before the adjacent vehicular lanes, and thereby jumps to the front of the line of traffic. This treatment allows for quicker, more reliable transit movement through congested intersections. The lanes can also be used by emergency vehicles to improve response time.

Key Features

- If there is not a Right Turn Except Bus lane or a far side bus pullout, a queue jump requires an exclusive signal phase that allows transit to get a green light first, bypassing the general traffic waiting at the signal
- If paired with a Right Turn Except Bus lane, no dedicated signal phase is needed
- Requires a far-side stop out of lane/in a bus pocket, or a near-side stop for the bus in its own lane
- Bus detection and signal control can increase queue jump effectiveness. Otherwise, the bus must accelerate and merge with general traffic while crossing an intersection, which is not recommended

Application

- High-traffic intersections where a general purpose right turn lane can also serve as a transit queue jump lane
- Queue jump lanes can either be curb-tight or center-running, depending on intersection design and operations
- Queue jump lane may be dedicated or shared with a general purpose turn lane (left or right turn), as long as a dedicated transit signal is present
- Right Turn Except Bus lanes are curb-tight or in floating lanes adjacent to parking/bike facilities
- In some queue jumps, the bus feeds into a bus stop pullout even if no advanced signal phase is present



Local Examples

- **Queue jump only** – Eastbound SE Powell Boulevard at SE Foster Road (Portland, OR)
- **Queue jump with Right Turn Except Bus lane** – Westbound SE Madison Street approaching the Hawthorne Bridge
- **Queue jump with bus pullout, no advanced signal phase** – Westbound SE Powell at Milwaukie





Transit-Only Aperture

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This treatment prohibits or redirects general traffic away from a transit route that continues through an intersection. An exclusive lane at the far side of the intersection is dedicated for transit and/or bicycle use only. Transit-only apertures reduce friction between buses and general traffic, allowing for more efficient travel through congested and/or strategically located intersections.

Key Features

- Traffic diversion features (curbs, pavement markings and or median islands) are accompanied by signage prohibiting general vehicle travel through the aperture
- Operation can be enhanced with dedicated signal phasing
- May include contra-flow bus and/or bicycle lanes

Application

- Intersections where it is beneficial for transit function or bicycle safety to limit through or turning traffic and prioritize bus movement
- Can be applied to either through lanes or turning lanes

Local Example

Northbound SE 52nd Avenue at SE Division Street (Portland, OR)





Pro-Time (Peak Period Only) Transit Lane

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Pro-time transit lanes are dedicated for exclusive bus use during specific times of day – often during peak commute hours. They convert to general purpose travel lanes or parking lanes at other times of day. Separation from general purpose traffic during congested peak periods improves bus travel time and reliability; allowing off-peak parking or travel lessens the impact of that separation on adjacent land uses.

Key Features

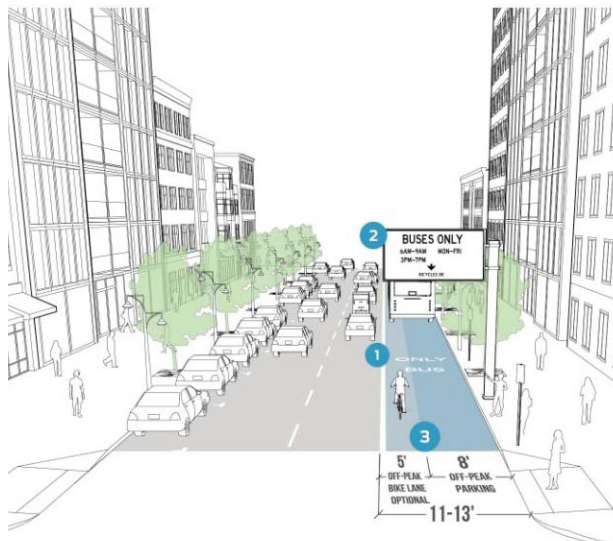
- Signage and/or pavement markings indicating peak hour restrictions
- Consistent enforcement of transit exclusivity is needed, especially for parking violations

Application

- High-volume, highly-congested locations that are particularly affected by peak hour traffic fluctuations and backups (e.g. access to bridgeheads)
- Lanes are typically curb-tight along existing parking lanes

Local Example

Westbound SE Morrison Street approaching the Morrison Bridge (Portland, OR)



NACTO "Peak-only" bus lane



Bus on Shoulder

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On freeways and highways, shoulders can be re-purposed to provide transit-only operating space with very little cost. Providing separated space that is restricted to buses only can improve bus reliability and travel time by enabling free movement through otherwise congested traffic conditions.

Key Features

- Creates a transit-only lane with very low capital cost and low impact to other modes
- Typically only requires signage and some re-striping
- Can require bus operator training for use

Application

- High-speed freeways and highways with adequate shoulder width (10 feet or more)
- May be allowed during all times of the day or only during peak periods



TriMet

Regional Example

The Washington Department of Transportation (WSDOT) has a Bus on Shoulder corridor operating on sections of southbound I-405. The system operates from 6AM to 9AM only, when regular traffic is moving at or below 35 mph



Minneapolis, Metro Transit



Bikes Behind Station



Often called “island” stations, these side-boarding bus platforms feature a channelized bike “wrap-around” behind the station area. This allows for continuous bicycle separation from general traffic and transitways, minimizing conflicts between buses, passengers, and bicycles at stations. In addition to improving safety, this type of stop layout typically keeps the bus in-lane, reducing delay and friction associated with merging into and out of traffic – and enabling faster and more reliable transit operations.

This station configuration is designed to improve safety for bicyclists and pedestrians, and clarify interactions among all modes. Some locations may necessitate context-specific tradeoffs for transit users at the station.

bike lane to the bus stop island. This channelizes pedestrian crossings and alerts cyclists to yield to pedestrians

Application

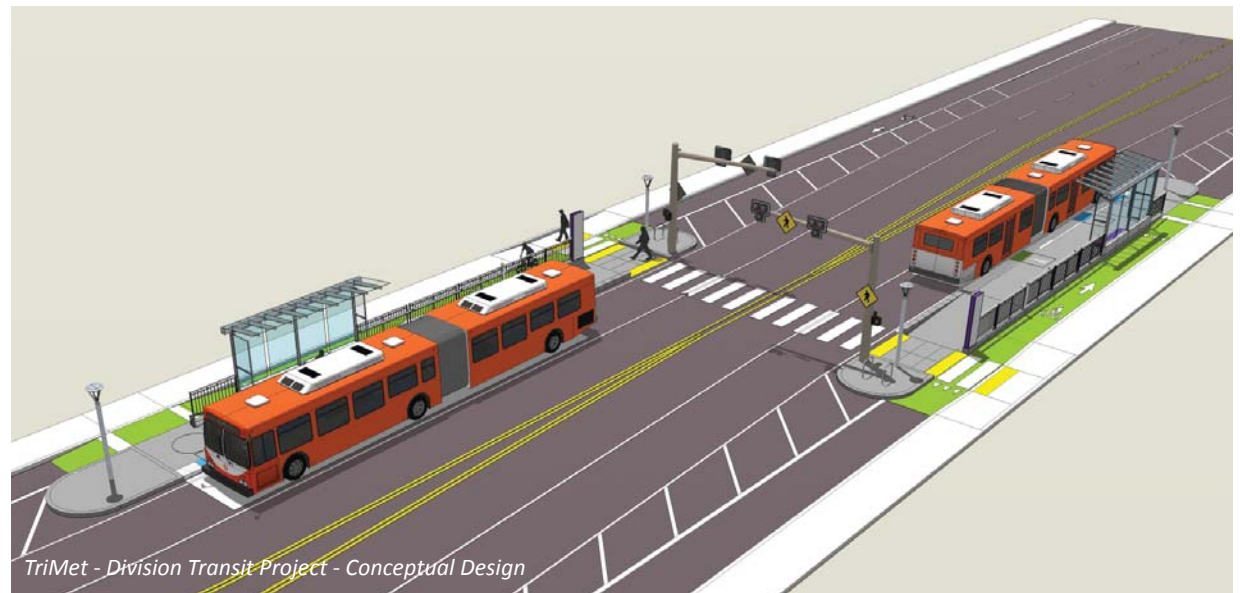
- Streets with heavily-used transit routes and protected bikeways where adequate right-of-way permits the “island” configuration
- Where right-of-way is limited, bicycles may be directed up onto a shared platform/sidewalk environment around the back of a transit stop. This requires adequate platform space, clear markings, and features that slow bicycles down as they move through the station area
- This treatment is most appropriate for wider roadways, with a high level of interaction among bicycles, pedestrians, and transit.

Key Features

- Concrete platform constructed along the right side of the roadway, typically within a current parking area or travel lane. Alternatively, the roadway may be widened to accommodate the platform and bikeway
- Pavement markings (including green pavement treatment) and signage create a separate lane that directs bicycle riders around the back of transit boarding areas
- Pedestrian access across the bike lane is delineated with recognizable crosswalk treatments (ladder striping, yield markings, tactile warning), creating clear connections to/from the platform and sidewalk
- A raised the crosswalk is preferred across the



TriMet - Moody and Gaines Traffic Island



TriMet - Division Transit Project - Conceptual Design



Left-Side Bike Lane



Dedicated bike lanes running on the left side of one-way streets can minimize or eliminate bus/bike conflicts for right-side boarding buses, improving safety and allowing for more efficient transit operation.

Application

- One-way streets with heavily used transit routes where traffic speed and volume requires separated bicycle facilities



Google



Jonathan Maus/BikePortland



Dedicated Bike Signal

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Dedicated bike signal phasing near a transit stop – or at intersections where the bus turns – can improve multi-modal integration and reduce conflicts by clarifying the interaction among bicycle riders, pedestrians, and transit vehicles and users.

In some cases, dedicated bike signals can minimize transit delay by providing reliable and specifically-timed separation of transit and bicycle movements. However, the primary purpose is to improve safety for bicyclists.

Key Features

- Requires a dedicated signal head, a specialized signal controller, and adequate queuing space for bicycles

Application

- Heavily used bicycle routes where transit/ bicycle interactions present safety challenges or impact transit performance
- These treatments do not always increase transit travel time. The benefits are more for organizing interaction between the modes and increasing safety

Local Example

SW Moody Ave at Tilikum Crossing Bridge (Portland, OR)





Shared Bus/Bike Zone

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Shared bike/bus zones are dedicated for use by buses and bicycles only. Designed to clarify multimodal interactions and improve safety, shared zones are typically short segments near stops or stations that provide bicycle connections to exclusive bike lanes.

This type of treatment is appropriate only in highly constrained locations. It is not ideal for either bicycle safety or bus operations, and should be avoided if more separation is possible.

Key Features

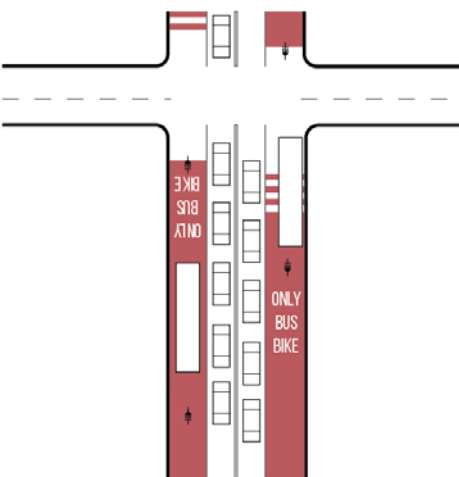
- Signage and pavement markings clarify expected bus and bicycle movements
- Not appropriate for long distances or areas where buses are traveling at speed
- Preferred configuration separates bikes from buses at stations/stops, with buses stopping in the lane and bikes separated from buses behind the station

Application

- Transit stop/station vicinity where full separation is not feasible, and buses and bicycles must share space safely as buses move into and out of from stop or station areas

Local Example

Westbound SW Jefferson at SW 10th Avenue (Portland, OR)



NACTO "Shared Bus - Bike Lane"



Curb Extension for Stations/Stops

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Also known as “bus bulbs,” these sidewalk curb extensions provide a larger passenger waiting area and allow buses to stop in lane. They help minimize bus delay, reducing time spent waiting for gaps in traffic to re-enter the travel lane. Curb extensions provide other benefits, as well: they can improve pedestrian safety by shortening crossing distance at intersections, and minimize parking removal by reducing the transition area needed for a bus to reach the curb.

Key Features

- The curb extension must be long enough to accommodate passengers boarding and alighting by the front and rear doors of the vehicle
- Strategic placement can aid in crossing safety and traffic calming

Application

- Can be applied in both mixed-flow and dedicated transit lane conditions
- Can be installed at near or far side of an intersection, or at mid-block stops
- Requires a street cross section with on-street parking or other curbside uses between curb extensions (cannot interrupt a general purpose travel lane)

Local Example

Northbound and southbound at NW 23rd Avenue at NW Irving Street (Portland, OR)





Level Boarding

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To achieve near-level or level boarding stop/station platform, heights are raised to match the height of the bus floors, allowing for easier access into and out of the bus at the front and back doors. Level boarding means less time raising and lowering ramps (or the bus itself), facilitating faster boarding and alighting for all passengers, especially those using mobility devices and strollers. In turn, this minimizes overall bus dwell time, improving transit speed and reliability.

Key Features

- Buses have ramps and bridge plates that extend or fold out to cover any horizontal gap between vehicle and station platform

Application

- Application varies based on adjacent land uses, right-of-way availability, and integration with the sidewalk environment

Cost Considerations

- The cost of level boarding improvements can vary widely, depending on the need for new or rebuilt boarding platforms – and whether buses must be retrofitted with specialized equipment for ease and safety of boarding

Local Example

EmX Bus Rapid Transit System (Eugene, OR) and Portland Streetcar (Portland, OR)



CH2M



Railroadforums.com



All-Door Boarding



All-door passenger boarding allows riders to board and alight using all doors of a transit vehicle, minimizing passenger queues and delay associated with longer dwell time at busy transit stops.

While it can improve travel time and reliability, all-door boarding also raises fare payment considerations, since bus operators do not automatically serve as fare inspectors as they would with front door-only boarding.

Key Considerations

- All-door boarding can be combined with off-board fare collection and/or on-board electronic fare technology at each door to facilitate quick entry and compliant fare payment
- In areas where electronic fare technology is in place, cash fare payment is still accepted at the front door
- Designated “pre-queuing” areas at boarding platforms help identify locations where bus doors will open, orienting passenger line-ups to reduce passenger conflict and streamline the boarding process
- The efficiency of all-door boarding is increased further by level boarding

Case Study

San Francisco, CA: 36% reduction in dwell times reported with all-door boarding evaluation (Source: SFMTA, 2014)



SFMTA All Door Boarding Evaluation Final Report



Far-Side Bus Stop Placement

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In general, buses move more efficiently through signalized intersections when a stop is placed on the far side of the intersection. This enables the bus to clear an intersection before stopping, minimizing delay at traffic signals. In addition, it allows the bus to pull back into the travel lane by moving into the gap created by a signal phase. Bus stops can occupy less space since the transition to curbside is partially accommodated within the intersection. In addition to minimizing transit delay, far-side stops minimize conflicts with right-turning vehicles and can make pedestrians safer, since pedestrians are crossing behind the bus (rather than in front of it) and are visible to other roadway users.

Application

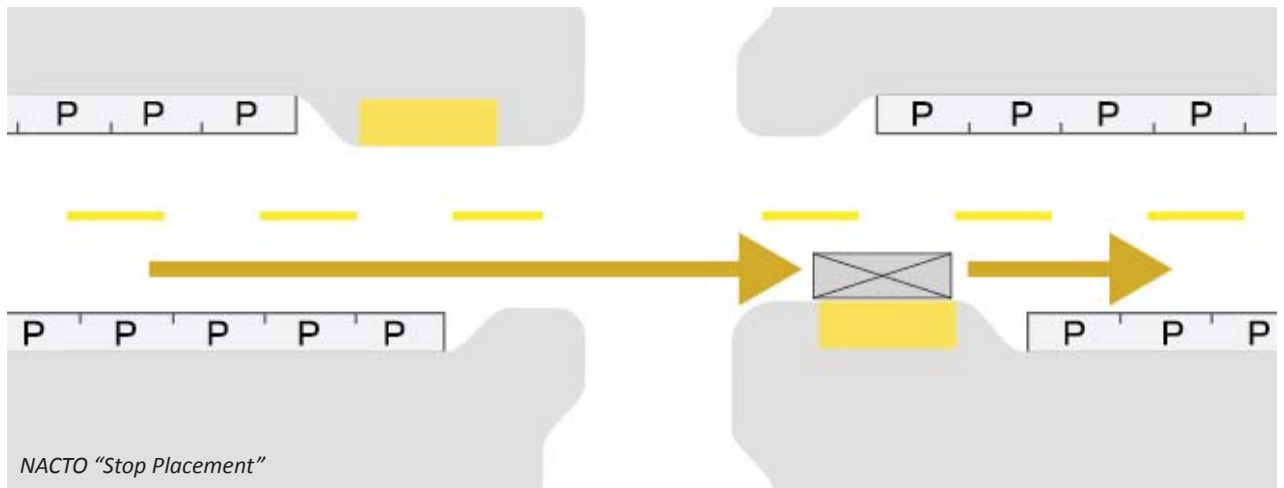
- Far-side placement is most effective when used in combination with transit signal priority (TSP)
- Stop placement depends on corridor land use, street/intersection design, sidewalk availability, driveway locations, and other conditions
- Stops can be placed in lane or in the shoulder
- Far-side placement can accommodate dedicated lane configurations and median stops (either right-side or left-side)

Cost Considerations

- Far-side bus stop costs vary based on specific stop configuration. “Bus bulbs” (as shown in the figure to the right) that allow the bus to stop in-lane increase the cost of this treatment considerably. These are rare, however; in general, buses cross the intersection and pull over to the curb.

Local Example

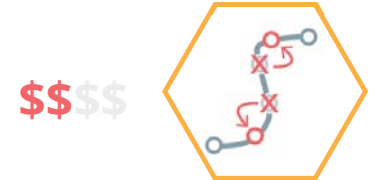
Westbound Stop at SE Division Street and 148th Avenue (Portland, OR)



NACTO "Stop Placement"



Bus Stop Consolidation



Consolidating stops can improve bus travel time by reducing delay associated with deceleration to, acceleration from, and dwell time at bus stops.

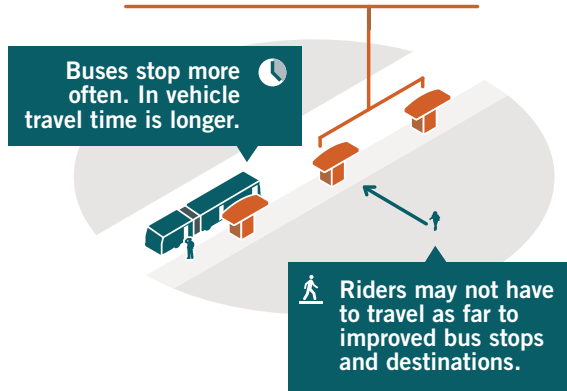
Key Features

- Creating “super stops” at major transfer points can provide rider amenities in addition to improving bus travel time
- Consolidating stops and removing underutilized stops requires public outreach and education
- Different types of service (e.g. local, limited, express) can exist in the same corridor, utilizing a different subset of stops

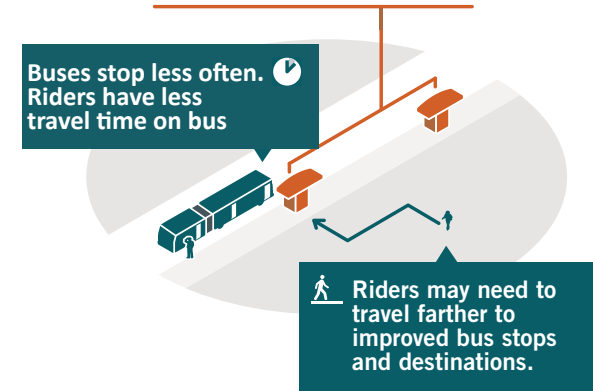
Application

- Corridors with a large number of closely spaced stops where roadway and pedestrian conditions allow for continued safe access to consolidated stops
- Consolidating bus stops may create opportunities for enhanced pedestrian crossing treatments
- Existing transit operating and maintenance facilities may need to be retrofitted or redesigned to accommodate longer vehicles, adding to the cost and time line for implementation

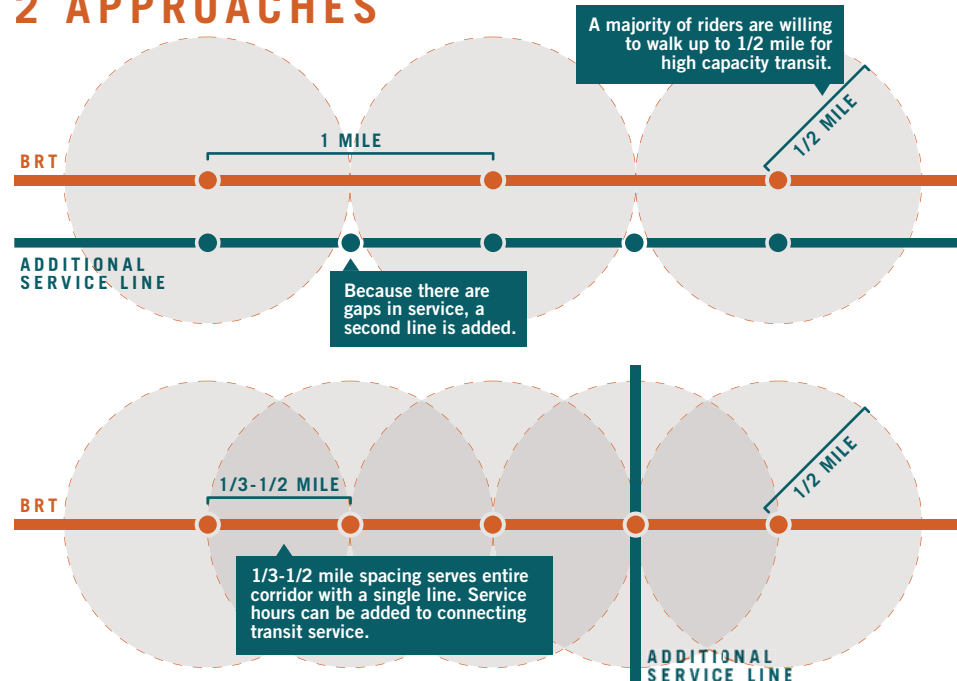
WHEN STOPS ARE CLOSER TOGETHER



WHEN STOPS ARE FARTHER APART



STOP-SPACING TRADEOFFS 2 APPROACHES



TriMet - Division Transit Project - Conceptual Design



Rolling Stock Modification



Procurement and deployment of larger, modern buses offers a range of benefits to transit agencies, operators, and passengers alike.

- **Longer vehicles accommodate more passengers**, reducing pass-ups and adding capacity while minimizing the need for more frequent headways (including more buses and more operators)
- Modern **low-floor vehicles better accommodate level boarding and all-door boarding** more easily; these vehicles may be designed with left-side or right-side boarding (or both) to accommodate a range of station locations and designs
- **Precision docking technology** enables better platform/curb alignment, requiring less roadway space for stops
- Larger capacity vehicles have more space to **accommodate on-vehicle fare machines, bicycles, and passengers with mobility devices**. However, these features may reduce the space available for additional passengers
- Articulated configuration of a 60-foot bus can **improve bus turning radius**
- Existing transit **maintenance facilities may need to be retrofitted or redesigned** to accommodate longer vehicles, adding to the cost and timeline for implementation



BYD 60' Articulated Bus BYT.com



New Flyer Xcelior- 60' Articulated Bus Newflyer.com

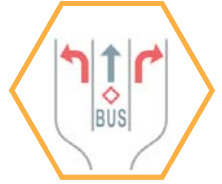


Portland Street Car



Street Design Traffic Flow Modifications

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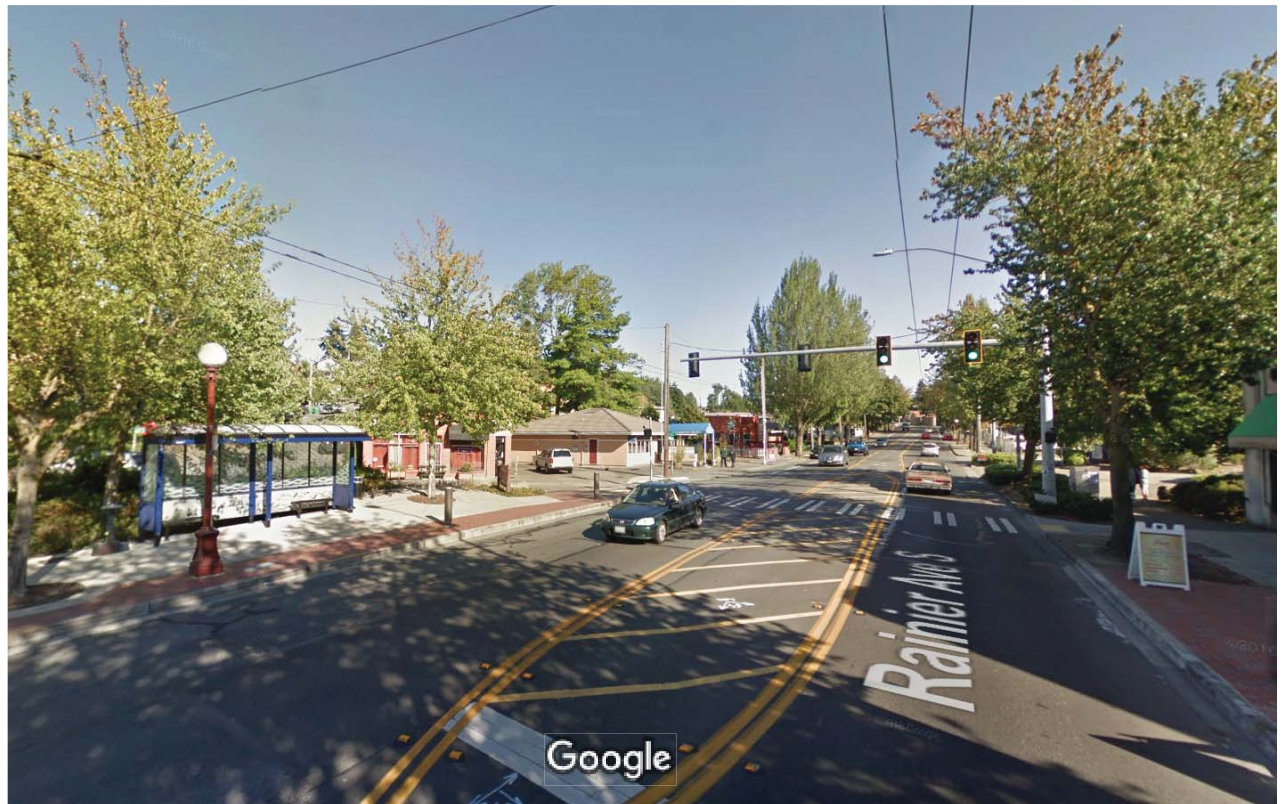
Street design modifications to improve traffic flow can also improve transit vehicle speed and reliability. Adding right or left turn lanes provides roadway space for turning vehicles that would otherwise block transit and/or general traffic lanes. Using signage, pavement markings, and/or raised traffic barriers to manage access and turning movements at driveways and intersecting streets can reduce travel time, improve reliability, and increase safety by reducing multi-modal friction.

Tools to do this may include:

- Adding **right or left turn pockets** at intersections
- **Restricting left turns** to/from corridor driveways
- Striping bus **acceleration/deceleration lanes**
- Adding two-way left turn lanes
- **Driveway consolidation**
- Using **raised medians and other physical barriers** to direct traffic flow and minimize conflicts

Regional Example

Rainier Avenue South Safety Corridor Project (Seattle, WA)

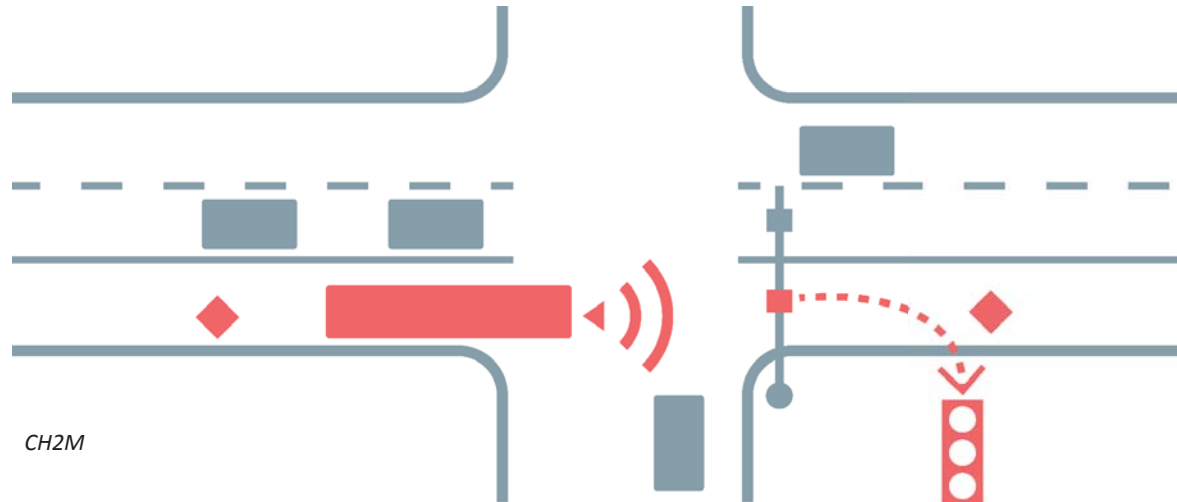




Transit Signal Priority and Signal Improvement



Transit signal priority (TSP) uses a variety of signal technologies to give transit vehicles some measure of preference moving through intersections. The technology enables communication between transit vehicles and traffic signals (or the traffic control system) to alter signal timing/phasing and/or trigger a transit-only or transit-inclusive phase. TSP reduces transit delay at intersections, facilitating faster, more efficient – and in many cases safer – transit vehicle movement, while improving overall corridor operations. TSP is often an important element of queue jump effectiveness.

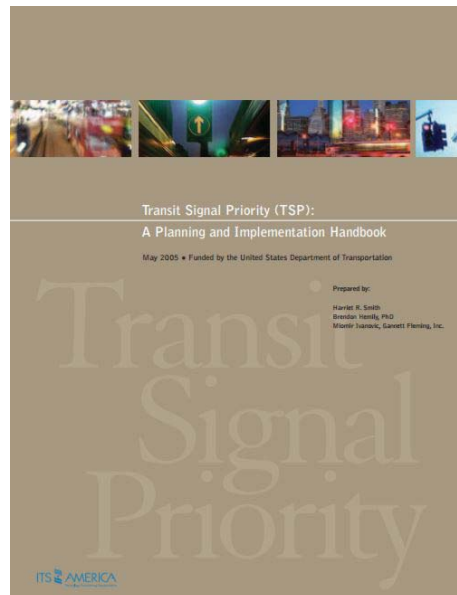


Signal adaptations may include:

- Truncating a red light or extending a green light
- An advanced call to clear a traffic queue
- Triggering a transit priority phase (either conditional or unconditional)
- Signal timing modifications or progression that improves conditions for all traffic, including transit vehicles
- Dynamic phase change rotation

Technological characteristics may include:

- TSP communication (DSRC vs. cell-based central system)
- Peer-to-peer communication
- Block signals dedicated to transit
- Dynamic messaging and signing



NACTO Planning and Transit Signal Priority Handbook, 2005
Regional Transit Signal Priority Study



Headway Management

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Bus bunching occurs when two or more buses immediately follow one another (or “bunch”) when they were scheduled to be evenly spaced running along the route. Transit agencies use a variety of transit operation strategies to address this problem and improve on-time performance as well as reliability and safety. These strategies include:

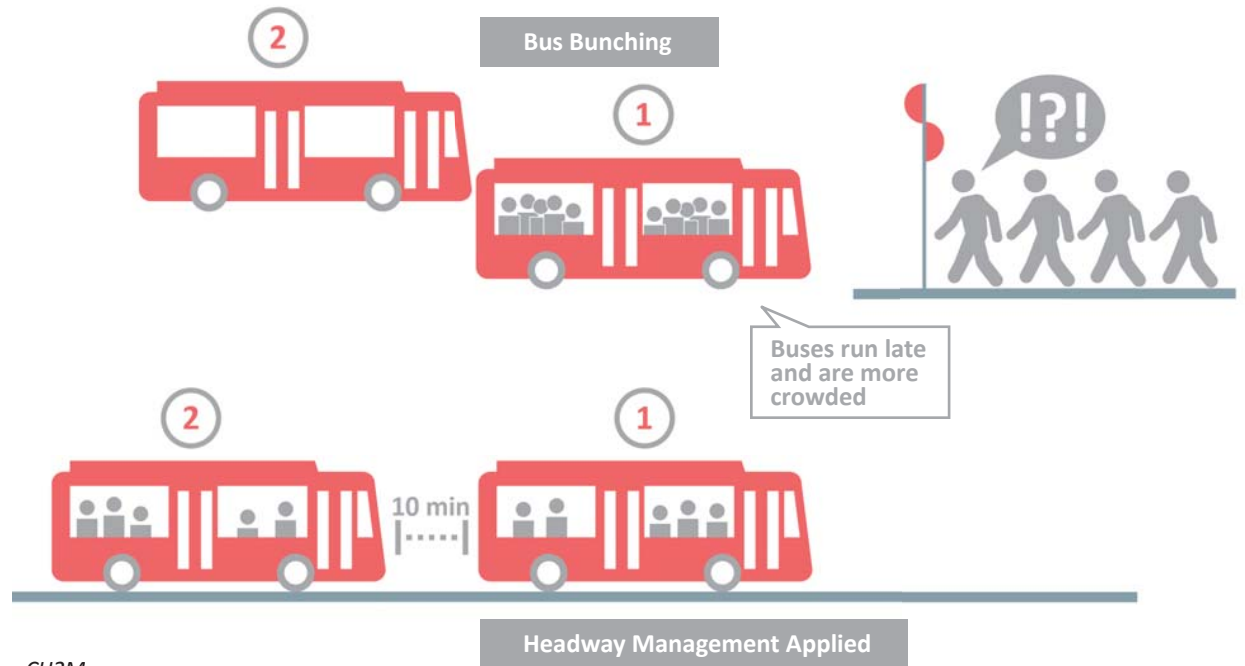
- **Line management** – where dedicated supervisors and dispatch staff monitor headways and manage operations performance for specific lines or groups of lines, including the use of CAD/AVL and modern dispatch technology, and managing departure from terminals to improve on-time performance.
- **Headway-based service** – in which service operates without published schedules, eliminating the requirement for an operator to follow time-point schedules. This can reduce time-point waits, improving travel times and operating speed. Headway-based service may include advisory schedules for passengers, but typically relies on real-time information (connected to CAD/AVL systems) for “next arrival” times.



HDR



SounderBruce-Flickr



CH2M