Transit Priority Toolkit

translink.ca

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About this Toolkit

The Transit Priority Toolkit provides TransLink and municipal partners with specific strategies to improve travel time and reliability of transit service for over 900,000 customers who ride the bus each day. The toolkit focuses on 14 transit priority strategies from 5 different groups ranging from interagency coordination to minor capital enhancements to significant infrastructure improvements.

These strategies include:

A. Bus Stop and Curb Management

A1. Bus Stop Placement
A2. Curb Management

B. Traffic Regulations

B1. Movement Restrictions

C. Street Design

C1. Bus Stop Infrastructure
C2. Turn Pockets
C3. Vertical Control Devices
C4. Queue Jump
C5. Transit Approach Lanes
C6. Peak-Hour Bus Lanes
C7. Dedicated Bus Lane

D. Signal Priority

D1. Passive Signal Priority
D2. Transit Signal Priority (Active)

E. TransLink Practices and Policy

E1. All-Door Boarding
E-2. Schedule/Operator Recovery

Each strategy addresses one or more specific challenges that fall into four broad categories:

- Congestion
- Delay
- Operations
- Safey

The summary table (Figure 1) illustrates which specific challenges are addressed by each strategy, as well as relative costs, benefits, and level of coordination required between TransLink and other stakeholders.

Figure 1: Transit Priority Strategy Summary Table

STRATEGY	CONGESTION		DELAY			OPERATIONS				SAFETY			COST/COORDINATION	
	INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
A. Bus Stop and Curb Management														
A1. Bus Stop Placement	★		★			★★★	★★	★	★	★★	★★		$–$$	Medium/ High
A2. Curb Management		★				★★	★	★		★	★	★	$–$$	Medium
B. Traffic Regulations														
B1. Movement Restrictions	★★★		★	★★★	★★★		★★		★★	★	★	★★	$–$$$$	Medium/ High
C. Street Design														
C1. Bus Stop Infrastucture						★★	★★	★★★		★★★	★★★		$–$$$	Low
C2. Turn Pockets	★		★★	★	★							★★	$–$$	Medium
C3. Vertical Control Devices		★★★				★★	★		★★	★★★	★★★	★	$	Medium
C4. Queue Jumps	★★★		★★★						★★				$–$$	Medium
C5. Transit Approach Lane	★★★		★★★						★★				$	Medium
C6. Peak-Hour Bus Lane	★★	★★		★★	★★	★★	★★	★★	★★★		★	★★	$$–$$$$	High
C7. Dedicated Bus Lane	★★★	★★★		★★★	★★★	★★★	★★★	★★★	★★★		★	★★	$$–$$$$	High
D. Signal Priority														
D1. Passive Signal Priority	★★	★	★★						★★	★	★	★★	$–$$	Medium
D2. Transit Signal Priority (Active)	★★★		★★★	★★★	★★★				★★★				$$–$$$$	High
E. TransLink Practices and Policy														
E1. All-Door Boarding								★★★	★★	★				Low
E2. Schedule/Operator Recovery									★★★					Low

$ UNDER $50,000
$$ $50,000 - $100,000
$$$ $100,000 - $250,000
$$$$ OVER $250,000

Benefits: ★ LOW ★★ MEDIUM ★★★ HIGH

REPORT STRUCTURE

Each transit priority strategy is detailed in a profile with a brief definition, description of required stakeholder coordination, and a summary of benefits and costs. Each profile concludes with examples of successful implementation in North American cities. The following paragraphs give an overview of the individual sections covered within each profile.

STRATEGY OVERVIEW

Each profile begins with a definition of the transit priority strategy. This includes a summary of technical specifications and a brief explanation of how the strategy improves transit performance. This section also contains information about variations or major considerations.

COORDINATION

Implementation of transit priority strategies requires coordination between agencies and stakeholders. Each profile includes a brief description of required coordination efforts between stakeholders. The list of stakeholders always includes TransLink and the local road authority. It sometimes includes other stakeholders like the business community, residents, or law enforcement.

BENEFITS AND COST

The benefits and costs section describes the typical benefits of each treatment in terms of travel time, transit reliability, customer experience, and safety. The associated typical range of costs of each strategy are provided after the benefits, using costs compiled from similar examples of planned and implemented strategies. These estimates are indicative only. Individual project benefits and costs may vary widely based.

+ This symbol indicates a benefit. − This symbol indicates a cost.

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
Travel time is the ability of transit to operate service at an ideal speed. Treatments can benefit travel time through increased travel speeds or reduced delays, which contribute to more consistent and faster travel through a corridor.	**Reliability is the ability of transit to operate on schedule.** Consistent and predictable operations reduce travel time variability and dwell times, which can be a major source of delay to transit.	**Customer experience can be improved through transit prioritization.** Though travel time and reliability are major components of customer experience, other factors such as stop amenities or pedestrian infrastructure can reduce confusion and improve customer experience.	**Safety is a vital concern for transit operations.** Strategies must promote transit efficiency without compromising the safety of customers, pedestrians, cyclists, or other drivers. Safety concerns include interactions with pedestrians, cyclists, and motor vehicles.

CHALLENGES

Each strategy describes the typical challenges, complementary and alternative treatments for each strategy, and specific agency examples. Challenges describe logistical, temporal, or stakeholder limitations pertaining to the implementation and effectiveness of the treatments.

This table illustrates which specific challenges are addressed by each strategy, as well as relative costs, benefits, and level of coordination required between TransLink and other stakeholders.

COMPLEMENTARY AND ALTERNATIVE TREATMENTS

Complementary treatments highlight other strategies within the Transit Priority Toolkit that can be used to enhance the benefits to transit. Alternative treatments identify treatments that may be either redundant or counterproductive to the specific strategy.

AGENCY EXAMPLES

The final section provides examples of cities in the United States and Canada that have implemented the treatments. It consists of an overview of the project, a description of how the treatment was implemented, and the outcome of implementation including any measured or perceived benefits of the project.

A. Bus Stop and Curb Management

A1. Bus Stop Placement

Bus stop placement directly impacts the convenience and accessibility of the transit system.

Strategy Overview

Determining the proper location of bus stops involves choosing between near-side, far-side and mid-block stops. Each of these stop locations have benefits and drawbacks, and the choice between these stop locations is affected by the existing conditions along a route such as roadway type and width, transit service characteristics, and land use.

Far-side bus stops are located after an intersection, allowing the bus to travel through the intersection before stopping to load and unload customers. Far-side bus stops support the use of a broad array of active transit signal priority treatments, and take up the least amount of curbside space. Near-side bus stops are located before an intersection, allowing customers to load and unload while the vehicle is stopped at a red light or stop sign. Mid-block bus stops are located between intersections.

The minimum stop requirements for curb-side stops are shown in the designs below. However, the design of individual stops may be modified due to complimentary treatments such a curb-side dedicated lane or a boarding island/bulge out.

Stop spacing refers to the distance between bus stops along a route. Stop spacing affects overall travel time and, therefore, demand for transit. The tradeoff is between close stops, which result in short walking distances but longer trip times, and spaced stops, which result in longer walking distances but higher speeds, more reliable bus service, and shorter trip times. Routes and corridors with higher demand and frequency should have stops spaced further apart, while feeder and shuttle services require stops closer together.

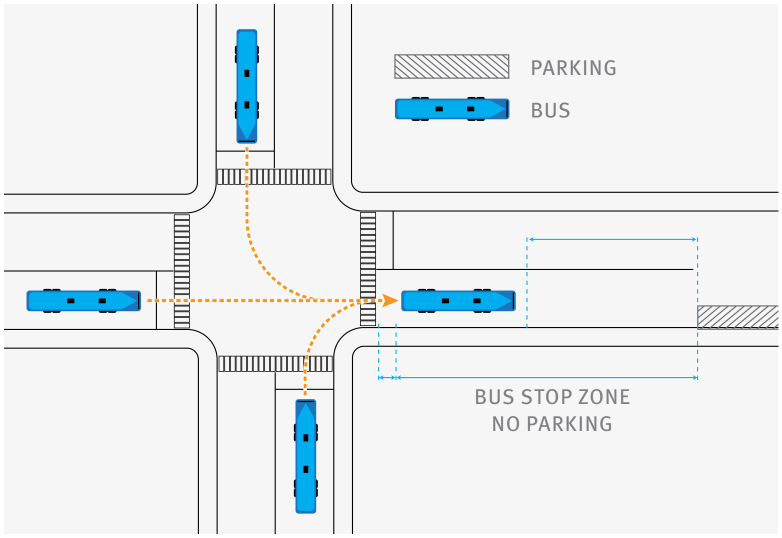
COORDINATION

Bus Stop Placement generally only requires coordination with the local municipality that owns the right-of-way. If bus stops will be located on private property, TransLink will also need to coordinate with the private land owners. Even if bus stops are located on public property, locating or consolidating bus stops can be difficult due to opposition from adjacent businesses or residents.

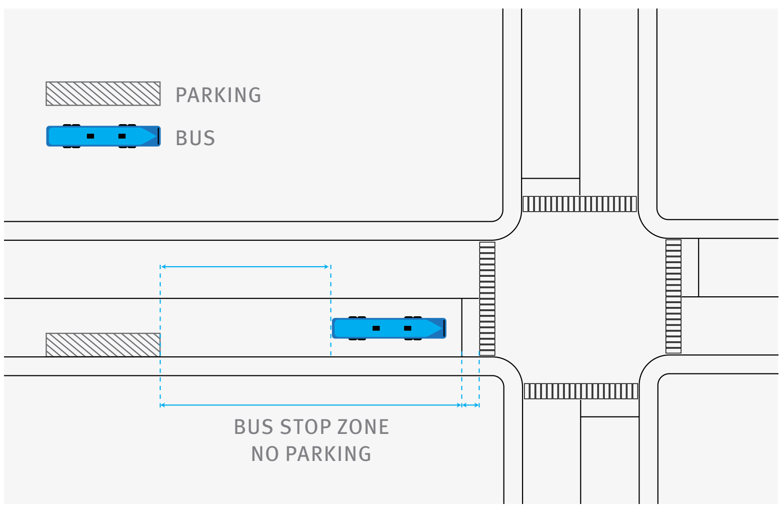
STAKEHOLDER	INVOLVEMENT
TransLink	• Planning of preferred and alternative bus stop locations and determining appropriate spacing of stops along bus routes.
Municipality / Private Land Owner	• Impact on street right-of-way from the installation of passenger landing pads and any additional bus stop infrastructure such as bus stop signs, shelters, etc. Stop locations can be delineated with pavement markings onstreet, on the curb, and/or on the sidewalk.

Figure A1.1: Bus Stop Designs (not to scale)

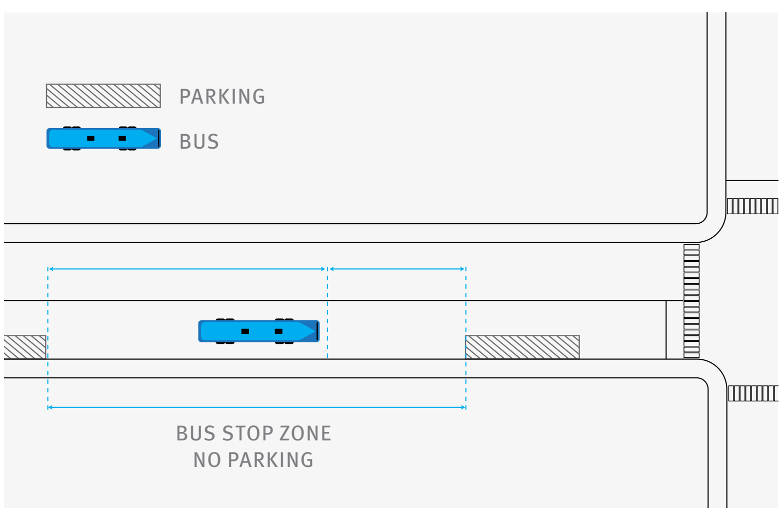
Far-side



Near-side



Mid-block



BENEFITS AND COSTS

FAR SIDE

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Enhances benefits of signal priority	+ Allows buses to travel through an intersection before stopping + Signals provide time for buses to reenter traffic − Queueing buses may block intersections	+ Under correct timing customers pass through intersections before stopping − Can result in stopping twice, one at light and one at bus stop	+ Customers cross behind bus + Creates gaps to reenter traffic + Clears right turn lanes for traffic and other transit vehicles − Drivers may not expect buses to stop immediately after intersections

NEAR SIDE

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Can be used as queue jump lanes + Customers can board when vehicle is stopped at light	*NA*	+ Customers can load/ unload when vehicle is stopped at light or stop sign	+ Allows driver to look for oncoming traffic including other buses for transfers − Customers cross in front of bus − Conflicts with right-turning vehicles

MID-BLOCK

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Useful where buses must make left turns at an intersection − Buses may have to merge to reenter traffic	*NA*	+ Less customer congestion − Increases walking distance	+ Useful where traffic conditions would create safety issues at intersections + Reduces sight distance problems − Encourages jaywalking − Requires a mid-block pedestrian crossing

BENEFITS AND COSTS

STOP CONSOLIDATION

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Overall travel time reduced by up to 6% + Dwell times are a significant portion of overall travel times	+ Reduces maintenance cost due to fewer bus stops + Reduces running time variability	+ Fewer stops with improved facilities − Greater walking distance between stops	*NA*

ESTIMATED TYPICAL COSTS	PER STOP
Basic stops, including stop landing pad, sidewalk, and curb work	$10,000 - $14,000
Sheltered stops, including a shelter and bus bay/curb extension	$14,000 - $40,000

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
★		★			★★★	★★	★	★	★★	★★		$–$$	Medium/High

CHALLENGES

- Requires full bus stop inventory, analysis, and engineering in order to identify and change location of bus stops.
- Adjacent developments, such as businesses or residents, may resist bus stops at specific locations due to additional right-of-way space used by bus stops and parking removed (if applicable).
- Depending on local municipalities, private owners, and need for public outreach to customers, the timeline can be a few months to a few years to change bus stop locations.
- Regardless of stop location, areas must be designed to accommodate bus queuing at stops served by multiple routes.
- Customers may oppose stop relocation.
- There must be sufficient space for amenities.

COMPLEMENTARY TREATMENTS

Optimizing the location of bus stops can reduce dwell times and improve transit reliability, but often requires other treatments to enhance those benefits.

Bus Stop Infrastructure
In-lane stops that are in optimized locations improve boarding and further decrease dwell times.

Curb Management
Curbside management can eliminate conflicts with delivery vehicles and passenger drop-offs in front of bus stops.

Movement Restrictions
Restricting turning can reduce conflicts with turning vehicles at near-side stops and allow buses to more easily access near-side stops.

Queue Jumps
At near-side stops, buses can access the queue jump lane after boarding, and far-side stops can also be paired with signal priority.

Transit Approach Lane
An exclusive transit lane leading up to an intersection can easily enable buses to reach far side stops.

Peak-Hour & Dedicated Bus Lane
Bus lanes can improve travel times between stops, with stop consolidation and optimized stop location improving travel times.

Passive Signal Priority & Transit-Signal Priority
Signal priority can enable buses to clear intersections before reaching far side stops or after near side stops.

All-Door Boarding
Stop locations with all-door boarding allow for a higher volume of passenger activity, reduce dwell times, and facilitate stop consolidation.

ALTERNATIVE TREATMENTS

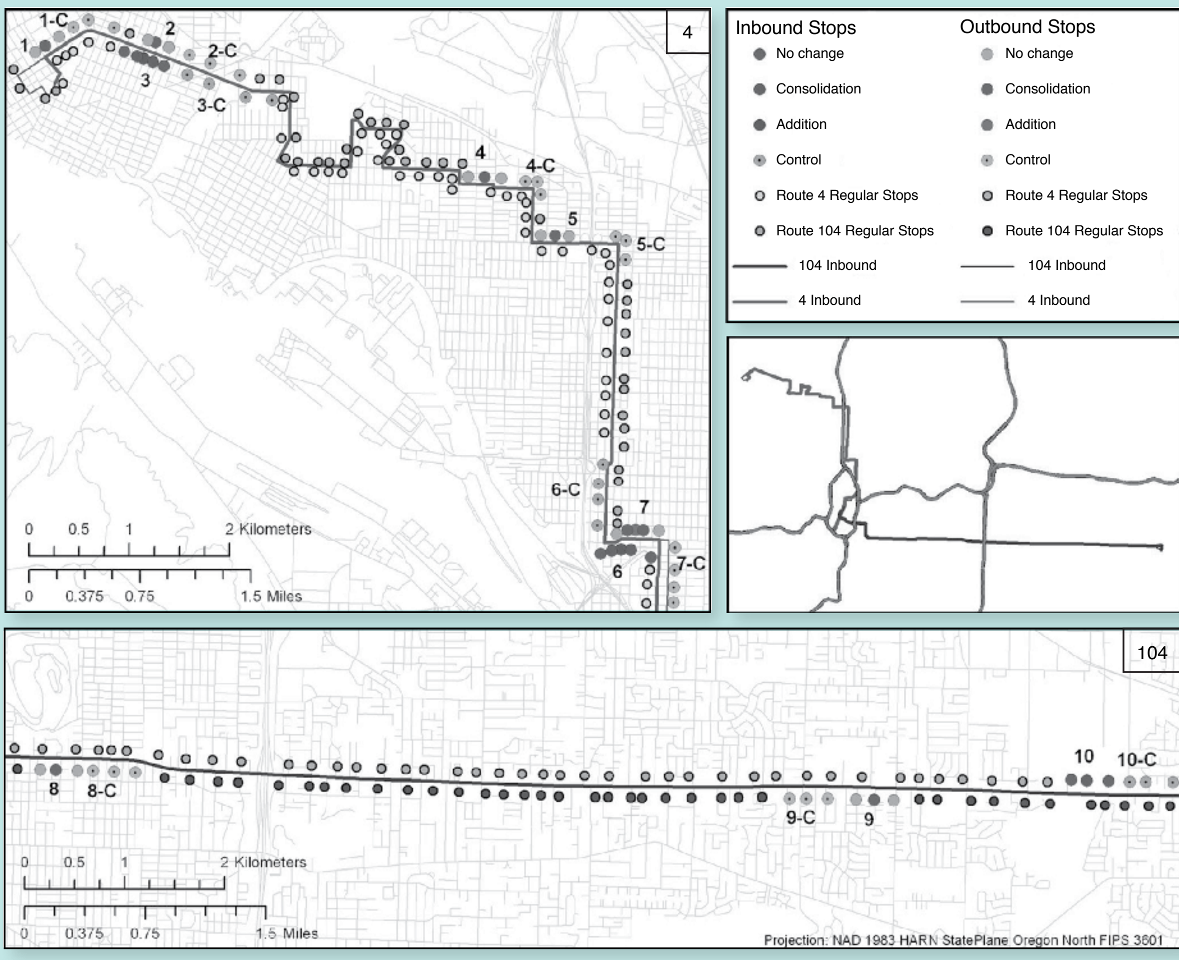
Not applicable

BUS STOP PLACEMENT EXAMPLES

Multiple transit agencies have done partial or full implementation of moving bus stop locations and consolidating bus stops. Results vary based on the level of intervention and use of complementary treatments.

- In 2005, a study analyzing the implementation of bus stopconsolidation for TriMet in Portland, Oregon found that passenger activity was unchanged after bus stop consolidation. Additionally, **bus running times decreasedby 6%**, and may have been greater, due to lack of schedule adjustments.[1]
- In 2013, a study of potential bus stop consolidation in Fairfax, Virginia proposed removing about 40% of bus stops, as the walking distance threshold was increased to 800m. 83% of existing service area was still covered, while **travel time could be reduced by up to 23%**.[2]

Figure A1.2: TriMet Stop Consolidation Example[1]

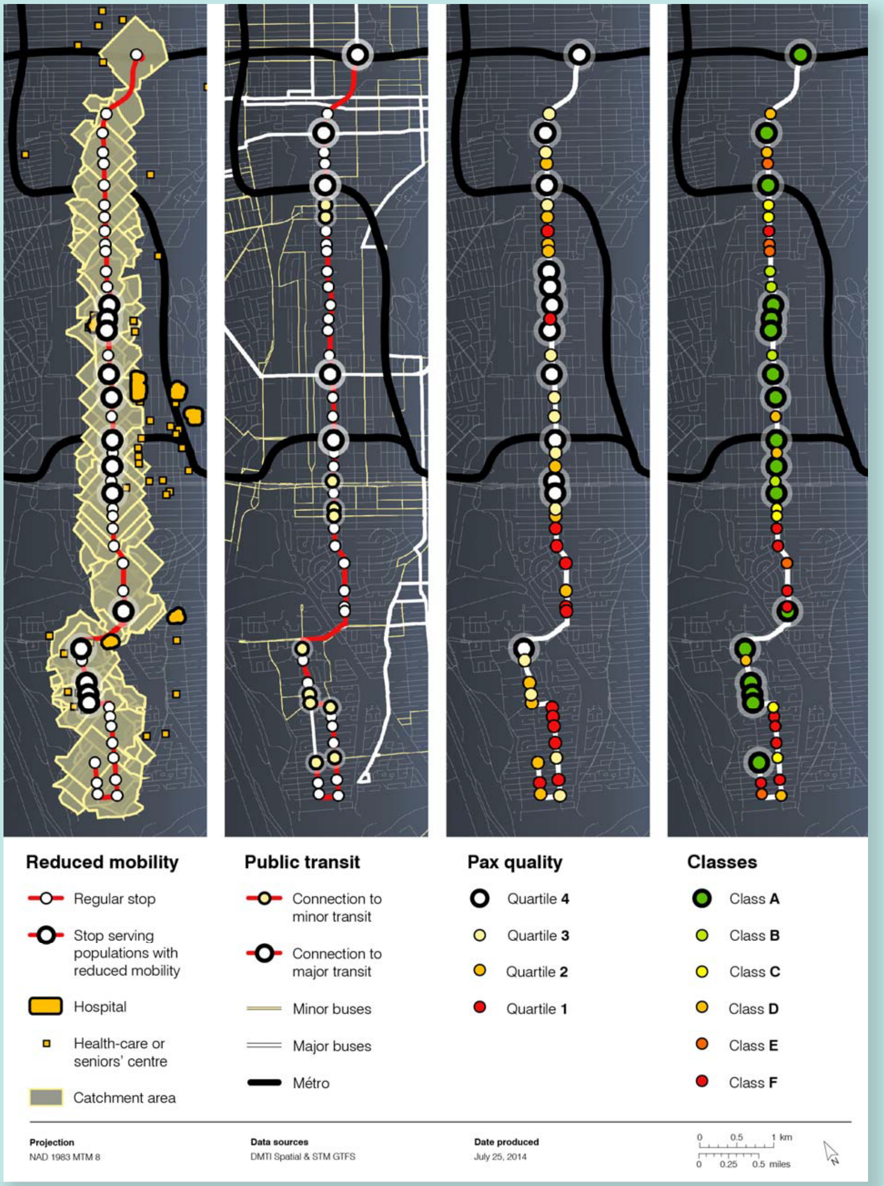


1 El-Geneidy et al., "Effects of Bus Stop Consolidation on Passenger Activity and Transit Operations," 2005. http://tram.mcgill.ca/Research/Publications/Bus_Stop_consoildation.pdf

2 Shrestha & Zolnik, "Eliminating Bus Stops: Evaluating Changes in Operations, Emissions, and Coverage," 2013. http://www.nctr.usf.edu/wp-content/uploads/2013/07/16.2_zolnik.pdf

- In 2015, a study from McGill University analyzed potential bus stop consolidation on the Société de transport deMontreal (STM) using a simpler methodology. The study assumed a removal of 23% of bus stops while only reducing service area by 1%. 75 bus routes would be able to **operate with one fewer bus and reduce running times by 2% system wide.**[3]
- From 2009 to 2014, the MBTA implemented the Key BusRoute Improvement Program, which increased overall quality of service on the 15 busiest routes in MBTA system. As part of the improvements, the MBTA aimed to remove 25% of bus stops and improve the remaining stops with better passenger amenities. The program was able to reduce 20% of all stops along the corridors and add additional transit priority strategies along select corridors, such as queue jump lanes, transit signal priority and bus stop curb extensions.[4]

Figure A1.3: Montreal Stop Consolidation Example



3 Stewart & El-Geneidy, "Don't Stop Just Yet!: A simple, effective, and socially responsible approach to bus-stop consolidation," 2015. http://tram.mcgill.ca/Research/Publications/Bus_stop_consolidation_Montreal.pdf

4 MBTA, "Key Bus Route Improvement Program", 2015. http://old.mbta.com/about_the_mbta/t_projects/default.asp?id=190479

A2. Curb Management

Curb management is the act of organizing the various demands for curb space through clear, legible rules about when, where, and under what conditions specific uses are permitted.

Strategy Overview

Effective curb management reduces conflict between transit and other vehicles in travel lanes and at bus stops to improve schedule reliability and customer access.

Cities can manage curb space by thoughtfully regulating the total supply and specific location of curb dedicated to each use. Supplying clearly designated loading zones, taxi stands, parking spaces, and bus stops maximizes the efficient use of curb space and flow of vehicles in adjacent travel lanes. Signage and enforcement are common tools for curb management. Enforcement can help maintain compliance.

Cities can also manage curb space by guiding the demand for each use. On-street parking pricing strategies and time limits are common tools for redistributing parking activity to times or locations where parking is more readily available.

Some curb management practices may include converting parking lanes into bus lanes during peak hours or on high-frequency transit corridors. Parking revenues can also help fund other community amenities through a parking benefits district.

Managing the space along a curb helps improve reliability and efficiency for all travelers—including people in buses.

COORDINATION

Changes to street curbs requires close coordination with local municipalities.

STAKEHOLDER	INVOLVEMENT
TransLink	• Identification of bus stops or blocks with poor customer access due to in adequate bus stop spacing or heavy delay due to bus stops and travel lanes being used for passenger and commercial loading. • In some cases, consideration of consolidating or deactivating closely-spaced bus stops to provide space for other uses like passenger or commercial loading.
Municipality/ Private Land Owner	• Management of street curbs falls solely onto the local municipality. • The city also has the ability to manage parking costs on-street and off-street in public lots to reduce on-street demand and allow for additional curb uses.

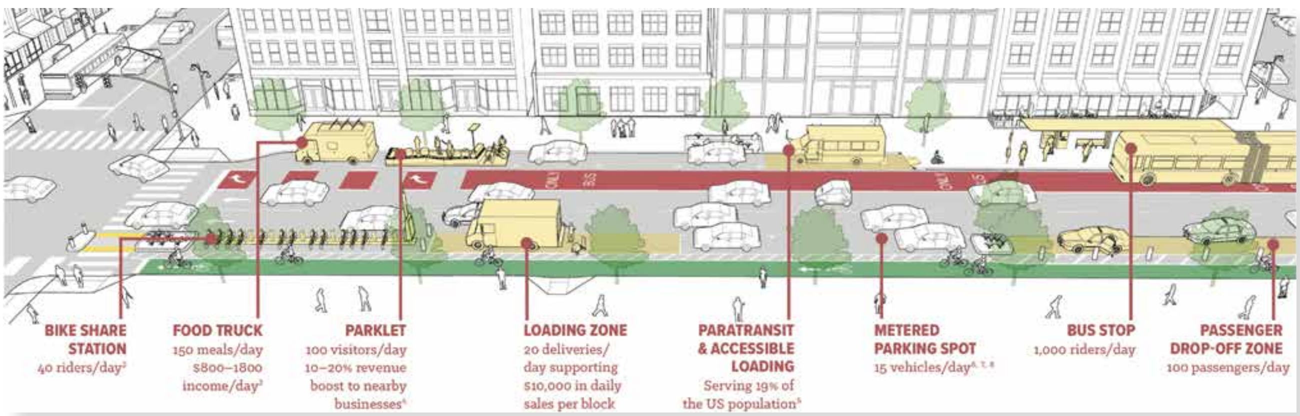
Figure A2.1: Sidewalk Parking Zones

Source: Google Maps

Figure A2.2: Designated Rideshare Location

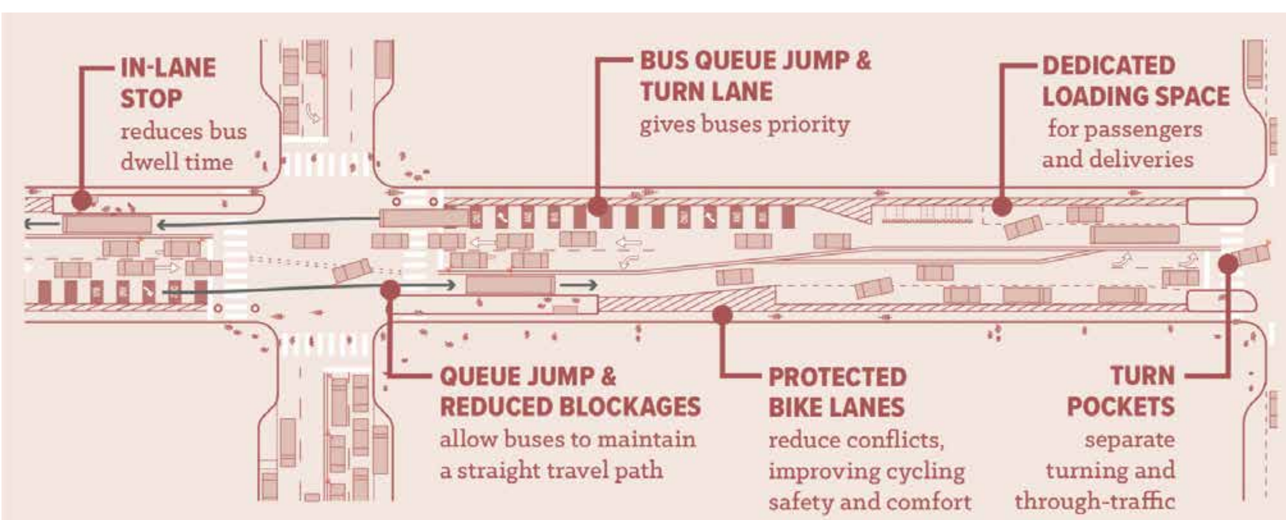
Source: Cincinnati Enquire

Figure A2.3: Different Curbside Uses



Source: NACTO

Figure A2.4: Curb Management Allows for More Efficient Traffic Flow



Source: NACTO

BENEFITS AND COSTS

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Travel time decreased by up to 22% + Transit is less vulnerable to double-parking	+ 2% increase in transit speeds + Double parking reduced by 22% – Requires enforcement to ensure uses adhere to designated spaces	+ Dedicated bus stop space is less confusing and safer for boarding – Drivers may object to removing spaces or raising rates	+ Fewer conflicts with passenger drop-offs + Improves visibility

ESTIMATED TYPICAL COSTS	PER 30M
Signage and striping per 30m	$500-$3,000

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
	★				★★	★	★		★	★	★	$–$$	Medium

CHALLENGES

- Requires full bus stop inventory, analysis, and engineering in order to identify and change location of bus stops.
- Adjacent developments, such as businesses or residents, may resist bus stops at specific locations due to additional right-of-way space used by bus stops and parking removed (if applicable).
- Customers may oppose stop relocation.
- Depending on local municipalities, private owners, and need for public outreach to customers, the timeline can be a few months to a few years to change bus stop locations.
- Regardless of stop location, areas must be designed to accommodate bus queuing at stops served by multiple routes.
- There must be sufficient space for amenities.

COMPLEMENTARY TREATMENTS

Curb management can improve transit operations and efficiency, but incorporating other treatments can reinforce and enhance the benefits of managing the space along the curb.

Bus Stop Placement

Optimally locating bus stops in designated zones further reduces conflicts and delays caused by other curbside uses.

Bus Stop Infrastructure

Bus bulges and boarding islands prevent buses from having to make curbside stops, which reduces the potential for conflict and interference with other curbside uses, thereby decreasing travel time, increasing reliability, and increasing safety.

Transit Approach Lane

A bus-only lane on the approach to an intersection allows for transit prioritization through an intersection while allowing curb space in the rest of the block for other curbside uses.

Dedicated & Peak-Hour Bus Lane

Curb-side bus lanes clearly reinforce space for transit and discourage other vehicles from using bus lanes. Clear lane striping (e.g. red lanes) or strong enforcement during introduction is advisable to ensure lanes are not misused by other vehicles.

ALTERNATIVE TREATMENTS

Not applicable

CURB MANAGEMENT EXAMPLES

Multiple cities have implemented various curb management techniques to reduce the impacts of other curbside uses.

- In 2011, San Francisco implemented SF park, a parking management pilot focused on improving parking availability through demand-responsive pricing, improved meters, and real-time information. As a result, blocks were full 16% less often, with a 43% decrease in the amount of time spent searching for parking. This reduced peak period congestion, contributed to an **8% decrease in traffic volumes**, and **reduced double parking by 22%**, which enabled a **2.3% increase in transit speeds** and improved reliability for Muni.[1]

1 SFMTA, "SFpark: Pilot Project Evaluation", 2014. http://sfpark.org/wp-content/uploads/2014/06/SFpark_Pilot_Project_Evaluation.pdf

Figure A2.5: SFpark Transit Travel Time Savings[1]

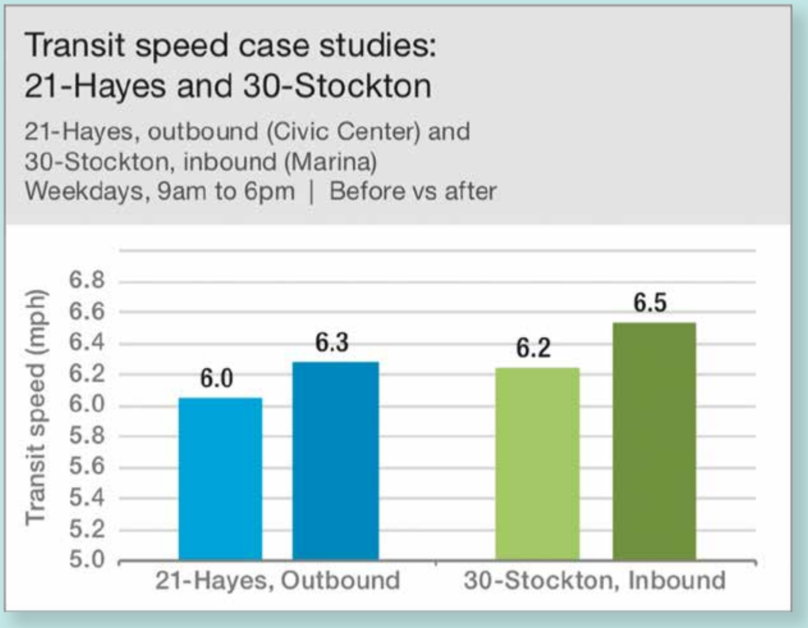
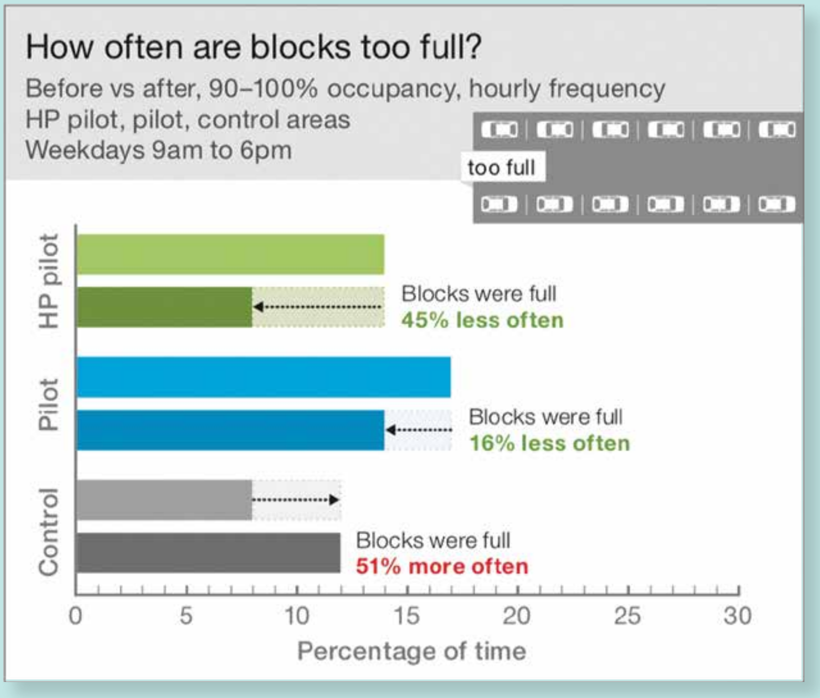


Figure A2.6: SFpark Parking Availability Improvements[1]



- In 2013, NYC DOT implemented curbside improvements in conjunction with Select Bus Service upgrades on the B44 route in Brooklyn. NYC DOT provided loading zones with delivery windows according to merchant surveys that allowed trucks to access the curb, reducing double-parking which had largely been caused by loading vehicles. **Travel times along Nostrand Avenue decreased by 19-22%** due to curbside regulations that expanded “No Standing” zones and added commercial loading zones. They were able to justify prioritization of transit to merchants based on a survey of customers that found that 84% of shoppers on Nostrand Avenue had walked or arrived by transit.[2]

- Toronto’s Curbside Management Strategy, as part of their Congestion Management Plan, aims to prioritize curbside uses without impacting traffic. Strategies include designated zones for delivery vehicles, turn and stopping restrictions, taxi drop-off areas, encouraging off-peak deliveries, and increased enforcement.[3] Though they are still in the process, initial measures taken have been successful in minimizing the impact of curbside uses on traffic operations.[4]

- Seattle has utilized pricing strategies to reduce the number of people who drive alone. The most effective strategy has been the shift from monthly parking fees to daily payments for garages or lots. Whereas monthly parking fees encourage driving to work because parking has already been paid for, daily parking fees provide the flexibility for commuters to decide their commute mode on a daily basis.[5]

2 NYC DOT, “B44 SBS on Nostrand Avenue Progress Report”, 2016.
http://www.nyc.gov/html/brt/downloads/pdf/brt-nostrand-progress-report-june2016.pdf

3 City of Toronto, “Congestion Management Plan”, 2016.
https://www.toronto.ca/legdocs/mmis/2017/pw/bgrd/backgroundfile-109153.pdf

4 Toronto Transportation Services, “Curbside Management Strategy: Improving How Curbside Space Is Used”, 2017.
https://www.toronto.ca/legdocs/mmis/2017/pw/bgrd/backgroundfile-109153.pdf

5 Gutman, David, “The not-so-secret trick to cutting solo car commutes: Charge for parking by the day”, 2017.
https://www.seattletimes.com/seattle-news/transportation/the-not-so-secret-trick-to-cutting-solo-car-commutes-charge-for-parking-by-the-day/

B. Traffic Regulations

B1. Movement Restrictions

Movement restrictions are limitations on general vehicular movements to either use travel lanes more efficiently or limit access to corridors in order to reduce delay for transit vehicles.

Strategy Overview

The use of movement restrictions improves bus travel speeds and reliability by reducing delays caused by motor vehicle traffic at key intersections. These improvements reduce travel time and operating cost of service.

Left-turns can cause delay to buses traveling straight or turning left. For buses traveling straight, a single motorist queuing in a general purpose lane to turn left can severely limit the flow of traffic through an intersection. Because left-turn signal phases are often very short, any queue of left-turning motorists reduces a bus's likelihood of getting through an intersection in a single signal cycle.

Because buses often travel in the curbside lane, restricting right turns reduces delay at intersections and unnecessary weaving in and out of traffic to avoid queuing vehicles. Right-turn restrictions have the added benefit of reducing conflict between right-turning motorists and pedestrians crossing the intersection.

Restricting through traffic reduces the amount of congestion along a stretch of roadway. While some movement restrictions try to interrupt vehicular traffic at an intersection, using transit only signage can create a transit exclusive area, such as a transit mall or bypass road.

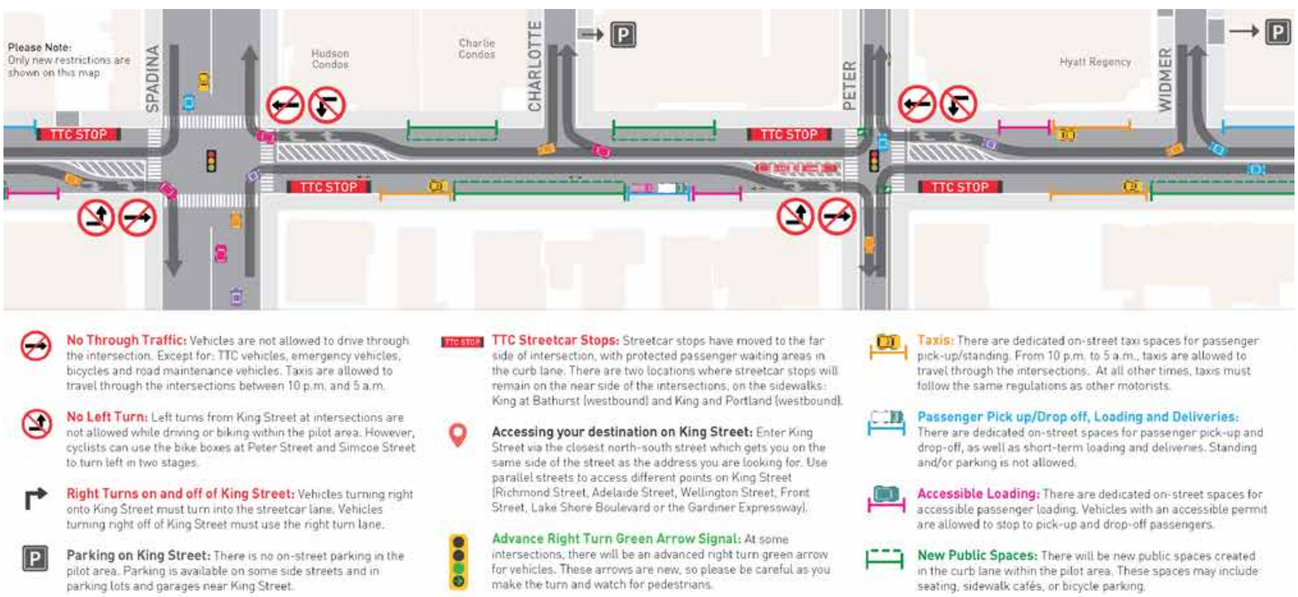
COORDINATION

The implementation of movement restrictions requires close coordination with local municipalities.

STAKEHOLDER	INVOLVEMENT
TransLink	• Identification of locations for effective implementation of turn or movement restrictions to maximize potential benefits.
Municipality	• Impact on city street right-of-way from the addition of lane striping and signage placement. • Additional traffic enforcement requirements.

Figure B1.1: Example of Transit Only/General Vehicular Restriction Signage

Figure B1.2: Toronto King Street Movement Restrictions



Source: City of Toronto and the Toronto Transit Commission

BENEFITS AND COSTS

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Corridor travel time reduced up to 25%	+ 33% reduction in travel time variability	+ Increases travel speed and reliability	+ Reduces interaction with motor vehicle traffic, bicyclists, and pedestrians

ESTIMATED COSTS	
Cost of Design and Implementation (includes cost of new turn lanes and signal adjustments)	$255,000 per km $20,000 per intersection

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
★★★		★	★★★	★★★		★★		★★	★	★	★★	$–$$$$	Medium/High

CHALLENGES

- Each movement restriction will place higher traffic volumes elsewhere. For example, left-turn restrictions may increase capacity in general traffic lanes, but can also increase right-turn traffic.
- Thorough network analysis must be completed for all modes of transportation to identify conflicts or holes in implementation.
- While movement restrictions can be applied on their own, maximum benefits for turn-restrictions are often combined with other complementary treatments.
- Requires traffic enforcement.

COMPLEMENTARY TREATMENTS

Implementing movement restrictions alone can reduce delays and improve travel times, but other treatments can be included alongside restrictions to enhance these benefits.

Bus Stop Placement

Locating bus stops where turns are restricted can mitigate safety concerns and allow for additional space for passenger amenities.

Curb Management

Curb management ensures that curbside uses do not interfere with transit or traffic operations.

Bus Stop Infrastructure

In-lane stops allow buses to remain in the through lane while other vehicles must turn, minimizing interference with transit operations.

Peak-Hour & Dedicated Bus Lane

Bus-only lanes combined with turn restrictions can minimize delays and conflicts with other vehicles, enabling faster and more reliable service.

Passive Signal Priority & Transit-Signal Priority

Signal priority for buses allows transit to consistently move through a corridor with movement restrictions with minimal delays or variability at intersections.

Vertical Control Devices

Vertical control devices can be used in conjunction with movement restrictions as a physical restriction on the roadway.

ALTERNATIVE TREATMENTS

Turn Pockets

Separate lanes for turning vehicles at intersections are unnecessary when turns are not permitted.

MOVEMENT RESTRICTION EXAMPLES

Multiple transit agencies have implemented turn restrictions on high demand corridors.

- Starting in 2011 as a way to address pedestrian and bicycle safety, SFMTA began implementing movement and turn restrictions along the Market Street corridor in downtown San Francisco from 10th Street to the Embarcadero. First to be implemented was the forced right turn off of Market Street at all applicable intersections for general travel. In 2015, turn restrictions were put into place for almost all general vehicular traffic turning onto Market Street,[1] which resulted in a 22% reduction in traffic and a 72% decrease in speeding.[2] In 2017, SFMTA announced a new plan to remove all general vehicular traffic and only allow transit, emergency vehicles, bikes, and pedestrians. Specific transit savings on travel time or reliability are difficult to calculate due to the additional improvements also implemented such as center-running dedicated transit lanes, transit stop islands, and all-door boarding.

Figure B1.4: Market Street Turn Restrictions starting Aug 2015 [1]

1 SFMTA, "Safer Marker St: Vision Zero in Action", 2014.
https://www.sfmta.com/sites/default/files/projects/2014/SMS_web_final.compressed.pdf

2 Zendrive, "Turning Towards Safety: San Francisco's Market Street", 2016.

MOVEMENT RESTRICTION EXAMPLES

Multiple transit agencies have implemented turn restrictions on high demand corridors.

- Starting in November 2017, the City of Toronto and the TTC implemented a pilot of movement restrictions on King Street in downtown Toronto. General vehicular traffic must make right turns at most major intersections that have two-way traffic. No left turns or continuation on King Street is allowed. The total project cost was $1.5 million CAD and included other transit priority strategies, including stop placement and infrastructure and reconfiguring the curb space along King Street. While the pilot has just a few months of data, the results are already very positive. Ridership on the King Street streetcar has increased by 25%, without decreasing on parallel routes. Streetcar reliability has improved by 33%, as the range of travel time variability went from 10 minutes to 6.7 minutes. Additionally, overall travel time on the route has increased by 6%, which is about a 20-25% increase in travel time on the section of the corridor with the pilot.[3]

Figure B1.5: Toronto King St Pilot Design Before (Top) and After (Bottom) [3]

3 City of Toronto, "King Street Transit Pilot", 2017.
https://www.toronto.ca/city-government/planning-development/planning-studies-initiatives/king-street-pilot/

C. Street Design

C1. Bus Stop Infrastructure

Bus stop infrastructure can take many forms, as different bus stop configurations may prioritize transit, motorists, bicyclists, or pedestrians.

Strategy Overview

Bus stops may be designed to pick up and drop off customers in the travel lane ("in-lane") or in the parking lane ("curbside"). In-lane stops reduce delay associated with accessing, serving, and exiting bus stops by eliminating the need for buses to merge in and out of traffic.

Bus bulges (also known as bus bulbs or curb extensions) and boarding islands commonly permit buses to stop in-lane while providing an area for transit customers to comfortably wait without blocking the sidewalk.

Bus bulges extend the curb into the parking lane so that buses can pick up or drop off customers without exiting the travel lane. Bus bulges can be implemented for near-side, far-side, or mid-block stops, and work particularly well with offset transit lanes. Bus bulges can also be designed to function as a raised bike lane, reducing weaving movements between buses and bicyclists on shared corridors. Bicyclists can use the bike lane when there is no boarding occurring, but must yield when a bus stops.

Boarding islands can be separated from the curb by a travel lane or a bike lane. When paired with a bike lane, boarding islands allow buses to make stops while eliminating the conflict between buses and bicyclists. In-street boarding islands, separated from the sidewalk by a travel lane, enable in-lane stops for center-running transit, as transit vehicles can pick up and drop off customers at a boarding island or median in the street. At intersections with a high volume of right turns or heavy transit activity, in-street boarding islands also separate right turns from through movements.

Boarding islands and bus bulges improve transit travel times and speeds by separating some of the other traffic movements on the street, such as turning lanes, other travel lanes, or bike lanes. In-lane stops also reduce delay accessing, serving, and exiting bus stops, further improving transit service and efficiency.

COORDINATION

The development of bus stop infrastructure requires coordination between TransLink and the local municipality that owns the right-of-way at each stop.

STAKEHOLDER	INVOLVEMENT
TransLink	• Identification of routes and stop locations that will most benefit from improved stop infrastructure. • Identification of additional structural (trolley wire) or operational (rapid/local tandem, turning movements) analyses or changes required.
Municipality	• Impact on street right-of-way from the installation of bus bulges or boarding islands and any additional bus stop infrastructure such as bus stop signs, shelters, real-time info, etc. • Permitting and possibly construction of bus stop infrastructure.

Figure C1.1: Near & Far-Side Boarding Island Stops

Source: NACTO

Figure C1.2: In-Street Boarding Island Stop

Source: NACTO & SFMTA

Figure C1.3: Bus & Streetcar Bulge

Source: NACTO

Figure C1.4: Shared Cycle Track Stop

Source: NACTO & Toronto TTC

BENEFITS AND COSTS

TRAVEL TIME

+ Travel times reduced due to up to 3 km/h increase in vehicle speeds
+ 7% increase in vehicle speed at stops with bus bulges
− Bus bulges preclude peak-hour bus lanes from operating in the parking lane

RELIABILITY

+ Reduces variability from traffic delays due to merging
+ Reduces dwell times by 15-30 seconds per stop with the elimination of delays due to merging

CUSTOMER EXPERIENCE

+ Increased footprint allows for more stop amenities, such as shelters, benches, etc.
+ Facilitates bus alignment with customer waiting area to improve accessibility
− Bus bulges or boarding islands paired with bike lanes or travel lanes increase the interaction between customers walking to/from the bus and other modes

SAFETY

+ Reduces vehicle conflicts with bicycles and pedestrians
+ Additional space for passengers to wait
+ Reduces crosswalk distance
− Increase in conflicts with vehicles when bus stays in travel lane
− Increases interaction between customers walking to/from the bus and other modes
− High volume stops may not be suitable for cycle tracks

ESTIMATED COSTS	PER STOP
Bus Bulge/Curb Extension	$20,000-$90,000
Single Bus Boarding Island	$35,000-$200,000

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
					★★	★★	★★★		★★★	★★★		$-$$$	Low

CHALLENGES

- Boarding islands require consideration of how transit customers will cross bike lanes or street traffic to access the bus stop.
- High volume stops may not accommodate cycle tracks due to safety concerns.
- In-lane stops without a dedicated bus lane can cause large delays to traffic depending on dwell times.
- All bus stop infrastructure should be able to accommodate customers who use wheelchairs, walkers, canes, strollers, and other mobility devices.

COMPLEMENTARY TREATMENTS

Implementing enhanced bus stop infrastructure alone will yield some speed and reliability improvements. However, combining bus stop infrastructure with additional treatments will enhance the overall benefits.

Bus Stop Placement

Bus stop locations are supported by proper curb management which allows the optimum placement of bus stops to improve safety, reduce dwell time, and improve travel speed.

Curb Management

Curb management ensures that stops are serviceable, reducing dwell time and increasing safety.

Dedicated Bus Lane

Bus-only lanes improve safety and ensure that traffic does not back up when stops are placed in-lane.

Passive Signal Priority & Transit-Signal Priority

Signal prioritization supports the use of in-lane stops by allowing the bus to board customers at intersections and immediately continue, improving travel speed.

All-Door Boarding

All-door boarding can reduce dwell time at bus stops, making efficient use of larger bus stop footprint and minimizing impacts to general traffic.

ALTERNATIVE TREATMENTS

Peak-Hour Bus Lane

Bus bulges cannot be used with peak-hour bus lanes that are parking lanes during non-peak hours, as bus bulges require dedicated space in parking lanes.

BUS STOP INFRASTUCTURE EXAMPLES

While the majority of transit agencies have utilized bus bulges/curb extensions on some routes, only a few have installed side boarding or in street bus stop islands.

- Starting with designs in the late 1980's, San Francisco's Muni developed median transit lanes with transit islands to serve bus routes on Market Street and the F Line streetcar. Since then, Muni has implemented bus bulges and bus islands along many surface streets with rapid transit (light rail and frequent bus). A report on the effects of bus bulges on transit found that buses experienced a 7% increase in vehicle speed and delays were significantly reduced at near-side stops.[1] Additionally, the amount of space for pedestrians also increased by 134%, allowing for a more comfortable and safe transit experience.[1]
- Seattle Department of Transportation has implemented bus boarding islands on multiple corridors in order to provide safer streets for bicyclists and pedestrians. Bus boarding islands have been installed on Dexter Avenue, Broadway, and Roosevelt Way. Over the 2.5 km of Dexter Avenue to be reconfigured, travel time remained the same as traffic volumes increased by 19%. Ridership on the corridor also increased by 40%.[3]

Figure 5: SFMTA Boarding Island on Market Street[2]

Figure 6: Seattle DOT Bus Island on Dexter Avenue[4]

1 Fitzpatrick et al., "TCRP Report 65: Evaluation of Bus Bulbs," 2001. https://nacto.org/wp-content/uploads/2015/04/tcrprpt65_fitzpatrick.pdf

2 Google Maps, 2017. https://www.google.com/maps/@37.7804934,-122.4125139,3a,75y,41.02h,90.38t/data=!3m6!1e1!3m4!1sZcg5GZpvKJRWlXBqqkyKVQ!2e0!7i16384!8i8192

3 Chang, Dongho, "Expanding Networks to Seattle's Job Centers," 2015. http://www.lgc.org/wordpress/wp-content/uploads/2015/07/Dongho-Chang.pdf

4 NACTO, "Transit Boarding Islands, Dexter Avenue, Seattle," 2018. https://nacto.org/case-study/dexter-avenue-bus-island-seattle/

- In Toronto, multiple corridors along streetcar and bus lines have had a shared cycle track stop installed. These stops are generally used when right-of-way space is limited. Example corridors include Sherbourne Street and Roncesvalles Avenue. Additionally, as part of the King Street Transit Pilot, most of the stops within the pilot area along King Street have been marked out with partial and temporary bus bulges. These temporary bus bulges can be seen in Figure 8.[6]

- In 2005, a study for the New Jersey Department of Transportation found that after bus bulges were implemented, buses saved 15-30 seconds per stop at along high traffic corridors. Bus speeds along corridors increased by 3 km per hour.[7]

- Many agencies, such as AC Transit in Okaland and New York MTA, have also implemented temporary or piloted bus infrastructure by using temporary materials. These include implementing "stoplets" (a play on the parklet concept), painting the street and using wood ramps, or using rubber pads bolted to the street until a permanent bus bulge or boarding island can be installed.[8]

5 NACTO, "Shared Cycle Track Stop," 2018. https://nacto.org/publication/transit-street-design-guide/stations-stops/stop-configurations/shared-cycle-track-stop/

6 Neil, Lauren, "Toronto Can't Seem to Agree on Future of King St," 2018. https://www.blogto.com/city/2017/12/toronto-future-king-street-pilot-project/

7 Daniel and Konon, "Effectiveness of Bus Bulbs for Bus Stops," 2005. HTTPS://NTLREPOSITORY.BLOB.CORE.WINDOWS.NET/LIB/24000/24700/24789/BUSNUBS.PDF

8 Transit Center, "Why Tactical Transit is the Next Big Thing," 2016. http://transitcenter.org/2016/12/19/why-tactical-transit-is-the-next-big-thing/

Figure 7: Toronto TTC Shared Cycle Track Stop on Roncesvalles Avenue[5]

Figure 8: TTC King Street Temporary Transit Bulge[6]

C2. Turn Pockets

Turn pockets are separate lanes for vehicles turning left or right at an intersection or driveway. Turn pockets provide space for vehicles to wait for a dedicated turn signal, a break in opposing traffic, or pedestrians to cross an intersection.

Strategy Overview

This specialized storage space minimizes delay to other users of the roadway, including transit vehicles, as transit and other vehicles would otherwise have to weave around turning vehicles.

Turn pockets are commonly employed at intersections with a high volume of turns. Turn pockets can also be effective tools to reduce delay and conflicts at intersections with relatively low—but consistent—turning volumes and high volumes of concurrent pedestrian movements and/or a high volume of transit vehicles. Right-turn pockets are often placed in the parking lane, while left-turn pockets may be placed in an existing median. However, turn pockets may require widening a roadway where those options are not available. On wide roads, turn pockets may be paired with boarding islands or transit approach lanes to further reduce conflict between buses and motorists.

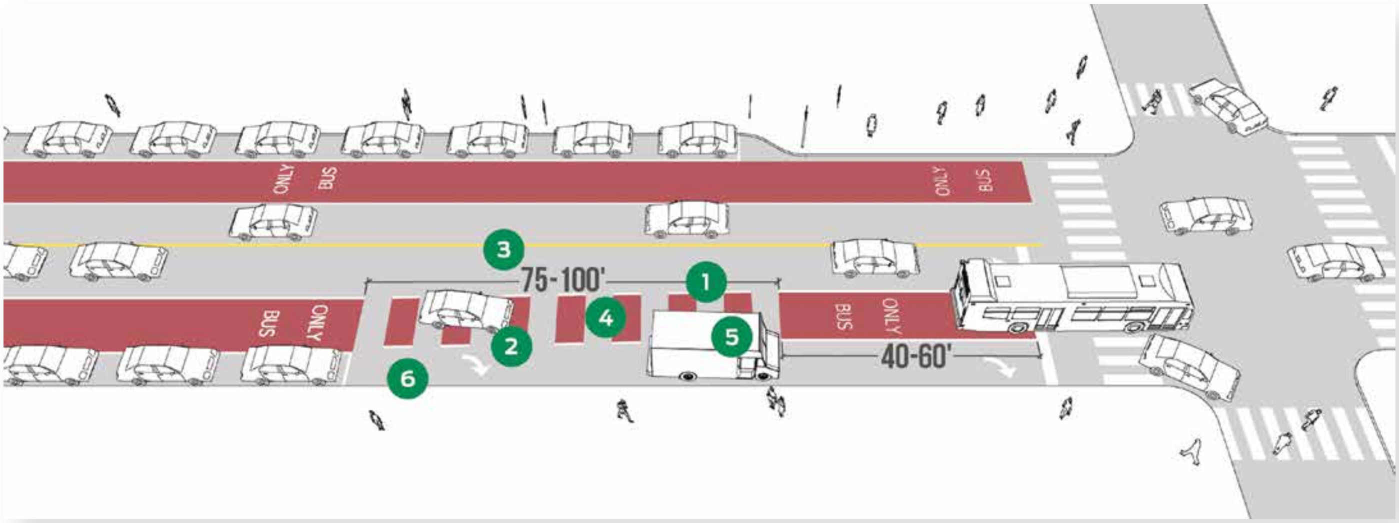
Motor vehicle turns made from a general purpose lane can cause delay to transit by limiting the flow of buses through an intersection. Turn pockets reduce delay to buses caused by turning vehicles, thereby reducing the likelihood of encountering a red light.

COORDINATION

The implementation of turn restrictions requires close coordination with local municipalities.

STAKEHOLDER	INVOLVEMENT
TransLink	• Identification of locations where turning movements cause delay to transit operations.
Municipality	• Impact on city street right-of-way from the addition of lane striping and signage placement. • Additional traffic enforcement, if necessary.

Figure C2.1: Right-Turn Pocket



Source: NACTO

Figure C2.2: Las Vegas Right-Turn Pocket

Source: Google Maps

BENEFITS AND COSTS

TRAVEL TIME

+ Allows transit to remain in lane improving travel times by 2 minutes over a 4 km corridor

+ Fewer delays for through-moving transit

RELIABILITY

+ Reduces delays at intersections with high right-turn, pedestrian, and/or transit volume

− Large turning queues or lack of enforcement can block transit lane

CUSTOMER EXPERIENCE

+ Reduces travel time through corridor

+ Improves reliability of scheduled service

SAFETY

+ Reduces weaving of motorists around turning vehicles

+ Can reduce accidents by up to 85%

− Additional interactions between transit and turning vehicle traffic

− May increase pedestrian crossing distance

ESTIMATED COSTS	COST
Single Bus Boarding Island	$35,000-$200,000
Left turn pocket signage and striping	$500-$3,000
Signal upgrades	$500-$14,000

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
★		★★	★	★							★★	$–$$	Medium

CHALLENGES

- May require the removal of a median, parking spaces, or other curbside uses.
- Turning vehicles must still cross the transit lane, which can cause delays if there is a high volume of turning vehicles.
- The location of bicycle lanes or cycle tracks must also be considered so that turning vehicles are not in conflict with cyclists.
- May lengthen pedestrian crossing distance.

COMPLEMENTARY TREATMENTS

Turn pockets are most effective when paired with the following complimentary treatments:

Bus Stop Placement

Curb-side bus stops should be located downstream from turn pockets, ideally on the far side of the intersection.

Curb Management

On-street parking may be adjusted to provide turn pockets.

Bus Stop Infrastructure

Transit boarding islands allow for physical separation of turning vehicular traffic, increasing safety. Access to pocket lane must be provided before boarding island, which may require additional curb space.

Dedicated Bus Lane

Turning traffic crosses dedicated right of way for buses to reach turn pocket.

ALTERNATIVE TREATMENTS

Movement Restrictions

Restricting vehicle traffic to making only left or right turns would negate the need for pocket lanes, instead requiring full travel lanes separated from dedicated lanes. Additionally, restricting turns would negate the need for turn pockets.

Transit Approach Lane

Turning traffic may be split off from dedicated transit before intersection through the use of a transit approach lane.

TURN POCKET EXAMPLES

Multiple road authorities and transit agencies have implemented turn pockets at intersections with a high volume of right turns.

- Turn pockets are frequently used by SFMTA to reduce delays at intersections caused by right-turning vehicles. Implementation includes both full-time and peak-hour turn pockets, where on-street parking is prohibited during peak hours to allow for a right turns across transit lanes. In 2017, SFMTA completed the 14 Mission Rapid Project, which consisted of a number of transit treatments along Mission Street, including the implementation of turn pockets at 20 intersections. Though specific benefits of turn pockets were not calculated, the project reduced Muni collisions by 85%, reduced corridor travel times by two minutes, and improved reliability by reducing time spent waiting at signals.[1]

Figure C2.3: Mission Street Treatments, Including Turn Pockets[1]

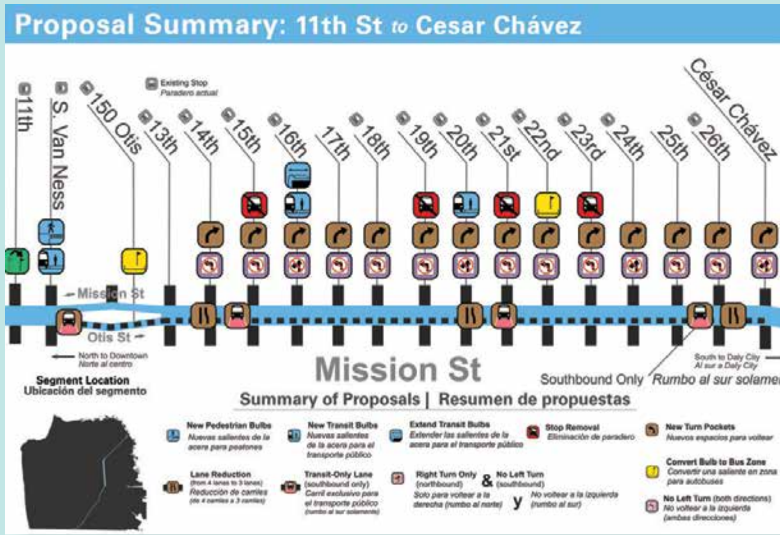


Figure C2.4: Transit Lane Turn Pockets on 3rd Street in San Francisco[4]

- The United States Federal Highway Administration has found that by adding right turn lanes at major intersections, collisions between right turning traffic and through traffic can be reduced by 5%. By using part of a transit lane to lengthen the deceleration area for right turning traffic, all collisions can be reduced by an additional 10%.[2]

- Many other cities, such as Los Angeles, use turn pockets to prioritize through-moving transit. Left-turn pockets are used to accommodate left turns across center-running transit, while right-turn pockets are useful for curbside or offset transit.[3]

1 SFMTA, "14 Mission Rapid Project", 2017. https://www.sfmta.com/projects/14-mission-rapid-project

2 https://www.fhwa.dot.gov/publications/research/safety/04091/12.cfm#c123

3 Los Angeles Department of City Planning, "Complete Streets Manual", 2014. http://planning.lacity.org/Cwd/GnlPln/MobiltyElement/Text/CompStManual.pdf

4 Google Maps

C3. Vertical Control Devices

Vertical control devices are protrusions or depressions in the roadway that limit the speed or movement of vehicles through a corridor or intersection.

Strategy Overview

These devices can be modified to mitigate impacts to transit speed and customer comfort or even promote exclusive access to transit vehicles.

Speed humps and speed tables are most commonly used in low-volume corridors, narrow intersections in commercial corridors with heavy pedestrian volume, or residential neighborhoods to promote slow, consistent speed and discourage through-traffic. As an alternative, speed cushions are protrusions in the roadway that include wheel cut-outs to allow larger transit vehicles, emergency response vehicles, and bicyclists to pass through unimpeded, while slowing down general purpose traffic.

Some vertical control devices are designed to limit access of a roadway for the exclusive use of transit vehicles. Hydraulic bollards can allow transit vehicles into limited access areas by lowering the bollards with automatic readers or remote control when a bus approaches. Sump busters are raised concrete barriers designed to permit access to buses and emergency response vehicles, but not smaller motor vehicles. Similarly, bus traps are depressions in the roadway designed to accommodate the wheelbase of buses and emergency vehicles, but not smaller motor vehicles. Hydraulic bollards, sump busters, and bus traps may be placed at the entrance of a dedicated busway as an extra precaution to deter any unauthorized vehicle access.

COORDINATION

STAKEHOLDER	INVOLVEMENT
TransLink	• Identification of locations for possible transit cut through or need to limit potential vehicular traffic from transit lane.
Municipality	• Minor impact on city street right-of-way from the installation of vertical speed controls to major impacts with street closures to general vehicular traffic.

Figure C3.1: Vertical Control Devices – Speed Hump (Left), Speed Table (Middle), and Speed Cushion (Right)

Source: NACTO

Figure C3.2: Sump Buster (Left) and Bus Trap (Right)

Source: https://bracknellblogger.wordpress.com/2014/09/03/what-is-a-sump-trap/ & https://twitter.com/pbakhmut/status/850370440350416896

BENEFITS AND COSTS

TRAVEL TIME

+ Restricting access to only transit improves travel time by creating transit-only streets

− Some vertical control devices reduce vehicle speeds

RELIABILITY

+ Speed humps, tables, and cushions may reduce vehicle volumes

− Larger vehicles may be able to avoid devices

CUSTOMER EXPERIENCE

+ Transit-only streets eliminate congestion

− May face public opposition in restricting access to motor vehicle traffic

SAFETY

+ Transit-only restrictions eliminate interactions with other vehicles

+ Up to 14 km/h speed reduction and up to 30% injury collision reduction

− Sump busters can be tampered with and damage buses

ESTIMATED COSTS	COST
Speed table	$3,000-$30,000
Hydraulic bollards	$15,000-$100,000

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
	★★★				★★	★		★★	★★★	★★★	★	$	Medium

CHALLENGES

- Devices should be paired with visible signage or clear street markings to indicate that speed must be reduced or access is not permitted.
- Devices should be located on streets that do not interfere with emergency vehicles' access routes.
- Neighborhoods and communities should be consulted before implementing vehicle control devices, particularly those that restrict motor vehicle access.
- Devices should be part of a comprehensive traffic plan, as they may contribute to congestion on other streets or interfere with emergency services.
- Sump busters and bus traps are not as effective for larger motor vehicles, and tend to face public backlash.

COMPLEMENTARY TREATMENTS

Bus Stop Placement
Locating bus stops in areas that are restricted to all traffic except for transit significantly improves boarding times, transit reliability, and safety.

Movement Restrictions
Restricting turns with the use of diverters or bollards to prevent congestion can reduce conflicting traffic patterns to benefit transit.

Dedicated Bus Lanes
With separated dedicated transit lanes, vertical control devices can help provide passive enforcement of transit only lanes.

Transit-Signal Priority
When entering a transit-only area after a signal, activation of the transit signal priority can also automatically activate the use of a hydraulic bollard by a transit vehicle.

ALTERNATIVE TREATMENTS

Peak-Hour Bus Lanes
Permanent vertical control devices cannot be used with a peak-hour travel lane, as the lane must be used by general vehicular traffic during off-peak times.

VEHICLE CONTROL DEVICES EXAMPLES

Vertical control devices are often used for safety and speed reduction benefits, rather than as a means of promoting transit. While some devices may reduce vehicle speeds, they can also reduce vehicle volumes, which may improve transit reliability as fewer vehicles contributes to less congestion and delays for transit.

- Many cities in North America use raised intersections and crosswalks to reduce traffic speeds and increase safety.
- Speed humps are the most commonly used traffic calming device in Quebec, and have contributed to reduced speeds and fewer collisions.[1] For example, speed humps were installed in Saint-Aimé-des-Lacs, Quebec in 2008, which resulted in speed decreased of 5-14 km/hr, which correlates to a 10-30% reduction in injury collisions.[3]
- Sump busters are used on the O-Bahn Busway, a 12km long guided busway connecting Adelaide, South Australia to its suburbs. Though the sump busters are not directly responsible for the benefits of the O-Bahn, they reinforce the exclusive right-of-way for buses that has reduced travel times between Adelaide and the suburbs from 40 minutes to 25 minutes.[4]
- In 1992, the City of Cambridge, UK implemented hydraulic bollards to restrict traffic into and out of the city center at key entry points, permitting only local buses, taxis, and bicycles.[5] The bollards were successful in aiding transit, and resulted in a 21% decrease in traffic through the city center and an 88%increase in bicycling along with additional infrastructure. The bollards were removed in 2016 due to complications with emergency vehicles and replaced by more cost-effective cameras that automatically capture and ticket vehicles that use the restricted streets.[6]

Figure C3.3: Raised Crosswalk in Cambridge[2]

Figure C3.4: Sump Buster on the O-Bahn Busway[7]

Figure C3.5: Rising Bollards on Bridge Street in Cambridge, UK[5]

1 Ministère des Transports du Québec, "Traffic Calming in Québec: Speed Humps and Speed Cushions", 2013. https://nacto.org/wp-content/uploads/2015/04/traffic_calming_in_quebec_berthod.pdf

2 Google Maps

3 "Motorized Traffic and Health: Interventions to Mitigate its Impacts", 2012. http://www.ncchpp.ca/docs/CPHA2012_4Highways_en.pdf

4 "Adelaide, Australia: O-Bahn Guided Busway, 2003. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp90v1_cs/Adelaide.pdf

5 Walls, Tom, "Traffic Management in City Centres", 2015. http://www.atgaccess.com/wp-content/uploads/2015/09/white-paper-traffic-management.pdf

6 Brown, Raymond, "Nearly 100 drivers a day are fined for using city 'rat runs' where rising bollards used to be", 2017. https://www.cambridge-news.co.uk/news/cambridge-news/cambridge-rat-run-anpr-roads-13014779

7 https://railgallery.wongm.com/adelaide-obahn/E112_7604.jpg.html

C4. Queue Jumps

Queue jump lanes are either short dedicated transit lanes or shared turn pockets paired with transit signal priority that allow transit vehicles to bypass traffic at an intersection.

Strategy Overview

Queue jumps can be implemented at both near-side and far-side bus stops, though different treatments are appropriate depending on the stop placement. In either case, queue jumps must be implemented with transit signal priority (TSP). When paired with TSP, buses approach an intersection in a dedicated lane or shared turn pocket and receive an early green signal or transit-only signal that allows them to proceed through an intersection before other traffic.

Allowing transit vehicles to bypass the queue can significantly decrease delay at traffic signals and reentry from the bus stop to travel lane. By reducing delays at intersections, queue jumps can further improve the reliability of the route, especially if paired with transit signal priority.

COORDINATION

STAKEHOLDER	INVOLVEMENT
TransLink	• Identification of locations for effective implementation of queue jump lanes. • Working with municipality to locate stops to maximize potential benefits.
Municipality	• Signal installation, programming, and coordination for transit signals, if necessary. • Impact on city street right-of-way from the addition of lane striping and signage placement. • Assistance relocating bus stops to maximize benefits.

Figure C4.1: Queue Jump Diagram

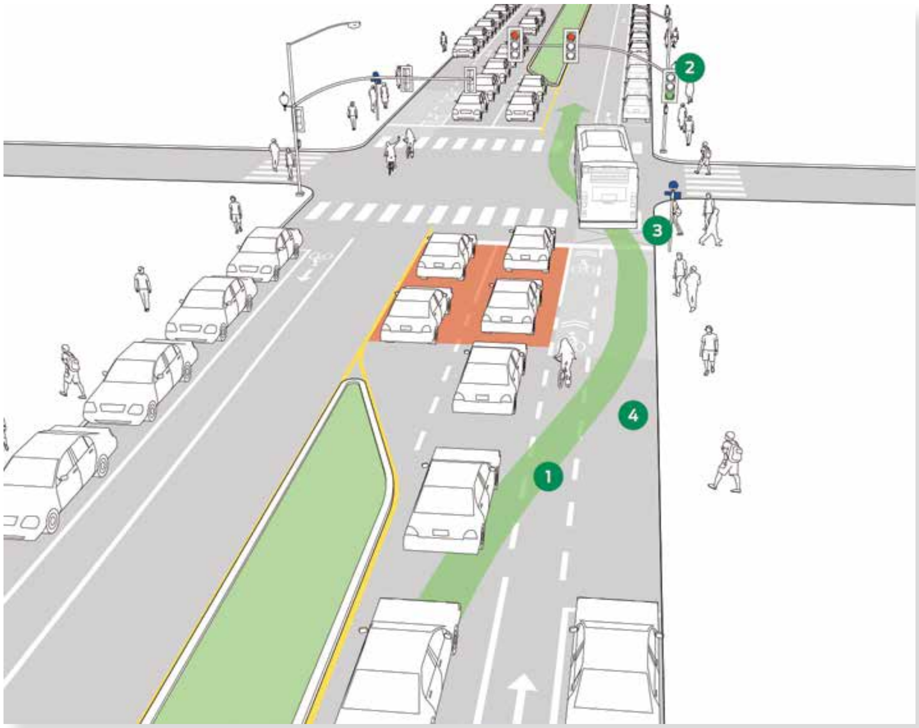


Figure C4.2: New York MTA Select Bus Service Queue Jump Lane

Source: NACTO; NYC DOT

BENEFITS AND COSTS

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Reduces travel times by up to 30%	+ Reduces delays at intersections by 7% + Improves schedule adherence by 45% – Right-turns can congest queue jump lanes	+ Reduces wait times at traffic signals	+ Fewer conflicts at intersections + Visibility improvements – In non-TSP lanes merging can be hazardous

ESTIMATED COSTS
$5,000-$20,000, based on the type of detection deployed, including $500-$3,000 for signage and striping

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
★★★		★★★						★★				$–$$	Medium

CHALLENGES

- Requires either the construction of additional lanes or the conversion of existing general purpose or parking lanes.
- Requires transit signal priority.
- High volume of right turns and/or high volumes of concurrent pedestrian crossings limit the effectiveness of queue jumps in the right-turn pocket.
- The queue jump lane must be long enough to allow for turns and time savings, but not so long as to significantly impede traffic.
- Queue jumps can be implemented at both near-side and far-side bus stops, though different treatments are appropriate depending on the stop placement.
- Bus stop location must be considered.

COMPLEMENTARY TREATMENTS

Queue jump lanes can be effective when implemented alone, but are most effective when paired with the following complementary treatments:

Bus Stop Placement
Bus stops should be located mid-block or near-side the queue jump to avoid stopping both before and after the intersection to reduce dwell time.

Turn Pocket
Turn pockets allow conflicting turning traffic to be separated from the queue jump lane to ensure the bus can utilize the queue jump and improve travel speed.

Transit-Signal Priority
Designated bus signals with inserted green phase can improve the safety at queue jumps and reduce dwell time at nearside stop boarding locations.

ALTERNATIVE TREATMENTS

Movement Restrictions
Restrictions that prohibit through movements for non-transit vehicles would negate the need for queue jump lanes by only permitting access through an intersection for transit.

Transit Approach Lane
Transit approach lanes serve a similar purpose as queue jumps by allowing transit to bypass congestion at an intersection.

Dedicated & Peak-Hour Bus Lane
Dedicated right-of-way separates transit from general vehicular traffic at intersections, negating the need for queue jump lanes.

QUEUE JUMP EXAMPLES

Multiple transit agencies have implemented queue jumps at intersections, often in conjunction with other transit priority treatments.

- In 2015, the MTA launched Select Bus Service for the M86 route, which included three queue jump lanes. As a result of the queue jumps, time stopped in traffic was reduced by 7% in the westbound direction and 30% in the eastbound direction. Travel times were also decreased by 2 minutes, with an increase of 14% in the amount of time buses spent traveling above 15 mph.[1]
- Calgary Transit implemented queue jump lanes along a high volume corridor, resulting in travel time savings of 25-30% in the corridor and 1.5 to 2 minutes off of trip times. The queue jump lanes also improved schedule reliability by 45%, though merging back into travel lanes did contribute to some delay.[2]
- In 2003, TransLink implemented a number of bus treatments on the 98 B-Line route between Vancouver and Richmond, including queue jump lanes. The transit priority improvements resulted in travel time savings of 20%, and precluded need for five additional vehicles.[3]

Figure C4.3: Queue Jumps Reduced Average Dwell Times[1]

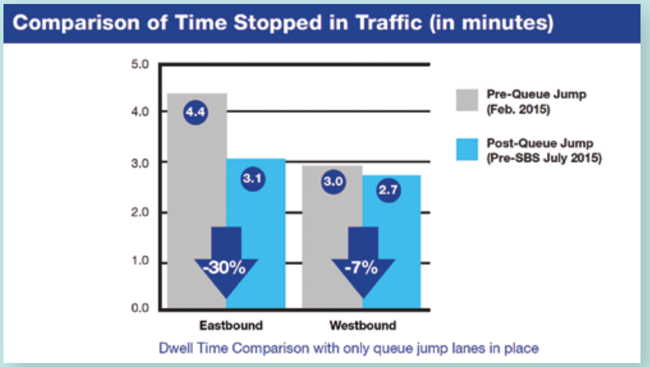


Figure C4.4: Queue Jump Lanes in Calgary, AB[2]

1 New York City DOT, "M86 Select Bus Service Progress Report", 2017. http://www.nyc.gov/html/brt/downloads/pdf/brt-m86sbs-progress-report-april2017.pdf

2 City of Calgary, "Bus Queue Jump (Lane) Utilization: A case study in Calgary, AB Canada", 2017. http://itsworldcongress2017.org/wp-content/uploads/2017/11/Asim.pdf

3 Transport Canada, "Bus Rapid Transit (BRT), Queue Jump Lanes, Transit Signal Priority", 2003. http://data.tc.gc.ca/archive/eng/programs/environment-utsp-tdm-prj18e-832.htm

C5. Transit Approach Lane

Transit approach lanes are short dedicated lanes that separate buses from traffic queues at intersections.

Strategy Overview

Transit approach lanes typically divide a general purpose lane and turn pocket at the approach of a controlled intersection. This treatment is often implemented with red paint, "bus only" decals, striping, and signage.

Transit approach lanes are beneficial at intersections with long queues of motorists, high frequency of right turns, and/or high volume of concurrent pedestrian movements that delay right-turning motorists. Unlike some queue jumps, transit approach lanes offer an exclusive right-of-way for transit. They also align with a receiving lane on the far side of the intersection, allowing transit approach lanes to function independent from any signal infrastructure.

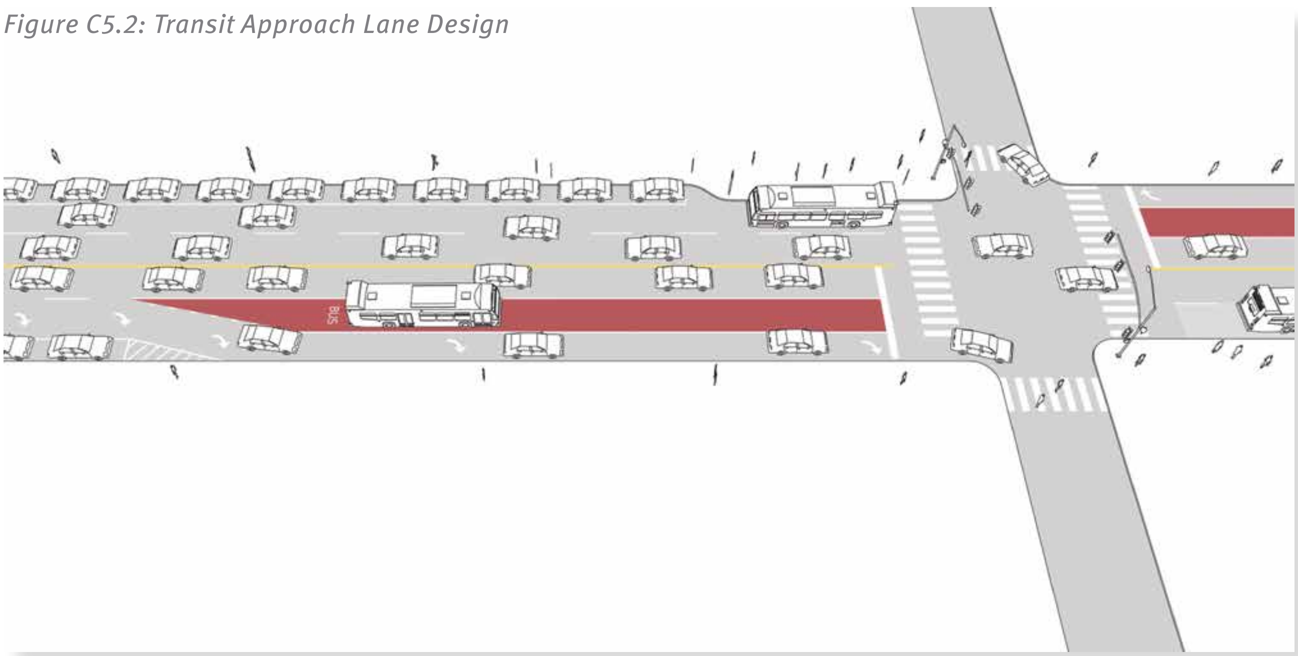
COORDINATION

STAKEHOLDER	INVOLVEMENT
TransLink	• Identification of locations with heavy congestion and turning traffic for effective implementation of transit approach lanes to maximize potential benefits.
Municipality	• Impact on city street right-of-way from the addition of lane striping and signage placement. Requires additional traffic enforcement.

Figure C5.1: San Francisco Muni Transit Approach Lane – Stockton St

Source: Google Maps

Figure C5.2: Transit Approach Lane Design



Source: NACTO

BENEFITS AND COSTS

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Allows transit to remain in lane, reducing travel time	+ Reduces delays at congested intersections or with longer cycle times – Lack of enforcement can block transit lane	+ Reduces wait times in traffic at signals by 30%	+ Visibility improvements – Potential conflicts with right turn vehicle traffic

ESTIMATED COSTS	COST
Signage and striping at intersection	$500-$3,000

RELATIVE BENEFITS AND COSTS														
CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
★★★		★★★						★★				$	Medium

CHALLENGES

- Requires either the construction of additional lanes or the reallocation of space on the roadway reducing the space available for general purpose lanes or on-street parking.
- Length of transit approach lane depends on length of right-turn queues and availability of curb to create right-turn pocket.
- Other vehicle queues may get longer if a lane is converted to a transit only lane.
- Requires enforcement of vehicle restrictions in transit approach lane, although highly visible markings (e.g. red lanes) improve compliance.

COMPLEMENTARY TREATMENTS

Transit approach lanes are effective when implemented alone, but are most effective when paired with additional complementary treatments:

Bus Stop Placement

Curb-side bus stops should be located mid-block or far-side, as the turn lane would be located at the near side of an intersection.

Curb Management

Reduction of parking along curb required to create turn lane.

Bus Stop Infrastructure

Transit boarding islands allow for physical separation of turning vehicular traffic, increasing safety.

Transit-Signal Priority

An extended green or truncated red signal allows transit to more reliably clear an intersection in a transit approach lane.

ALTERNATIVE TREATMENTS

Movement Restrictions

Restricting vehicle traffic to making only left or right turns would result in transit approach lanes becoming dedicated transit lanes.

Dedicated & Peak-Hour Bus Lane

Transit approach lanes are not needed if dedicated or peak-hour bus lanes are already present.

Queue Jumps

Queue jumps serve a similar purpose as transit approach lanes by allowing transit to bypass congestion at an intersection.

TRANSIT APPROACH LANE EXAMPLES

The use of transit approach lanes is almost always implemented as other strategies, such as queue jumps or the beginning of dedicated or peak-hour bus lanes.

- In 2015, the City of Chicago built the Loop Link to provide faster service in the downtown Chicago area. The main one-way pair of Washington St and Madison St were reconstructed to have dedicated transit lanes and level boarding platforms. Due to the north-south one-way streets in downtown Chicago, stations were placed on blocks where the next intersection had only left turn or straight traffic patterns. At the intersections between these blocks, traffic patterns are either straight or right turning. The right turning traffic is separated from the transit lane by a transit approach lane, as seen in Figure 4. The transit approach lane allows transit vehicles to pass queueing right turn traffic.[1]

- Many transit agencies, such as New York MTA, have implemented transit approach lanes as queue jump lanes with or without transit signal priority. From the M86 conversion to Select Bus Service, MTA tracked individual pieces of bus priority strategies. The transit approach lanes helped reduce time in traffic by 30%, while traffic volumes remained the same, even after removal of a travel lane.

- Transit approach lanes would also provide some of the benefits that queue jump lanes do, such as reducing the number of signal cycles transit must wait through at highly congested intersections.

1 City of Chicago, "Loop Link", 2018. http://www.transitchicago.com/looplink/

2 Google Maps

3 New York City DOT, "M86 Select Bus Service Progress Report", 2017. http://www.nyc.gov/html/brt/downloads/pdf/brt-m86sbs-progress-report-april2017.pdf

Figure C5.3: Beginning of Transit Approach Lane with Allowed Turning Traffic – Washington Street in Chicago[2]

Figure C5.4: End of Transit Approach Lane with Separated Turning Traffic – Washington Street in Chicago[2]

Figure C5.5: MTA Select Bus Service (SBS86) Approach Lane[3]

C6. Peak-Hour Bus Lane

Peak-hour bus lanes are lanes reserved for the exclusive use of buses during designated peak periods and free for general use or parallel parking during off-peak times.

Strategy Overview

These lanes are typically located curbside and facilitate improved transit service during periods of high demand. Designed lanes may be restricted to buses only in the peak commute direction, often inbound in the morning and outbound in the afternoon.

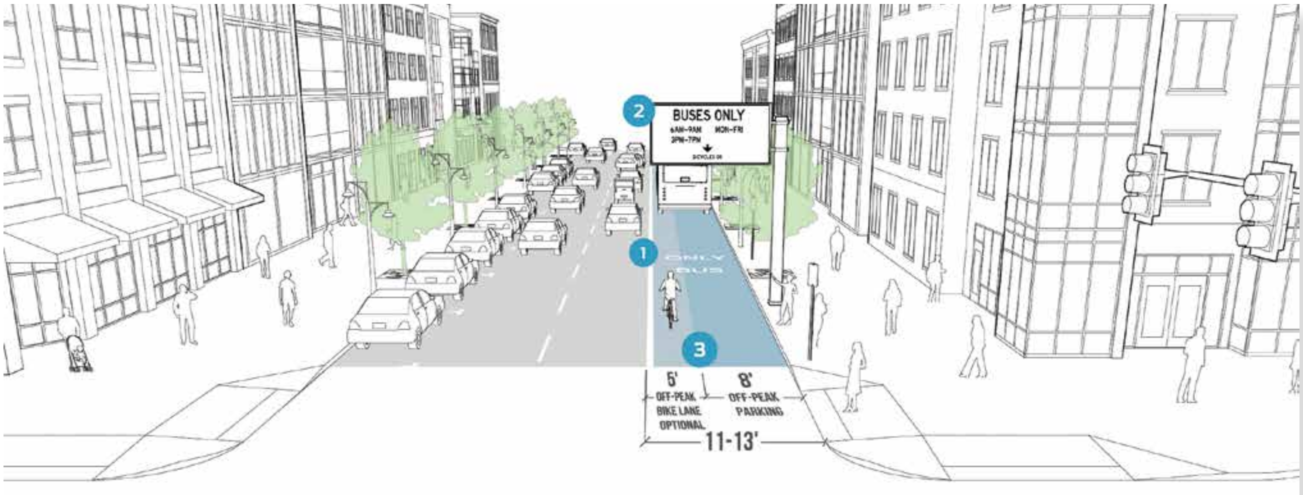
Peak-hour bus lanes improve bus travel speeds and reliability by reducing delays caused by motor vehicle traffic during the most congested times. These improvements reduce travel time and the cost of providing service. In addition to improving operating speed, peak-hour bus lanes improve schedule reliability by reducing variability in travel time.

COORDINATION

Peak-hour bus lanes require close coordination with local municipalities.

STAKEHOLDER	INVOLVEMENT
TransLink	• Identification of locations for effective implementation of peak-hour bus lanes and locating stops in optimum locations (far side) to maximize potential benefits.
Municipality	• Impact on city street right-of-way from the addition of lane striping and signage placement. Additional traffic enforcement requirements during transit only times.

Figure C6.2: Peak-Hour Bus Lane Diagram



Source: NATCO

Figure C6.1: WMATA Peak-Hour Bus Lane on Georgia Avenue (shared with bicycle, left) & LA Metro Peak-Hour Bus Lane on Wilshire Boulevard (right)

Source: NATCO

BENEFITS AND COSTS

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Corridor travel time reduced by up to 30%	+ On-time performance increased by 65% − Benefits only apply during peak times	+ Increases travel speed + Reduces time waiting at bus stop, as buses do not need to merge + Improves travel time reliability	+ Reduces interaction with motor vehicle traffic − Potential conflicts with right turn motor vehicle traffic

ESTIMATED COSTS	COST
Separated Lanes in Existing Right-of-Way	$4,000,000-$6,500,000 per lane km[1]
Converting Existing Lanes	$200,000-$450,000 per lane-km[1]
Maintenance Costs	$20,000 per lane-km per year[1]

1 TRB, "TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic", 2010. https://nacto.org/docs/usdg/tcrp_synthesis_83_danaher.pdf

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY				
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS	COST	COORDINATION
★★	★★		★★	★★	★★	★★	★★	★★★		★	★★	$$–$$$$	High

CHALLENGES

- While peak-hour travel times will be improved, customers will not experience travel benefits during off-peak hours.
- Lanes should be painted red and visibly marked to minimize violations.
- Benefits are dependent on the enforcement and legibility of lane restrictions.
- Peak-hour only lanes are often limited to curbside lanes, which may restrict additional stop improvements such as curb extensions and conflict with pedestrian traffic and right turning motor vehicle traffic.

COMPLEMENTARY TREATMENTS

Peak-hour bus lanes provide significant benefits to travel times and reliability, but can be combined with other treatments to enhance transit improvements.

Bus Stop Placement

Optimizing bus stop locations reduces dwell times and further increases the reliability and travel time benefits of bus lanes.

Curb Management

Curbside management can reduce the occurrence of parked or loading vehicles in bus lanes.

Movement Restrictions

Turn restrictions can reduce the conflicts with bus lanes at intersections.

Bus Stop Infrastructure

In-lane bus stops prevent buses in peak-hour lanes from having to merge to re-enter traffic.

Turn Pockets

Allow vehicles to make turns at an intersections while minimizing interruption to bus-only travel lanes.

Passive Signal Priority & Transit-Signal Priority

Signal priority for transit allows buses to travel through intersections in the bus lane, eliminating delays from traffic at intersections.

All-Door Boarding

Stop locations that facilitate all-door boarding can reduce dwell time and variability, providing further travel time benefits.

ALTERNATIVE TREATMENTS

Queue Jumps

Allowing transit to bypass traffic at an intersection is unnecessary with a bus-only travel lane.

Transit Approach Lane

An exclusive transit lane just before an intersection is unnecessary with a bus-only travel lane.

Dedicated Bus Lane

Providing a full-time travel lane for transit negates the need for peak-hour lanes.

PEAK-HOUR BUS LANE EXAMPLES

Multiple transit agencies have implemented peak-hour bus lanes.

- Starting in 1990, Montreal's STM has been operating reserved bus lanes as part of their Bus Preferential Measures (BPM). STM now has 221.7 km of reserved bus lanes with 19 peak-hour bus lanes and 17 24-hour bus lanes.[1] On an individual corridor, a reserved bus lane can yield 15-20% shorter travel times, with an increase of 65%in overall on-time performance.[2]
- In 2006, TransLink and the City of Vancouver implemented peak-hour bus lanes along the Broadway corridor on the 99B-Line. However, due to the high number of right turn traffic along the corridor, the bus only lanes provided little to no travel time savings.[3]
- In 2011, Calgary Transit and the City of Calgary announced the implementation of a peak-hour bus lane on 9th Ave in the Inglewood neighborhood. At time of implementation, the peak direction, peak-hour bus lanes carried 25 buses per hour through the corridor.[4]
- In 2016, the City of Everett, Massachusetts deployed a pop-up bus lane in the morning peak. The lane is used by buses from 4 am to 9 am and then reverts to on-street parking and a bicycle lane during all other hours. After a successful pilot for a week, the bus lane was extended permanently, and in 2017 was officially painted. Along the 1.5 km stretch, bus travel times decreased by 20-30%.[5]

1 Société de transport de Montréal, "Bus Preferential Measures," 2018. http://www.stm.info/en/about/major_projects/bus-preferential-measures-bpm

2 Surprenant-Legault, "Introduction of a reserved bus lane: Impact on bus running time and on-time performance," 2010. https://journals.sagepub.com/doi/10.3141/2218-02

3 City of Vancouver, "Bus Lanes on Broadway – Progress Report," 2007. http://council.vancouver.ca/20070612/documents/tt4_broadwayBusLanes.pdf

4 City of Calgary, "9 Avenue SE Bus-only lanes coming soon," 2011. http://www.calgarycitynews.com/2011/11/inglewood-9-avenue-se-bus-only-lanes.html

5 Transit Center, "Everett Bus Lane: The Little Pop-Up That Could," 2018. http://transitcenter.org/2018/01/02/everett-bus-lane-the-little-pop-up-that-could/

Figure C6.3: Peak-Hour Bus Lane Signs in Calgary[4]

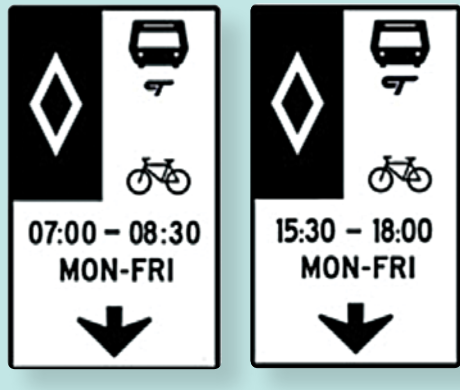


Figure C6.4: Peak-Hour Sign on Traffic Light in Calgary[4]

Figure C6.5: Peak-Hour Bus Lane in Everett, MA[5]

C7. Dedicated Bus Lane

Dedicated bus lanes are lanes reserved for the exclusive use of buses, except as specified. These lanes are typically found on corridors with heavy congestion and frequent bus service.

Strategy Overview

Dedicated bus lanes are often implemented by repurposing an existing travel lane or on-street parking lane. Legibility and compliance can be enhanced by designating bus lanes with red paint, "bus only" decals, signage above or adjacent to the lane, and separation from general travel lanes with a solid white line.

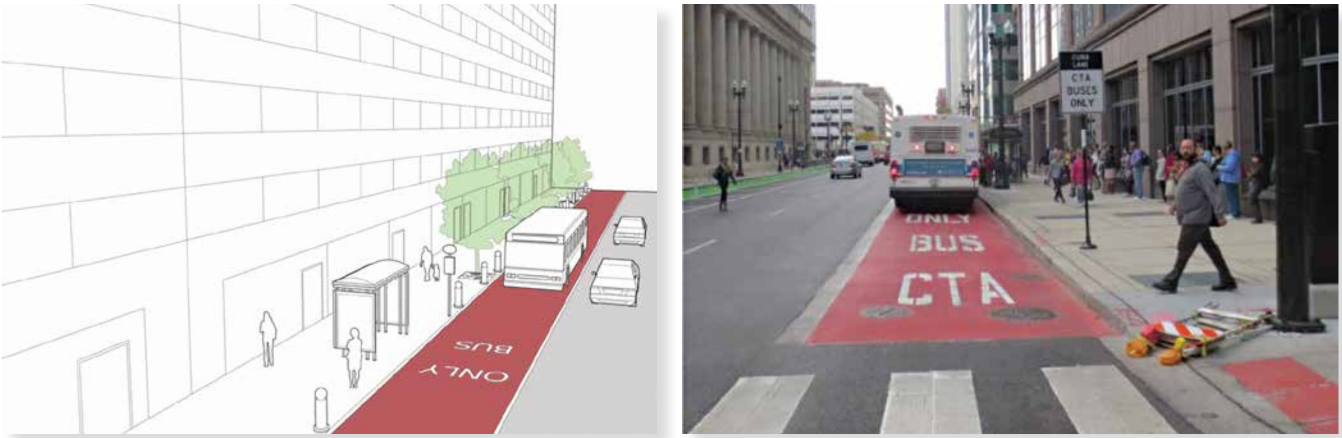
There are many variations of dedicated bus lanes. Dedicated bus lanes can be located curbside, offset from the curb by parking lanes or cycle tracks, or located in the median of a roadway. Bypass lanes allow buses to use existing right-turn lanes or shoulders to pass traffic at an intersection. Contraflow bus lanes allow buses to travel in the opposite direction of traffic on what would otherwise be a one-way street. Reversible bus lanes permit travel only in a single direction, often the peak commute direction.

Dedicated bus lanes can dramatically improve bus travel speeds and reliability by reducing delays caused by motor vehicle traffic. These improvements reduce the cost of providing service. Dedicated bus lanes also reduce conflict between buses and other vehicles, improving safety and comfort for roadway users.

COORDINATION

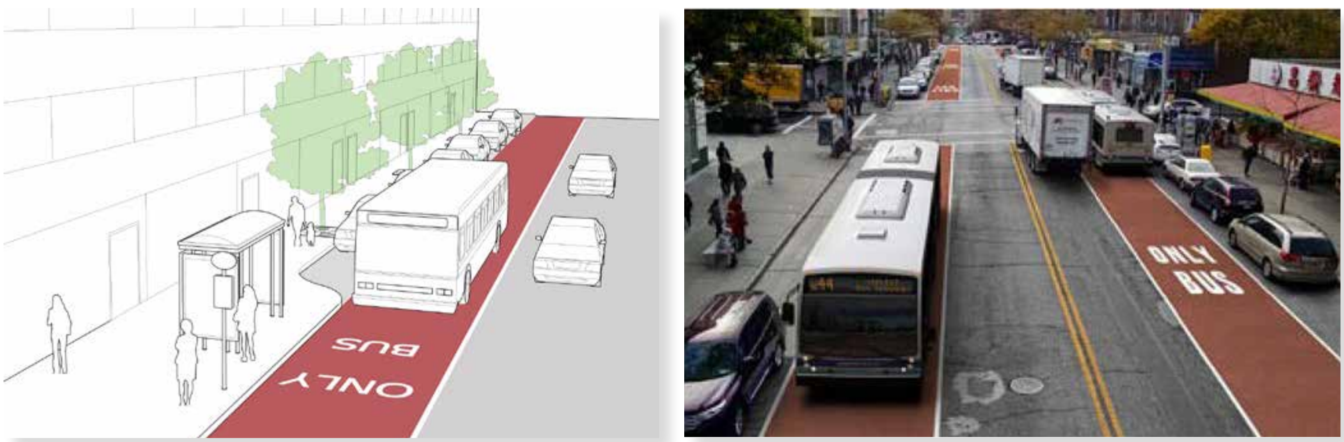
STAKEHOLDER	INVOLVEMENT
TransLink	• Identification of locations for effective implementation of peak-hour bus lanes and locating stops in optimum locations (far-side) to maximize potential benefits.
Municipality	• Impact on city street right-of-way from the addition of lane striping and signage placement. • Assistance relocating bus stops to maximize benefit, as needed • Traffic enforcement requirement to ensure use only by authorized transit vehicles. • Additional stop amenities or full separation from other travel lanes may require additional right-of-way space.

Figure C7.1: Diagram (Left) and Example of Curbside Bus Lane, Chicago CTA (Right)



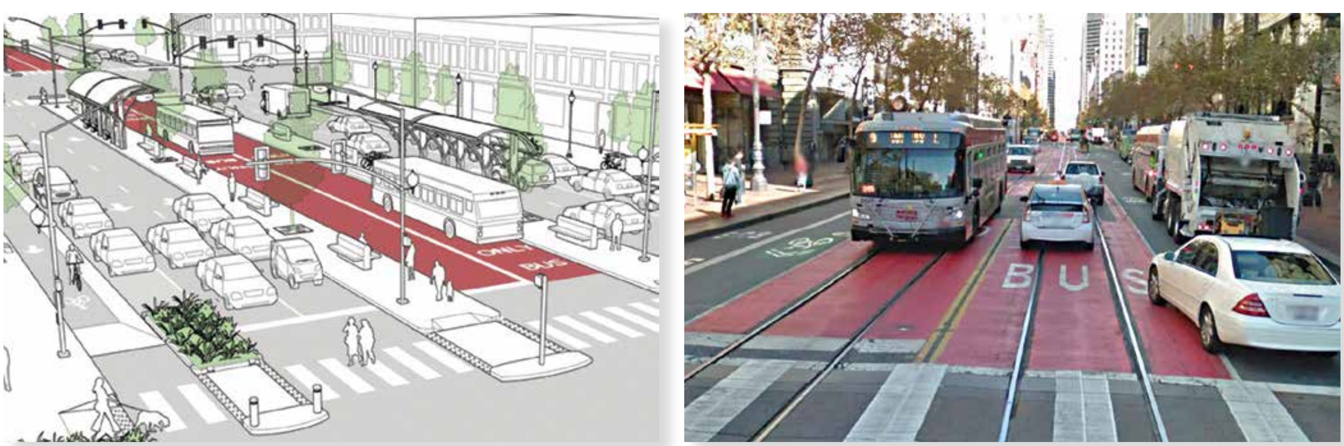
Source: MTA & NACTO

Figure C7.2: Diagram (Left) and Example of Offset Bus Lane, New York MTA Select Bus Service (Right)



Source: NACTO

Figure C7.3: Dedicated Median Bus Lane – Diagram (Left) & San Francisco Market St (Right)



Source: NACTO & Google Maps

BENEFITS AND COSTS

STOP CONSOLIDATION

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Increases travel speeds + Improves average travel times by up to 8 minutes per km	+ Separates transit from general traffic and congestion + Reduces traffic conflicts, delays – Vulnerable to double-parked vehicles	+ Reduces travel times by up to 23% + Improves schedule adherence by up to 27%	+ Fewer conflicts with other vehicles – Drivers may ignore restrictions without proper enforcement

ESTIMATED COSTS	COST
Separated Lanes in Existing Right-of-Way	$4,000,000-$6,500,000 per lane km[1]
Converting Existing Lanes	$200,000-$450,000 per lane-km[1]
Maintenance Costs	$20,000 per lane-km per year[1]

1 TRB, "TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic", 2010. https://nacto.org/docs/usdg/tcrp_synthesis_83_danaher.pdf

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
★★★	★★★		★★★	★★★	★★★	★★★	★★★	★★★		★	★★	$$–$$$$	High

CHALLENGES

- Requires either the construction of additional lanes or the conversion of existing lanes, which may reduce the space available for other traffic.
- Requires enforcement and signage to prevent the encroachment of double-parking, deliveries, taxis, or loading vehicles.
- Turning movements must be carefully managed to minimize conflicts with pedestrians, bicyclists, and other vehicle traffic.
- The conversion of travel lanes to bus lanes may face public opposition.

COMPLEMENTARY TREATMENTS

Dedicated bus lanes provide significant benefits to travel times and reliability, but are most effective when paired with the following complementary treatments:

Bus Stop Infrastructure

In-lane bus stops reduce lateral weaving of buses pulling into and out of bus stops, reducing acceleration and deceleration time and providing a more comfortable ride for customers.

Curb Management

Curbside management can reduce the occurrence of parking or loading activity taking place in the bus lane.

Movement Restrictions

Movement and turn restrictions can reduce the conflicts with bus lanes at intersections.

Turn Pockets

Turn pockets separate turning movements from transit lanes, reducing the potential for conflicts with turning vehicles queuing in dedicated bus lanes at intersections with a high volume of turns.

Passive Signal Priority & Transit-Signal Priority

Signal priority reduces delay caused by signals (red lights) and traffic (queues of cars).

All-Door Boarding

Curbside dedicated lanes or offset lanes with bus bulbs can reduce dwell times and variability by using all-door boarding.

ALTERNATIVE TREATMENTS

Dedicated bus lanes include a transit-only lane leading up to an intersection, which negates the need for any other treatments that allow buses to bypass vehicles to travel through intersections.

Queue Jumps

Allowing transit to bypass traffic at an intersection is unnecessary with a bus-only travel lane.

Transit Approach Lane

An exclusive transit lane just before an intersection is unnecessary with a bus-only travel lane.

Peak-Hour Bus Lane

Providing a peak-hour travel lane for transit negates the need for dedicated lanes.

DEDICATED BUS LANE EXAMPLES

Multiple transit agencies have implemented dedicated bus lanes. Dedicated lanes are often accompanied by a number of other bus prioritization treatments, such as transit-signal priority, turn-movement restrictions, and bus bulbs.

- In 2013, SFMTA implemented the Church Street Transit Lanes Pilot, which provided red-painted median bus lanes along three blocks on Church Street that were exclusive to transit and taxis. The dedicated lanes reduced travel time by 12-13% and travel time variability by 27%, providing faster and more reliable service along the corridor. Though left-turn restrictions and parking changes were also included, SFMTA found that delays for other vehicle traffic did not significantly increase and parking supply was not impacted, and the changes were made permanent.[1]
- Beginning in 2008, NYC DOT has implemented a number of Select Bus Service (SBS) routes, which benefit from several different prioritization treatments. In conjunction with off-board payments and the provision of real-time information, SBS routes included 61 km of dedicated bus lanes in the first five years. Bus lanes along the first six SBS routes have contributed to improved transit reliability and travel time savings of 13-23%, and helped increase ridership by 5-10%.[2]
- Many other cities have benefited from bus lanes, including:[3]
    - Los Angeles, CA – reduced travel times by 50-75 seconds per km for PM peak buses, improved reliability by 12-27%.
    - Dallas, TX – reduced travel times by 1.5-2.5 minutes per km.

1 SFMTA, "Church Street Transit Lanes", 2015. https://www.sfmta.com/sites/default/files/agendaitems/2015/6-2-15%20Item%2012%20%20Church%20St.%20Rapid%20Pilot%20-%20Final%20Report_1.pdf

2 NYC DOT, "Select Bus Service", 2013. http://www.nyc.gov/html/brt/downloads/pdf/brt-routes-fullreport.pdf

3 Transportation Research Board, "TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic", 2010. https://nacto.org/docs/usdg/tcrp_synthesis_83_danaher.pdf

Figure C7.4: Church Street Transit Lanes in San Francisco [1]

Figure C7.5: SBS Projects Implemented June 2008-November 2013[2]

D. Signal Priority

D1. Passive Signal Priority

Passive signal priority refers to adjusting signal timing on a corridor to promote the uninterrupted flow of transit between bus stops.

Strategy Overview

Transit signal progressions are pre-timed to provide a series of green lights, or a "green wave," that matches historic or desired transit speeds. The timing of the signal cycles can differ depending on the time of day or day of the week. This is most effective on high-volume streets with closely-spaced signals and short signal cycles.

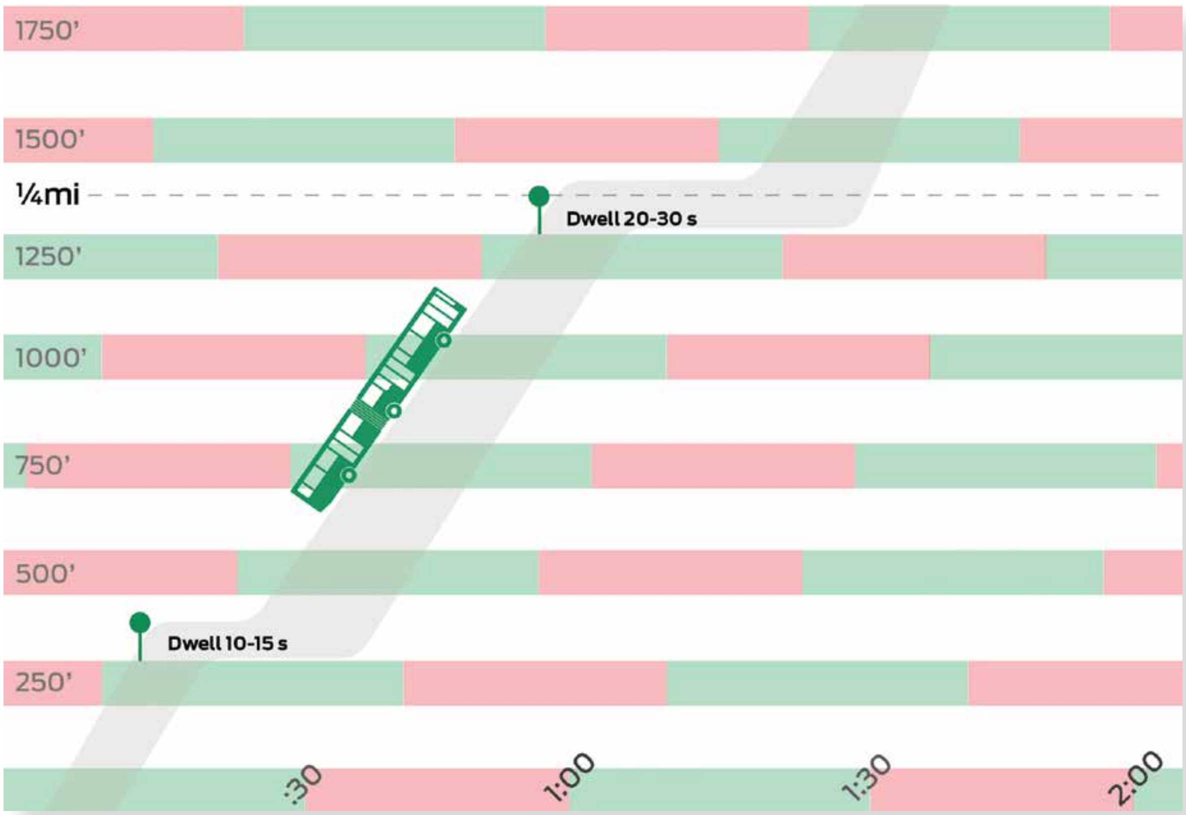
Passive signal priority can reduce travel times, minimize delays at signals, and increase travel time predictability, as transit can more reliably progress through intersections. Signal timing should account for dwell time at bus stops and traffic between signals. Passive signal priority strategies can be reinforced with complementary transit priority measures to reduce delay that might otherwise cause buses to fall behind the signal progression. Timing traffic signals for transit speeds also has safety benefits for bicyclists and pedestrians.

COORDINATION

Passive Signal Priority requires coordination with the local municipality that owns and operates the individual intersection signal. Corridors that cross highways or multi-jurisdictional streets may require the involvement of additional government agencies.

STAKEHOLDER	INVOLVEMENT
TransLink	• Determining preferred corridors to improve service and working with local transportation planners to determine corridors with high delay impacts due to signal timing.
Municipality	• Modeling of traffic impacts of corridor signal timing and the implementation of retiming at required signals.

Figure 1: Traffic Signal Progressions Provide Green Lights for Transit



Source: NACTO

BENEFITS AND COSTS

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Corridor travel time reduced by up to 12% – Signals cannot be timed to meet the needs of more the one service such as limited stop and local service	+ Provides standard travel times through corridors + Schedule variation reduced by up to 20% – Any change to scheduled running time eliminates all operating benefits – Signals should be retimed every 3-5 years	+ Reduces stopping + Reduces travel time through corridor	+ Lowers speeds of all vehicles

ESTIMATED COSTS	COST
Signal Retiming	$3,500 - $7,500 per intersection, including data collection and analysis

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
★★	★	★★						★★	★	★	★★	$–$$	Medium

CHALLENGES

- Targeted speeds must incorporate a variety of factors, including block length, traffic volume, and cross-street signals, to ensure that transit vehicles do not fall behind the signal progression.
- May require prioritizing some transit services over others (e.g. local service vs. limited-stop service).
- Signal timing must account for stop-related delays, such as dwell times and acceleration at stops, and should not simply be set at or near speed limits.
- Pre-timed signals cannot properly account for fluctuations in traffic or for isolated intersections.

COMPLEMENTARY TREATMENTS

Passive signal timing can benefit travel times, but other treatment measures may be necessary to ensure that buses can keep up with the “green wave”, or make up time to catch it when running behind schedule. Complementary treatments reduce dwell times and variability so buses can more reliably reach and travel through intersections at a consistent speed.

Bus Stop Placement and Consolidation

Stop consolidation can reduce dwell time variability and far-side stops ensure buses do not waste green signals.

Bus Stop Infrastructure

Allows buses to remain in the through lane at stops, reducing dwell times and variability so buses can keep up with the signal progression.

Queue Jumps

Mitigate the impact of congestion at intersections, allowing transit to travel through intersections.

Transit Approach Lane

Allows buses to reach and clear an intersection more reliably to benefit from signal priority.

Peak-Hour & Dedicated Bus Lane

Reduces traffic delays and variability, allowing for signal timing to be more reliable.

All-Door Boarding

Reduces dwell times and variability so buses can keep up with the signal progression.

ALTERNATIVE TREATMENTS

Active Transit-Signal Priority

Active signal timing would negate the need for passive TSP.

PASSIVE SIGNAL PRIORITY EXAMPLES

Many transit agencies have implemented passive TSP as part of a greater set of improvements for transit service along a corridor.

- In 2013, LADOT finalized the connection of all signalized intersections into the signal synchronization system. The system started in 1984 and works to adjust traffic patterns either on a passive or active basis. As of 2016, LADOT prioritizes rapid transit when possible. For passive transit priority, LADOT traffic engineers use pre-timed signals on major corridors to allow transit to move at a consistent pace. Along major corridors, signal synchronization increased travel speeds by 16% and reduced travel time by 12%.[1]
- In 2014, SFMTA implemented a pilot project on a 1.5 km section of Geary Street to improve travel times and reliability on Route 38L Geary Limited. The pilot sought to define the average speed of bus service along the corridor, while taking in consideration the additional dwell time. The dedicated bus lane allowed for more predictable traffic patterns, but varying dwell times reduced overall effectiveness. Over the 1.5 km corridor, buses generally had a 4% travel time saving and a 6% reduction in schedule variance on the limited route and a 20% reduction on the local route.[2]
- In 2016, King County Metro and the Seattle DOT partnered to develop multiple strategies to improve reliability on bus Route 8. In addition to stop enhancements, on-street parking restrictions, turn restrictions, and queue jump lanes, the Seattle DOT will adjust multiple adjacent signals to add additional green light time to allow for faster bus travel. These improvements are currently being implemented in multiple phases.[3]

Figure 2: Coordinated Signal Timing, Longview, WA[4]

- Many other major transit agencies, such as New York MTA and TTC have implemented signal timing adjustments as part of a larger strategy of active transit signal priority. Therefore, it is difficult to determine what benefits were from passive or active transit signal priority.

1 LADOT, "Los Angeles Signal Synchronization," 2016. http://ladot.lacity.org/sites/g/files/wph266/f/LADOT%20ATSAC%20%26%20Signals%20_%20Fact%20Sheet%202-14-2016.pdf

2 Pangilinan and Carnarius, "Traffic Signal Timing for Optimal Transit Progression in Downtown San Francisco," 2011. https://nacto.org/wp-content/uploads/2016/04/1-2_Pangilinan-Carnarius_Traffic-Signal-Timing-for-Optimal-Transit-Progression-in-Downtown-San-Francisco_2011.pdf

3 King County Metro, "Metro and Seattle DOT team up to ease Route 8 traffic choke points," 2016. https://kingcountymetro.blog/2016/12/12/metro-and-seattle-dot-team-up-to-ease-route-8-traffic-choke-points/

4 Knopf, Alfred. "A Speed Nudge?" 2008. http://howwedrive.com/2009/06/22/a-speed-nudge/

D2. Transit-Signal Priority (Active)

Transit-Signal Priority (TSP) is a set of tools and traffic management systems that detect transit vehicles and modify traffic signals to prioritize transit movements.

Strategy Overview

Signal prioritization can be given to all buses or exclusively to buses that are running behind schedule. TSP can be implemented throughout an entire corridor or at specific intersections.

Different TSP treatments include phase reservicing, phase extension, phase truncation, and phase insertion.

- Phase reservicing enables the same phase – such as a left-turn signal – twice in the same cycle, providing an additional opportunity for transit to clear an intersection.
- Phase extension prolongs a green light to allow transit more time to clear an intersection.
- Phase truncation ends a red light for cross traffic and provides an earlier green signal.
- Phase insertion prioritizes buses by providing bus-only phases that may make use of queue jumps to allow buses to bypass traffic.

The proper treatment depends on the conditions at an intersection or corridor, such as traffic volume and direction, cycle length, and distance between signals. TSP is most effective at intersections or corridors where signal cycles are long, causing large delays and frequent, lengthy queues, because longer cycles allow for greater flexibility in prioritizing transit. TSP strategies can be reinforced with complementary transit priority measures like far-side stops and an appropriate degree of dedicated lanes.

Signal delays can be a significant impediment to transit reliability and service. By prioritizing transit at intersections, TSP can reduce signal delays, improving travel time and reliability.

COORDINATION

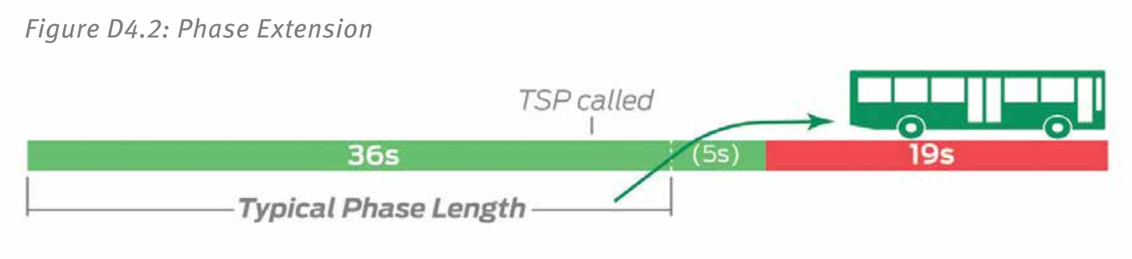
The development of TSP requires a high level of coordination between TransLink and the local or regional agency that owns the right-of-way and signal at each intersection. Coordination must be on-going to maintain hardware, manage systems, review performance, and implement changes, as needed.

STAKEHOLDER	INVOLVEMENT
TransLink	• Identification of routes and intersections that will most benefit from implementation of TSP. • Acquisition, installation, and maintenance of vehicle devices to ensure proper use of TSP on approved routes. • Adjustment of schedules accordingly to have highest probably use of TSP.
Municipality/Ministry of Transportation	• Acquisition, installation, and maintenance of TSP devices at intersections to ensure proper use of TSP on approved routes. • Hardware maintenance, systems management, performance review, and implementation of changes, as needed.

Figure D4.1: Phase Reservicing

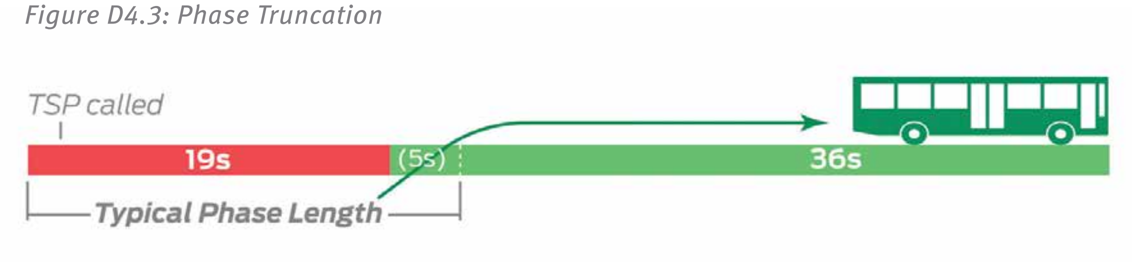
Source: NACTO

Figure D4.2: Phase Extension



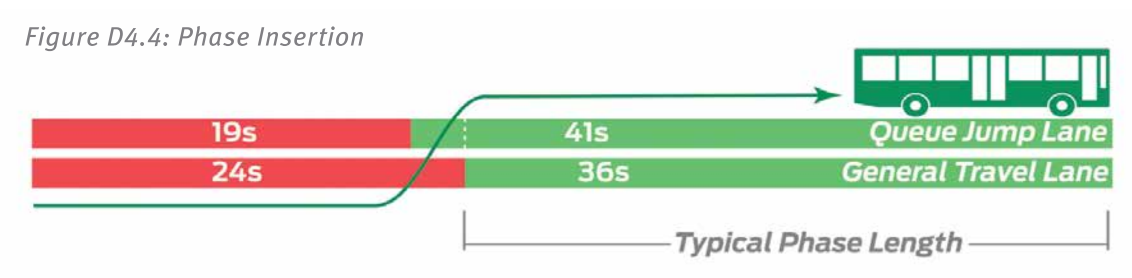
Source: NACTO

Figure D4.3: Phase Truncation



Source: NACTO

Figure D4.4: Phase Insertion



Source: NACTO

BENEFITS AND COSTS

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Travel time reduction of up to 18%	+ Decreases delay at single intersections by up to 80% + Travel time variability reduced by up to 40% – General traffic delay may increase slightly by up to 2.5%	+ Increases travel speeds of up to 40% + Fewer delays at intersections	+ Fewer conflicts at intersections – New signals may be confusing to drivers or pedestrians

ESTIMATED COSTS	COST
Existing equipment can be used	$4,000-$7,000 per intersection
Existing equipment must be replaced	$25,000-$40,000 per intersection

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
★★★		★★★	★★★	★★★				★★★				$$–$$$$	High

CHALLENGES

- Can increase delays on cross streets.
- Passive signal timing may be better for high-volume intersections or corridors with short distances between signals.
- Requires a high level of coordination between traffic and transit agencies.
- Heavy traffic congestion can impede the efficiency of TSP by preventing transit from reaching and activating the signal.
- Disaggregating the effects of TSP from other transit priority measures installed at the same time can be difficult.

COMPLEMENTARY TREATMENTS

Some aspects of TSP, such as phase insertion, are only useful with other treatments like queue jump lanes or transit approach lanes. The following are some complimentary treatments:

Bus Stop Placement

Bus stop location should be optimized to reduce delays caused by unnecessary or excessive stopping.

Movement Restrictions

Restricting vehicle movements, particularly unprotected turning movements, can minimize delay and ensure that transit vehicles are in ideal positions to utilize TSP, increasing travel speeds.

Bus Stop Infrastructure

Bus bulbs and islands can keep the bus in the traffic lane to reduce delay accessing, serving, and exiting a bus stop, ensuring that the bus benefits from modified signal timing.

Queue Jumps

Eliminating traffic delay at intersections ensures that the bus benefits from modified signal timing.

Transit Approach Lane

Eliminating traffic delay at intersections ensures that the bus benefits from modified signal timing.

ALTERNATIVE TREATMENTS

Passive Signal Priority

Where transit travel speeds are reliable, signal cycles are short, or service frequency is very high, signal timing on a corridor may be adjusted to match observed or desired transit travel speeds.

Dedicated & Peak-Hour Bus Lane

Eliminating traffic delay along corridors results in more reliable transit travel times, making it easier to program signal timing for transit speeds and ensuring that the bus benefits from modified signal timing.

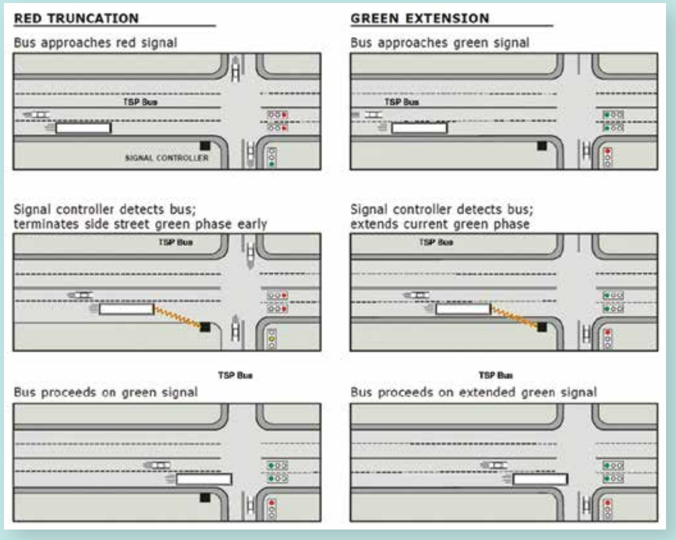
TRANSIT-SIGNAL PRIORITY EXAMPLES

Multiple transit agencies have implemented TSP on one or several corridors.

- Starting in 1998, the City of Ottawa implemented TSP at over 30 locations as part of their 2003 Transportation Master Plan. Ottawa TSP utilizes multiple TSP treatments including green phase extension, red truncation, and phase insertion for queue jump lanes. One corridor saw a 35-40% decrease in travel time due to TSP in conjunction with other transit priority treatments. Costs for TSP installation ranged from $3,000 to $35,000 per intersection.[1]
- In Portland, Oregon, TriMet has implemented TSP at over 250 intersections, with a 10% reduction in travel times and a 19% reduction in travel time variability. Travel time savings as a result of TSP enabled them to avoid having to add an additional bus.[2]
- Between 2012 and 2017, the MTA implemented TSP at 260 intersections on 5 corridors in New York City. MTA primarily used green extension and red truncation treatments. Routes that run along these corridors have travel times reduced by 18%. They plan to increase the number of intersections with TSP to nearly 1,000 by 2020.[3]
- Los Angeles County first implemented TSP in 1999, at 211 intersections with green extension and red truncation. Bus delays were reduced by 33-35% at intersections and the system realized an overall travel time savings of 8-10%. They have since expanded to provide TSO for multiple other routes.[4]
    - Many other cities have implemented TSP with positive results, including:[2]
    - Chicago, IL – Decreased travel times by 15-18%
    - Seattle, WA – Reduced travel times by 8%, with a 35% reduction in travel time variability
    - Vancouver, BC – Reduced travel time variability by 40%

Figure D4.5 : Current and Future TSP Locations in New York City[3]

Figure D4.6 : Red Truncation and Green Extension Diagrams[5]



1 Transport Canada, “Transit Priority Program: Putting Buses First”
http://publications.gc.ca/collections/collection_2012/tc/T41-1-01-eng.pdf

2 Transportation Research Board, “TCRP Report 118: Bus Rapid Transit Practitioner’s Guide”, 2007.
https://nacto.org/docs/usdg/tcrp118brt_practitioners_kittleson.pdf

3 New York City DOT, “Green Means Go: Transit Signal Priority in NYC”, 2017.
http://www.nyc.gov/html/brt/downloads/pdf/brt-transit-signal-priority-july2017.pdf

4 Transportation Research Board, “TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic”, 2010.
https://nacto.org/docs/usdg/tcrp_synthesis_83_danaher.pdf

5 Smith, et al. “Transit Signal Priority: A Planning and Implementation Handbook”, 2005.
https://nacto.org/docs/usdg/transit_signal_priority_handbook_smith.pdf

E. TransLink Practices and Policy

TRANS LINK

E1. All-Door Boarding

All-door boarding is an operational policy that allows customers to board a transit vehicle at any open door.

Strategy Overview

This practice is commonly used in transit systems with limited-access stations or designated fare-paid zones like rail and some bus rapid transit systems. Fares are enforced through validation at ticket vending machines (TVMs), on or off-board validators, fare gates, mobile ticketing applications, or by fare inspector personnel.

Buses spend up to one-third of operating hours at bus stops loading and unloading customers. This time, referred to as "dwell time," often increases with ridership. By reducing the length and variability of dwell time at each bus stop, all-door boarding improves total travel time and schedule reliability for customers and reduces operating costs for transit agencies.

COORDINATION

All-door boarding generally requires less coordination than other treatments. The level of coordination between stakeholders will vary depending on the fare validation method chosen.

STAKEHOLDER	INVOLVEMENT
TransLink	• Addition of fare validators and technology, hiring of fare inspection personnel, and requiring the necessary fare media to comply with the validation.
Municipality	• Impact on city street right-of-way from the installation and operation (powering) of off-board fare collection or validation. Could also include pavement or sidewalk markings to indicate boarding available at all doors.

Figure E1.1: New York MTA Select Bus Service with All-Door Boarding

Figure E1.2: LA Metro Platform Validation & SFMTA Fare Inspector

BENEFITS AND COSTS

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
+ Overall travel time reduced by 3%	+ Dwell times reduced up to 40% + Travel speed increased by 2% + 10% improvement in on-time performance – Additional maintenance cost for ticket validators	+ Reduces boarding time + Reduces time waiting at bus stop + Increases access to fare (new TVMs or mobile options)	+ Reduces door crowding – Rear door trip hazard

ESTIMATED COSTS
$3,000 per unit for mobile validators/ $80,000 per unit for TVMs

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
							★★★	★★	★				Low

CHALLENGES

- Requires the use of either off-board payment systems or all door proof-of-payment systems (such as cash & card front door payment and rear-door card readers). All TransLink buses are already equipped with all door proof of payment systems.
- Potentially requires implementation of fare inspections by dedicated staff, but reduces fare validation done by bus drivers.
- Timeline can be a few months, to use existing infrastructure and develop mobile app, or a few years, with new equipment and fare media.
- All-door boarding is most effective when implemented across an entire system, which requires greater upfront capital than a phased approach, and reduces confusion for transit customers about which routes in a system have all-door boarding and which do not.

COMPLEMENTARY TREATMENTS

Implementing all-door boarding alone will yield limited benefits in terms of speed and reliability. Combining all-door boarding with additional transit priority measures can enhance the benefits to transit operations.

Bus Stop Placement

Bus stops should be located at optimal locations to maximize the benefits of all-door boarding throughout a bus route.

Bus Stop Infrastructure

In-lane stops along with all-door boarding enable faster and more reliable boarding, further reducing dwell times.

Peak-Hour & Dedicated Bus Lane

Bus-only lanes facilitate faster and more reliable boarding, further reducing dwell times and variability.

ALTERNATIVE TREATMENTS

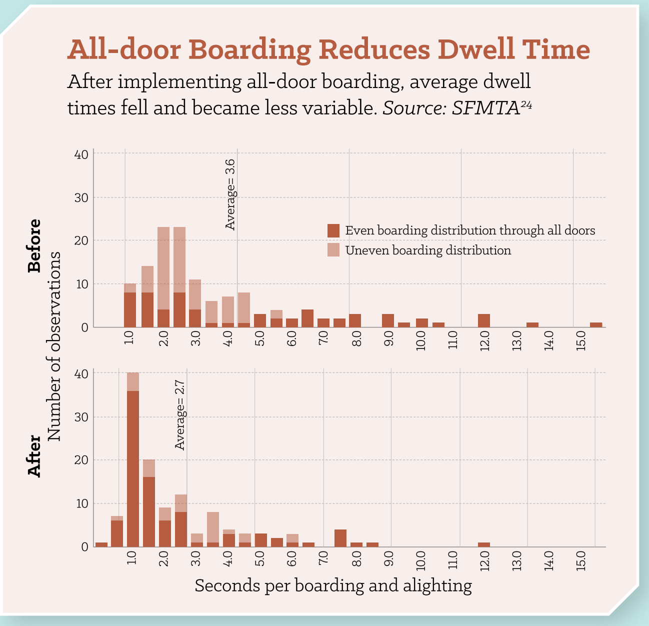
Not applicable

ALL-DOOR BOARDING EXAMPLES

Multiple transit agencies have done partial or full implementation of all-door boarding on buses.

- In 2012, SFMTA implemented full system all-door boarding. Dwell times decreased 38% per customer on average and bus speeds increased by 2% as ridership increased 2%.[1]

Figure E1.3: SFMTA All-Door Boarding Observations[3]



- In 2009, New York MTA implemented all-door boarding on their Select Bus Service using off-board fare collection and inspection based fare validation. Dwell times decreased by an average of 36% as ridership grew an average of 18%.[1]
- Austin Cap Metro implemented all-door boarding on their MetroRapid buses with on-board validation and implementation of a mobile payment system. 92% of customer used either a prepaid fare (80%) or the mobile app (12%) after implementation.[1]
- Since 2007, TransLink has used all-door boarding on Route 99 B-Line with card readers at all doors, while still allowing cash at the front door. Even though ridership increased, trip times fell by 3% and dwell times decreased by 17% per customer on average.[1]
- For two weeks in 2017, the MBTA Silver Line routes 4 and 5 operated with all-door boarding through a pilot funded by the Barr Foundation. During the pilot, dwell times decreased by 30% and fewer buses started trips late.[2]
- LA Metro implemented all-door boarding on the Metro Silver Line. The project increased on-time performance by 10%and lead to expanded trials on Wilshire Boulevard and Vermont Avenue.[3]

1 NACTO, “Better Boarding, Better Buses: Streamlining Boarding & Fares,” 2017. https://nacto.org/wp-content/uploads/2017/02/NACTO_Better-Buses_Boarding.pdf

2 Barr Foundation, “All-Door Boarding a Boost for the MBTA’s Silver Line Bus,” 2017. https://www.barrfoundation.org/blog/all-door-boarding-boosts-mbta-silver-line-bus

3 Metro, “L.A. Metro expands all-door boarding for key Metro Rapid Lines” http://www.metro-magazine.com/bus/news/726161/l-a-metro-expands-all-door-boarding-for-key-metro-rapid-lines

E2. Schedule-Operator Recovery

Requiring time in the schedule between the start and end of the trip (layover time), helps ensure operators are able to take a break and helps ensure the next trip starts on time.

Strategy Overview

If a route falls behind schedule during a trip, the recovery time provides an opportunity to get the route back on schedule, thereby improving the reliability of the route.

While a layover time of 10% of the running time is often used as an industry standard, enough layover time should be scheduled to ensure that 90-95% of trips start at their scheduled time.[1] Automatic Vehicle Location (AVL) devices can track the speed between stops for every trip. With this more precise data, individual trip layovers can maximize the cost effectiveness of a route, while maintaining high reliability.

COORDINATION

The location of layover locations may require some coordination with local municipalities.

STAKEHOLDER	INVOLVEMENT
TransLink	• Identifying locations at end of routes for vehicles to wait during layover time.
Municipality	• Providing sufficient curb space or right-of-way to allow laying over of transit vehicles.

1 Strathman et al., "Bus Transit Operations Control: Review and an Experiment Involving Tri-Met's Automated Bus Dispatching System," 2001. http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1742&context=jpt.

BENEFITS AND COSTS

TRAVEL TIME	RELIABILITY	CUSTOMER EXPERIENCE	SAFETY
NA	+ Clockface schedules for easier understanding of route schedule	+ Appropriate amount of recovery time can increase trip reliability	+ Layover allows for necessary breaks for transit operators for safer driving

RELATIVE BENEFITS AND COSTS

CONGESTION		DELAY			OPERATIONS				SAFETY			COST	COORDINATION
INTERSECTION	ROADWAY	SIGNAL	RIGHT TURN	LEFT TURN	ACCESS TO BUS STOP	LEAVING BUS STOP	DWELL TIME	INSUFFICIENT RUNNING TIME	PEDESTRIANS	CYCLISTS	MOTORISTS		
								★★★					Low

CHALLENGES

- Layovers require space for the bus to wait, which can be difficult to find in dense urban areas. Multiple buses requires more space that may take curb space from on street parking.
- In addition to recovery time, layover may need to be longer due to agency or union contracts.
- Layover time may result in inefficient cycle times, reducing productivity of routes.

COMPLEMENTARY TREATMENTS

Implementing appropriate layover times can improve reliability, but other treatments can enhance these benefits.

Bus Stop Placement

Locating terminal bus stops where buses layover reduces additional time moving the bus to and from the start/end of the route.

Curb Management

Curb management ensures that curbside uses do not interfere with layover space.

Passive Signal Priority & Transit-Signal Priority

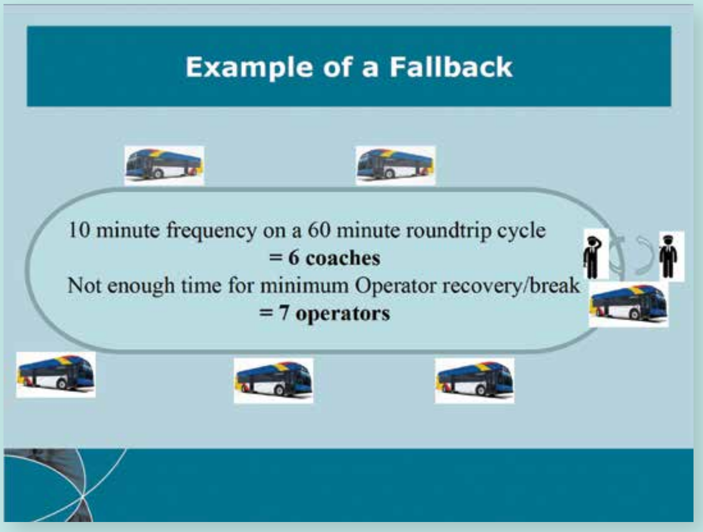
Signal priority for buses can allow transit to consistently move through a corridor, reducing variability in layover, and therefore cycle times, between trips.

SCHEDULE-OPERATOR RECOVERY EXAMPLES

Most agencies have minimum layover standards. However, in order to be more efficient with vehicles or operators, some transit agencies have adopted less common strategies.

- In King County METRO, layover space can be difficult to find, especially in more dense areas like downtown. In order to accommodate breaks for operators and maintain a higher frequency of service, King County has used fallback operators on some of their routes. A fallback operator is when there is an additional operator than vehicles on a route. At the end of a trip, the operator is switched with the one at the terminal, and continues with the next trip. The operator who just completed a trip takes a break and then waits for the following bus to arrive. While this allows for operators breaks, there is less time for recovery, so this type of operating scheme is only effective when there is little variability to trip times.[2]

Figure E2.1: King County METRO Actively Managed Fallbacks[2]



2 Bez, Jon. "King County Metro Transit: Actively Managed Fallbacks," 2017. https://www.apta.com/wp-content/uploads/Resources/mc/sustainability/previous/2017sustainability/presentations/Presentations/Actively%20Managed%20Fallbacks%20-%20Jon%20Bez.pdf