FEBRUARY 2024

On-Street Infrastructure Design Guide

BCTransit

7983

Territorial Acknowledgement:

We acknowledge with respect that BC Transit delivers our mission on the ancestral territories of Indigenous Peoples across British Columbia, and their historical relationships with the land continue to this day.

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CHAPTER 1 Introduction

1.1 PURPOSE

The *BC Transit Infrastructure Design Guide* (Guide) was created to promote best practice in transit infrastructure design.

The Guide identifies the design and operational requirements for the existing BC Transit bus fleet, while taking into consideration the interaction and needs of transit patrons and other road users.

They incorporate current BC Transit practices and best practices from: TransLink, the BC Ministry of Transportation and Infrastructure (MoTI), the Transportation Association of Canada (TAC) and other North American transit service providers.

BC Transit is proactively developing and sharing this Guide to promote uniform practices across local governments within its jurisdiction, resulting in enhanced efficiency, safety and accessibility of transit services provided in BC outside of Greater Vancouver.

Local governments are encouraged to adopt this Guide to achieve consistency in transit infrastructure. They are located on BC Transit's website, where feedback is welcome as this is an iterative document to be revised as needed in the future.

The following subjects of interest, while relevant, are excluded from this document:

- Operational measures (bus routing, schedules, fares, bus fleet operation and maintenance)
- Community planning strategies
- Education and marketing strategies
- Project funding and investment

1.2 STRATEGIC ALIGNMENT

The mandate of BC Transit, as set out in the British Columbia Transit Act, is:

> *"to plan, acquire, construct or cause to be constructed public passenger transportation systems and rail systems that support regional growth strategies, official community plans, and the economic development of transit service areas," [and] "to provide for the maintenance and operation of those systems."*

BC Transit's Strategic Plan focuses on being part of the solution for the challenges impacting communities across the province. The plan has five objectives to guide our organization:

- **Always safe:** We will put safety first in everything that we do
- **Engaged people:** We will support our people to achieve success
- **Satisfied Customers:** We will grow ridership by making mobility accessible and enjoyable
- **Thriving Communities:** We will work with Local Government and First Nations partners to improve livability
- **Responsible stewardship:** We will use our resources wisely and develop the most sustainable solutions

One of the Action Areas in the strategic plan is Supportive Infrastructure. Two areas of infrastructure investment are required in order to support transit being your best transportation solution in communities across the province.

The first is the introduction of new or expanded transit priority infrastructure. Investing in transit priority measures improves speed, reliability, comfort and convenience for public transit customers.

The second area for infrastructure investment is to continue to invest in adequate transit operations and maintenance (O&M) facilities. O&M facilities are an integral part of transit systems as they are where the buses are stored, maintained and dispatched to their assigned service.

1.3 INFRASTRUCTURE PRINCIPLES

There are four underlying principles of safe and efficient transit infrastructure:

Who

- People of all ages and abilities.

Why

- Transit infrastructure supports accessibility to all travelers. Transit, along with active transportation, is available as a sustainable travel option.

Where

- The location of transit infrastructure is safe, convenient and accessible.
- Best results are achieved when transit plays a key role in overall community planning and land use decisions.

How

- Transit infrastructure design is consistent with best practices and available guidelines.
- Safety and accessibility are prime considerations.

CHAPTER 2 Bus Operation Specifications

2.1 INTRODUCTION

This chapter provides an overview of the current BC Transit bus fleet, including the types of operating buses, their physical characteristics and specific geometric requirements.

Transit infrastructure designers should always consult with BC Transit regarding bus design requirements and provide BC Transit with opportunities to review the design of all infrastructure that is used by transit vehicles.

2.2 BC TRANSIT VEHICLE FLEET

BC Transit operates buses that vary in dimension and performance. To allow for interoperability between different buses on any given route, infrastructure must accommodate various bus models. Table 2.1 summarizes the dimensions of all vehicle types as of August 2023. Designers can contact BC Transit for the most up-to-date vehicle specifications.

BC Transit does not currently operate articulated buses but may in the future. Though longer than the New Flyer Hybrid bus, it is in fact more manoeuvrable due to the accordion in the middle. For design dimensions of articulated buses, refer to the TransLink Bus Infrastructure Design Guidelines (TransLink Guidelines).

This Guide does not include specific design requirements for handyDART/light duty vehicles because they can access most facilities built to accommodate single-unit trucks.

Table 2.1 Dimensions of Transit Vehicles Operated by BC Transit

Bus Type	Length	Height	Wheelbase		Overhang		Width	Left Mirror Projection	Mirror Projection		Track		
	Overall	Overall (rounded values)	(front axle to drive axle)	(front axle to tag axle)	Front	Rear	Bus Body (excl. mirrors)	Left-Sideways	Right-Sideways	Right-Forward	Front	Rear-Drive Axle	Rear - Tag Axle
New Flyer Diesel	12,600	3,100	7,550	-	2,100	2,920	2,570	270	210	110	1910	1250	-
New Flyer Hybrid	12,600	3,300	7,550	-	2,180	2,970	2,600	210	210	330	1960	1400	-
New Flyer CNG	12,500	3,400	7,220	-	2,210	3,060	2,600	210	210	330	1970	1370	-
Double-Decker (E-500 Diesel and Hybrid)	13,250	4,300	6,500	8,000	2,410	2,420	2,600	260	280	330	1910	1600	1780
Nova Bus	12,440	3,070	6,200	-	3,010	3,230	2,668	300	260	230	1940	1370	-
Vicinity 27.5'	8,380	3,000	4,110	-	2,140	2,130	2,500	230	230	310	1890	1850	-
Vicinity 30' Diesel	9,140	3,000	4,870	-	2,140	2,130	2,500	230	230	310	1890	1520	-
Vicinity 30' CNG	9,140	3,300	4,870	-	2,140	2,130	2,500	230	230	310	1890	1520	-
Vicinity 35'	10,670	3,000	5,760	-	2,170	2,740	2,500	230	230	310	1890	1520	-
International	9,830	3,120	5,520	-	1,010	3,300	2,410				1800	1290	-
ARBOC	8,080	3,020	4,850	-	1,010	2,180	2,420	210	210	-	1450	1430	-
Micro Bird G5	7,870	2,920	4,450	-			2,440						-
Micro Bird MBII	7,000	2,640	3,510	-			2,440						-

All dimensions in millimeters and rounded to the nearest 10 millimeters.

2.3 BC TRANSIT DESIGN VEHICLES

Table 2.2 outlines the Standard Bus dimensions which should be used for designing all streets with current or future conventional transit service. The dimensions are based on the New Flyer CNG and are also representative of future Battery Electric Buses. To account for the impacts the on-bus bike rack has on maneuverability, 20 cm has been added to the front overhang dimension in Table 2.2.

Table 2.2 Design Vehicles

Parameter	Standard Bus
Width	2.6 m
Track	2.6 m
Front Overhang	3.1 m
Wheelbase	7.2 m
Rear Overhang	2.4 m
Lock to Lock Time	6.0 sec
Minimum Turning Radius (Wall to Wall)	13.4 m

A vehicle turning speed of 15 km/h should be used when conducting vehicle swept path analysis. 10 km/h can be used in constrained locations with infrequent transit service.

A 45 cm lateral clearance is desired (30 cm minimum) between the vehicle body and adjacent obstructions (e.g. curbs, opposing travel lanes). This clearance is to account for variability in actual travel paths as well as bus mirrors which extend 20-30 cm beyond the vehicle body.

2.4 VEHICLE CLEARANCES

Vertical Clearance: The tallest bus in the BC Transit fleet is the Alexander Dennis E-500 double decker (both the hybrid and conventional models). These buses require a vertical clearance of at least 4.4 m. This design requirement applies to areas where double-decker buses operate either now or in the future. In all other cases, the clearance requirement should be least 3.4 m, based on the New Flyer CNG bus.

Horizontal Clearance: At 2.67 m excluding mirrors, and 3.2 m including mirrors, the Nova Bus is the widest in the fleet and defines the minimum horizontal clearance.

2.5 VEHICLE PERFORMANCE

Buses generally have lower acceleration and deceleration rates compared to passenger vehicles. For passenger comfort and safety, transit vehicle acceleration and deceleration rates should be considered in public road and transit facility design. The maximum deceleration rate for emergency situations should only be used in extreme conditions, e.g. to avoid a collision.

Table 2.3 Desirable Acceleration and Deceleration Rates for Buses

Item	Maximum Rate (m/s^2)	
	Standard Bus	Articulated Bus
Acceleration	0.9	0.7-0.9
Deceleration (normal service)	1.1	1.1
Deceleration (emergency condition)	2.7	2.7

Source: Canadian Transit Handbook (Canadian Urban Transit Association and Transportation Association of Canada)

2.6 BICYCLE RACKS

Although the width of a typical bicycle rack is less than the full width of the bus, the front corners of the bike rack may, in a sharp turn, encroach beyond the turning path of the front corners of the body of the bus. The road designer should ensure there is adequate clearance as well as access to the on-bus bicycle rack at bus stops.

2.7 VISIBILITY IMPAIRMENT ZONES

Visibility impairment zones must be considered when designing transit infrastructure because operators have limited visibility to the side and rear of the vehicle.

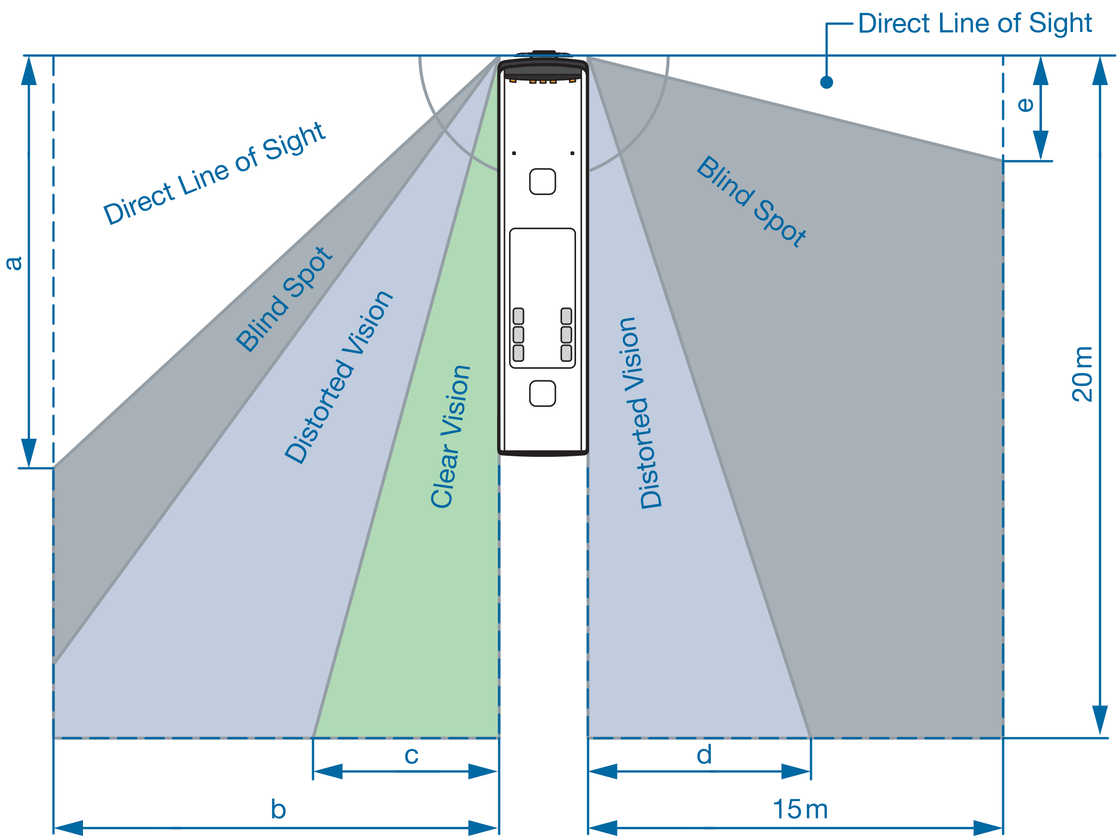


Figure 2.1 Visibility Impairment Zones

Source: TransLink Guidelines

Table 2.4 Visibility impairment zones

Vision	Means	Purpose	Var.	Bus Type	Angle (deg.)		Notes
					1	2	
Direct Line of Sight (Right Side)	Windows of the front door	Direct line of sight	e	Std NF	46	-	Door + first window (assumes no customers in front of red line in bus)
				STD Nv	49	-	Door + first window
				LD	38	-	Door + first window
				HD	52	2.7	(Angle 1) Door to red line on window (Angle 2) Door only
Distorted Vision (Right Side)	Single, slightly convex mirror on right	To check if customers have cleared door	d	Std NF	21	-	-
				Std Nv	26	-	-
				LD	64	-	-
				HD	22	-	-
Clear Vision (Right Side)	Flat mirror on right	To check real distance between approaching vehicles	d	LD	7	-	-
				HD	11	-	-
Direct Line of Sight (Left Side)	Shoulder checking left window of operator seat	Direct line of sight	a	Std NF	Full	-	Full sight of surrounding with mirrors
				Std Nv	Full	-	Full sight of surrounding with mirrors
				LD	64	-	-
				HD	55	-	-
Clear Vision (Left Side)	Flat mirror on left	To check real distance between approaching vehicles	c	Std NF	15	-	-
				Std Nv	9	-	-
				LD	13	-	-
				HD	13	-	-
Distorted Vision (Left Side)	Small convex mirror on the left	Check if there is a vehicle travelling next to a bus prior to a lane change	b	Std NF	34	-	-
				Std Nv	34	-	-
				LD	41	-	-
				HD	21	-	-

Source: TransLink Guidelines
Abbreviations: Standard Bus New Flyer (Std NF), Standard Bus Nova (Std Nv), Light Duty (LD), handyDART (HD).

- Due to the distortion in the convex mirror on the right side of the bus, the operator is unable to clearly judge the real distance between the bus and a vehicle approaching from behind;
- The blind area on the right side of the bus (see Figure 2.1) cannot be viewed either through the right-side mirror or by direct line of sight through the windows of the front door. Hence, bus movements that require merging to the right within a short distance, or making a left turn from the inside lane of the double left-turn lanes, may be hazardous; and
- The convex mirror on the left side of the bus creates a distorted image of the area that cannot be viewed either through the flat mirror or by direct line of sight through the windows in the bus operator's seat area. While this image has some use, it cannot be relied on to estimate either distance or speed of a vehicle approaching from behind.

CHAPTER 3 Bus Stop Planning Principles

3.1 INTRODUCTION

This chapter provides a high-level overview of bus stop planning principles. Further details regarding locating and designing bus stops is provided in Section 4.3. A qualified transit planner or engineer should review the appropriateness of a proposed bus stop location. Planning bus stops is an iterative process considering:

- Safety and accessibility;
- Stop intervals;
- Placement;
- Configurations; and
- Amenities.

3.2 SAFETY AND ACCESSIBILITY

The ability for transit users and operators to safely access stops in addition to the safety of all other road users is a primary objective. Patrons of all ages and abilities should be able to access bus stops.

The general provisions of an accessible bus stop are as follows:

- Non-slip finishes;
- Street furniture and signage are kept out of the way of pedestrian circulation by providing 0.6 m of clear space between elements and providing a clear width of 1.5 m at the point of embarkation.
  - Ensure that each designated area for mobility device users has a minimum length of 2.4 m, measured perpendicular to the edge of the curb or vehicular route, and a minimum width of 1.5 m, measured parallel to the vehicular route.
- Obstructions within or adjacent to the walkway are removed, or clearly marked if removal is not feasible;
  - Obstructions more than 0.1 m from walls, columns or free-stranding supports should be at or below 685 mm from the floor, making them white cane detectable or have the underside at a height of at least 2.05 m from the floor.
- Visual and tactile cues are made through colour and texture contrast;
  - Contrasting colour should be at a minimum of 70% contrast;
- Signage should be free of glare, use a sans serif font and be of high contrast.

Nearby crosswalks with ramps are recommended for all stops to facilitate access by people with wheeled devices, including wheelchairs, strollers, etc.

3.3 STOP INTERVALS

Bus stop intervals depend on the type of transit service, land use and the availability of safe stopping locations. The following table summarizes typical bus stop intervals; however, they may vary depending between transit systems.

Table 3.1 Stop Spacing by Type of Service

Type of Service	Stop Interval
Rapid Transit Network (RTN)	800 m to 2,000 m
Frequent Transit Network (FTN)	300 m to 500 m
Local Transit Network (LTN)	250 to 300 m
Targeted Transit	Varies

3.4 PLACEMENT

Bus stops are commonly placed in a location which balances safe, accessible and convenient access by transit users as well as other road safety and operational constraints.

BC Transit prefers stops to be located after an intersection (far-side), however, before an intersection (near-side) and mid-block can also be appropriate depending on the circumstances.

3.5 CONFIGURATIONS

There are three general bus stop configurations:

- **In-lane stops** where buses stop in the curbside travel lane;
- **Bus bulges** where a sidewalk extension is constructed such that buses can remain in their travel lane to stop. This typically occurs where the curb lane is used for parking so buses would otherwise need to switch lanes before and after stopping; and,
- **Bus bays** where buses can stop outside of the typical road width either for an extended stop or to not interrupt high-speed vehicle flow.

While flag stops are allowed in some places, BC Transit does not generally support this practice due to potential safety risks. Flag stops are currently used in rural areas only, at the discretion of the road authority and the transit operator.

3.6 AMENITIES

Passenger amenities should include an adequate waiting and queuing area, as well as the potential amenities listed in Table 3.2. The size of a passenger zone depends largely on the expected maximum number of waiting passengers at the bus stop, estimated by the on- and off-loading, the volume of transfer passengers and the scheduled bus frequencies at the stop.

Table 3.2 Bus Stop Amenities

Amenities	Criteria for Provision			
	Local Transit Stop	Frequent Transit Stop	Rapid Transit Stop	Transit Exchange
Bus stop pole and strip sign	Mandatory	Mandatory	Mandatory	Mandatory
System Icon	Recommended	Recommended	Mandatory	Mandatory
Route/Schedule information holder	Recommended	Recommended	Mandatory	Mandatory
Lighting	Recommended	Recommended	Mandatory	Mandatory
Passenger landing pad	Recommended	Recommended	Mandatory	Mandatory
Wheelchair pad	Recommended	Recommended	Mandatory	Mandatory
Curb letdown	Recommended	Recommended	Mandatory	Mandatory
Garbage Receptacles	Recommended	Recommended	Mandatory	Mandatory
Seating	Recommended	Recommended	Mandatory	Mandatory
Shelter	Recommended	Recommended	Mandatory	Mandatory
Passenger Information Display System (warranted if service headway is long and on-time performance is poor)		If Warranted	If Warranted	If Warranted
Wayfinding Information and local map (warranted if there are high-density of local attractions nearby)		Recommended	Recommended	Recommended
Bicycle Parking		If Warranted	Recommended	Recommended

Park & Ride		If Warranted	If Warranted	If Warranted
Passenger Queue Management (warranted if boarding volumes are high and/or all-door boarding is permitted)			If Warranted	If Warranted

3.7 MAINTENANCE

Bus stop maintenance is typically conducted by the road authority. Table 3.3 summarizes the recommended bus stop elements to be regularly inspected. Snow clearing should be prioritized on streets that have transit service including the sidewalks at and near bus stops.

Table 3.3 Maintenance Checklist

Element	Preferred Condition	Frequency of on-site check required (Typical)
Access routes used by passengers	No physical obstacles, clear of materials that create slippery surfaces	Once a year, or as requested by passengers
Crosswalks	Conspicuous sign and pavement markings	Part of regular roadway maintenance
Lighting	In operation, adequate lighting level	Part of regular roadway maintenance
Landscaping	Low-level shrubbery or canopied trees	6 months
Bus stop sign	Good visibility, not obscured by streetlights and trees	6 months
Bus stop pavement marking (red)	Good visibility	Part of regular roadway maintenance
Bus shelter and bench	Free of vandalism and weathering effects	6 months
Garbage receptacles	Free of vandalism, free of pooling of liquids	Monthly, or as requested
Bus schedules and route maps	Free of vandalism	6 months
Curbside	Free of potholes, no drainage issue	6 months
Bus pad	Free of cracks in concrete or asphalt	6 months

CHAPTER 4 Roadway Geometric Design

4.1 INTRODUCTION

Roads are designed in accordance with relevant national, provincial and local standards identified by the road authority. When a road is used by transit vehicles, additional considerations must be considered and the recommendations from this Guide should be included.

This chapter provides the specific geometric requirements for transit operations, based on the current BC Transit bus fleet.

4.2 PUBLIC ROAD FACILITIES

4.2.1 Lane Widths

The Nova Bus, the widest in the BC Transit fleet, has a total width of 3.2 m, including mirror protrusions. Lane widths must be at least this wide without the bus encroaching into adjacent travel lanes.

Section 4 of the TAC 2017 Geometric Design Guide for Canadian Roads (TAC Guide) outlines lane widths for different land uses, road classifications, and speeds. For a typical lane in an urban environment (less than 60 km/h posted speed), BC Transit recommends the following for regular bus service:

- A minimum lane width of 3.3 m, adjacent to curb and gutter where the gutter width is at least 0.3 m as per the Master Municipal Construction Documents (MMCD), for an effective lane width of 3.6 m to curb face;
- A minimum lane width of 3.3 m adjacent to a curb where no gutter is present, and where a minimum 0.25 m offset is provided as per the TAC Guide, for an effective lane width of 3.55 m to curb face; and
- A minimum lane width of 3.3 m adjacent to a bike lane (unbuffered or buffered), a designated bus lane or general traffic lane (assuming adjacent lanes are wide enough to accommodate legal width vehicles including mirrors, with no encroachment beyond the lane lines).

TAC guidance regarding lane widening on horizontal curves should be followed.

Buses typically pull up to the curb in a slightly angled manner, with the front bumper 180 mm laterally from the curb, and the rear bumper 360 mm laterally from the curb. This demonstrates the need for some wiggle room within the lane and gutter widths to safely accommodate stopped buses.

BC Transit recommends a minimum of 4.5 m for shared bicycle/bus lanes width as per the TAC Guide.

Figure 4.1 illustrates the lane width recommendations for multiple scenarios.

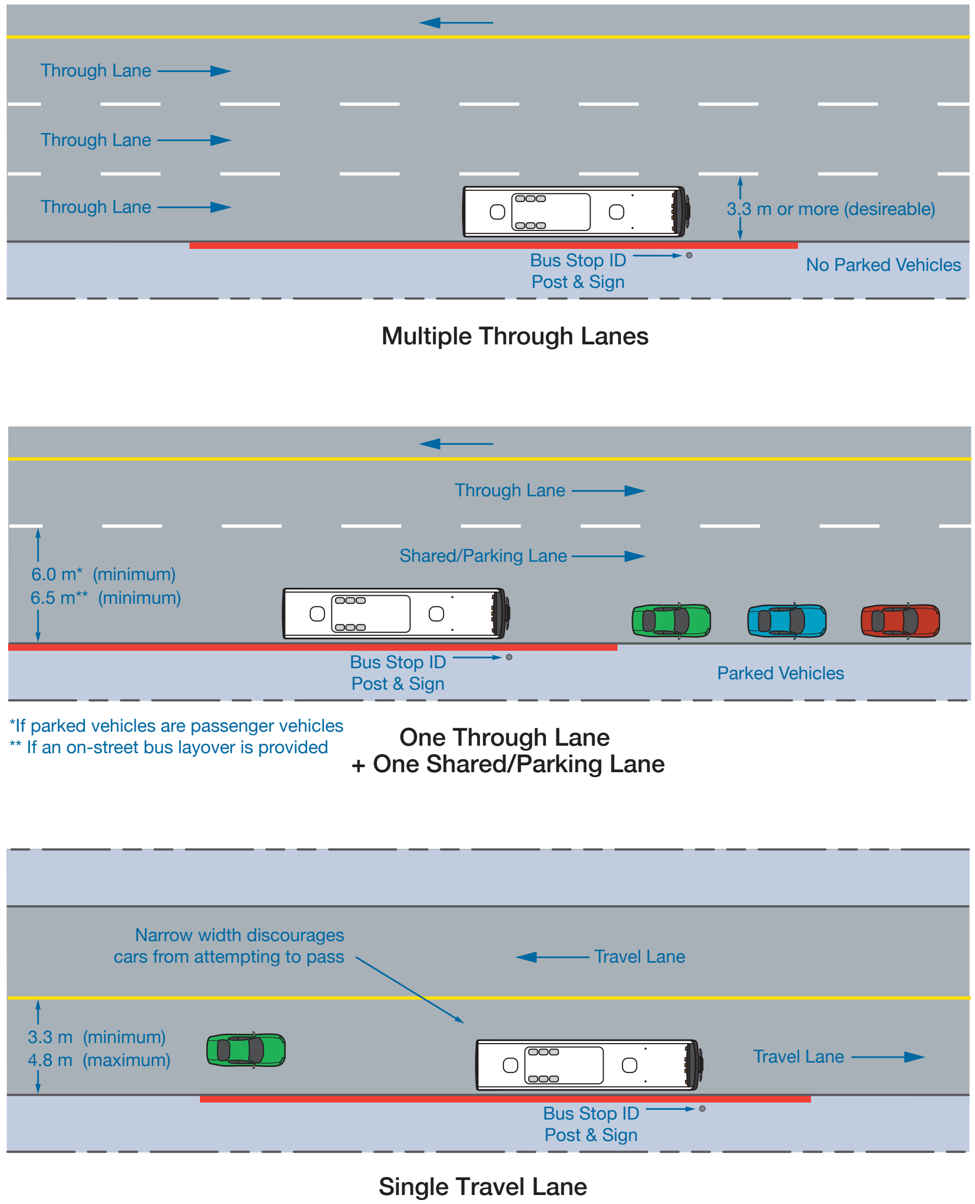


Figure 4.1 Lane Widths

4.2.2 Roundabouts

At roundabouts, the left-turn movement is usually the critical path for determining roadway width, however, all movements should be tested to confirm geometric requirements. The TAC Canadian Roundabout Design Guide should be consulted when they are utilized by transit vehicles.

- **Mini-Roundabout:** When the Inscribed Circle Diameter (ICD) is below 25 m, the central island may need to be flush with the roadway;
- **Single-Lane Roundabout:** ICD 25 to 60 m; raised central island may have traversable truck apron; and
- **Multi-lane Roundabout:** ICD 46 to 100 m; raised central island may have traversable truck apron.

Buses should not drive on the truck apron, as that could affect stability for standing passengers and increase wear on the vehicle.

In the roundabout planning stage, road designers can use a swept-path analysis software to test the BC Transit design vehicle. If the roundabout already exists, on-site testing will confirm performance.

4.2.3 Intersections

Table 4.1 summarizes the key design considerations for buses turning at intersections.

Table 4.1 Design Considerations for Bus Turning Movements

	Entry Lane	Receiving Lane
Left Turn	• Starting position of the turn • Sight triangles for crossing traffic from the left and right • Potential conflict with the turning path of opposing traffic • Sight line for opposing traffic	• Stop position of the cross-street traffic on the left • Width of the receiving lane(s) and physical treatments on the corner (for example, a curb extension) • Lateral clearance between any parked vehicles and the turning path of the bus
Right Turn	• Starting point of the turn • Sight triangle of traffic from the left • Buses typically leave the curb first, to avoid the rear of the vehicle from mounting the curb to make a right turn. Operators attempt to minimize the gap between the bus and the curb (to avoid bicycles, motorcycles and scooters from passing on the right)	• Corner radius, which may be subject to physical treatments such as a curb extension • Width of the receiving lane(s) • Lateral clearance between any parked vehicles and the turning path of the bus

Figures 4.2 illustrates the paths of a bus making turn movements. A 0.45 m offset from parked vehicles and opposing vehicles should be maintained. Trade-offs from reducing this distance can be considered but safety should be the primary consideration. Where bus turning movements are relatively frequent, the design should exceed the minimum required dimensions.

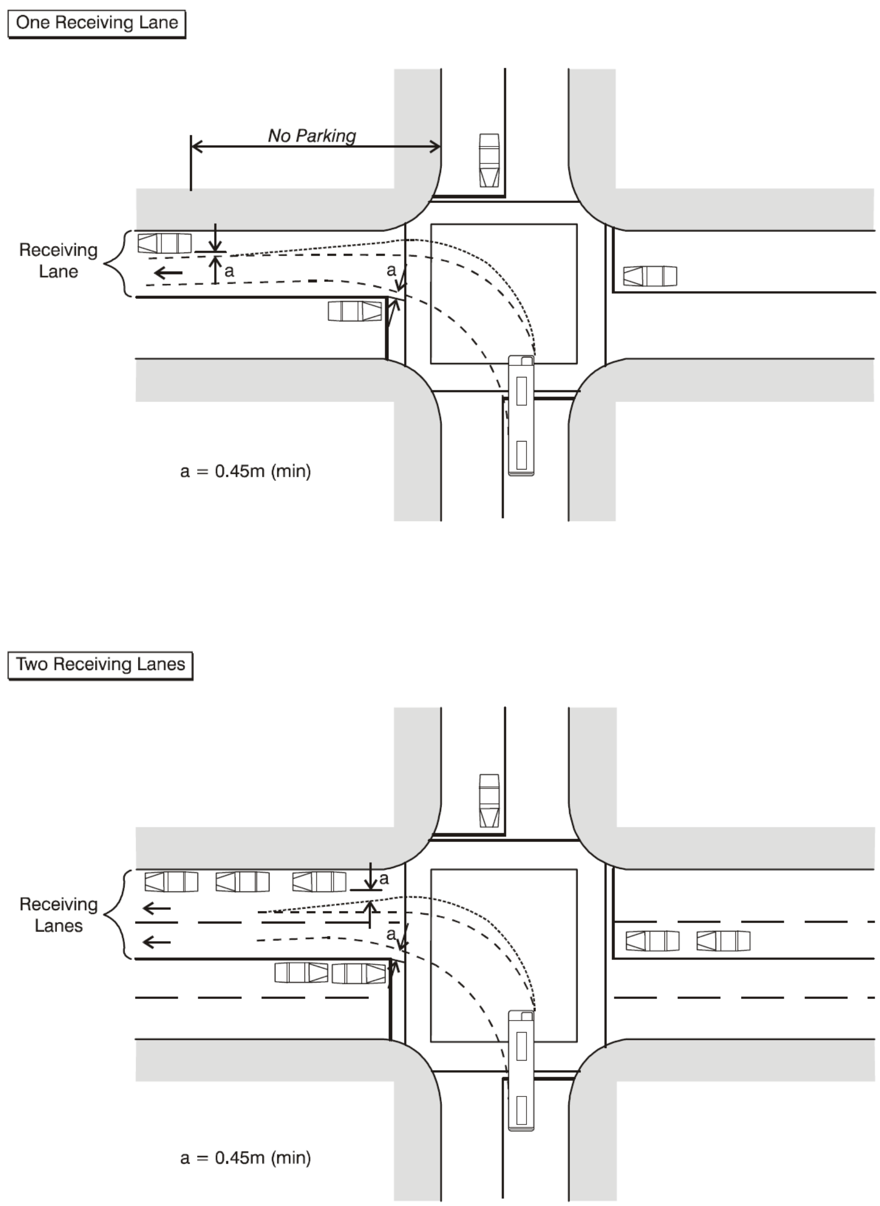


Figure 4.2 Bus Turning at Intersections

Source: TransLink Bus Infrastructure Design Guidelines

4.2.4 Road Alignment

Road alignment elements should be designed in accordance with the TAC Guide and applicable standards from other relevant authorities with jurisdiction. To ensure satisfactory bus performance and passenger comfort, minimum geometric design standards should be avoided wherever possible, due to the lower acceleration and deceleration capacities of transit vehicles, coupled with the requirements of their swept paths when turning.

4.2.5 Horizontal Clearance

MOTI suggests at least 0.6 m lateral clearance from adjacent traffic barriers along exclusive bus lanes or lanes with heavy bus use (greater than 7% of the traffic stream). The desired lateral clearance is 1.2 m from permanent structures. For non-permanent objects such as fire hydrants and signage poles, a minimum lateral clearance of 0.45 m is allowed. These standards should be adhered to, except in temporary conditions such as construction.

4.2.6 Maximum Gradient

Table 4.2 summarizes the maximum road grade for various scenarios. Designers should consider additional factors such as intersection density, number of lanes and heavy vehicle proportion when determining an appropriate grade.

Table 4.2 Maximum Road Gradients

Scenario	Maximum Grade
All scenarios except as noted below.	12%[1]
Buses comprise of at least 7% of the traffic stream.	10% (6% preferred)[2]
Gradients longer than 800 m.	8%[3]
Design speed of 100 km/h or greater.	5%[1]

Note 1: Based on TAC recommendations

Note 2: Based on MoTI recommendations

Note 3: Based on TransLink recommendations

The maximum road gradients also apply to traffic calming measures such as raised intersections and speed humps which should be discouraged on transit routes. BC Transit supports the City of Victoria's speed hump design (see Figure 4.3) in scenarios where speed humps are implemented.

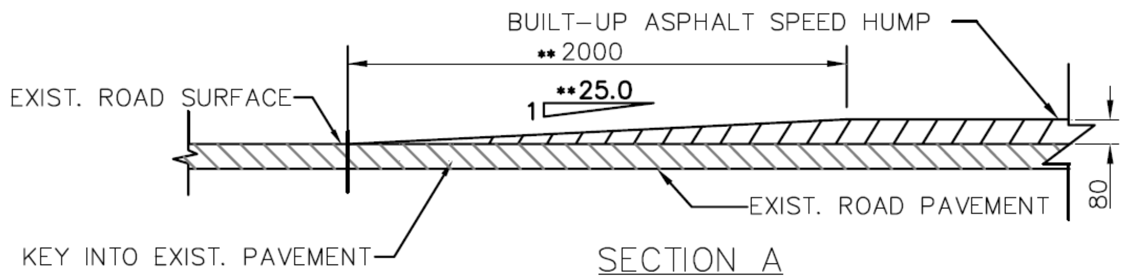


Figure 4.3 Recommended Speed Hump Design
Source: City of Victoria

4.2.7 Grade Change Points without Vertical Curves

On roadways with grade changes and no vertical curve, the transition at the grade change point should be no more than the transit design vehicle's permissible breakover, approach and departure angles. Appropriate grade change points prevent the underside or the front/rear bumpers of the bus from contacting the pavement. Figure 4.4 illustrates the maximum changes in road grades at breakover, approach and departure points

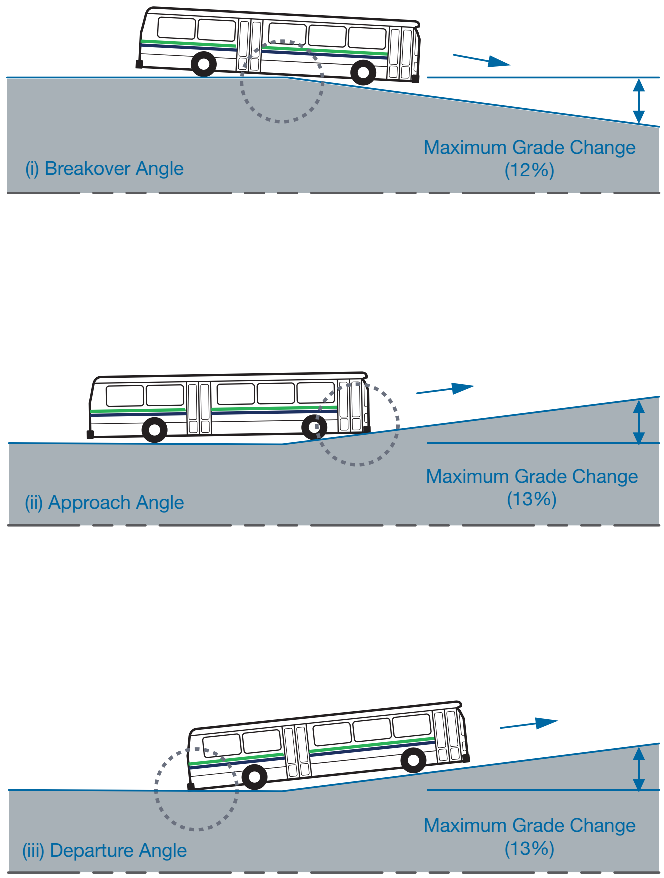


Figure 4.4 Grade Change Points for Design Vehicle

4.2.8 Sight Distances

When designing roads for transit operations, it's important to remember that sight distances for buses are different due to vehicle acceleration and deceleration capabilities, plus the need to protect passenger comfort and safety at all times.

Section 2.5 of the TAC Guide provides general sight distance requirements for vehicles and trucks.

Stopping Sight Distance

Stopping Sight Distance is the minimum sight distance criterion for transit vehicles (and other vehicles) approaching an intersection or travelling along a roadway. The minimum Stopping Sight Distance for transit vehicles is the sum of perception and reaction distance, and braking distance:

- **Perception and Reaction Distance** is the distance travelled at operating speed from a driver's perception of an incident to their subsequent brake reaction time. It corresponds with the time elapsed from the instant a driver sees something and contacts the brake pedal. For design purposes, perception and reaction time is 2.5 seconds.
- **Braking Distance** is the distance travelled after hitting the brake to a complete stop. Bus deceleration rates in Section 2.4 are used to calculate minimum braking distance for transit vehicles. The maximum deceleration rate for Standard and Articulated Buses in Service Conditions is 1.1 m/s^2; this rate is for normal operations where reasonable passenger comfort and safety is maintained. In Emergency Conditions, such as collision avoidance, the maximum deceleration rate for transit vehicles is 2.7 m/s^2.

Table 4.3 Transit Vehicle Stopping Sight Distance

Initial Operating Speed (km/h)	Perception and Reaction Time (sec)	Service Conditions			Emergency Conditions		
		Perception and Reaction Distance (m)	Brake Distance (m)	Minimum Stopping Sight Distance (m)	Perception and Reaction Distance (m)	Brake Distance (m)	Minimum Stopping Sight Distance (m)
40	2.5	28	56	84	28	23	51
50	2.5	35	88	123	35	36	71
60	2.5	42	126	168	42	51	93
70	2.5	49	172	221	49	70	119
80	2.5	56	225	281	56	91	137
90	2.5	63	284	347	63	116	179

Higher deceleration rates (such as the emergency deceleration rate) should only be used if the operator is in an extreme situation. These rates should not be used for design purposes.

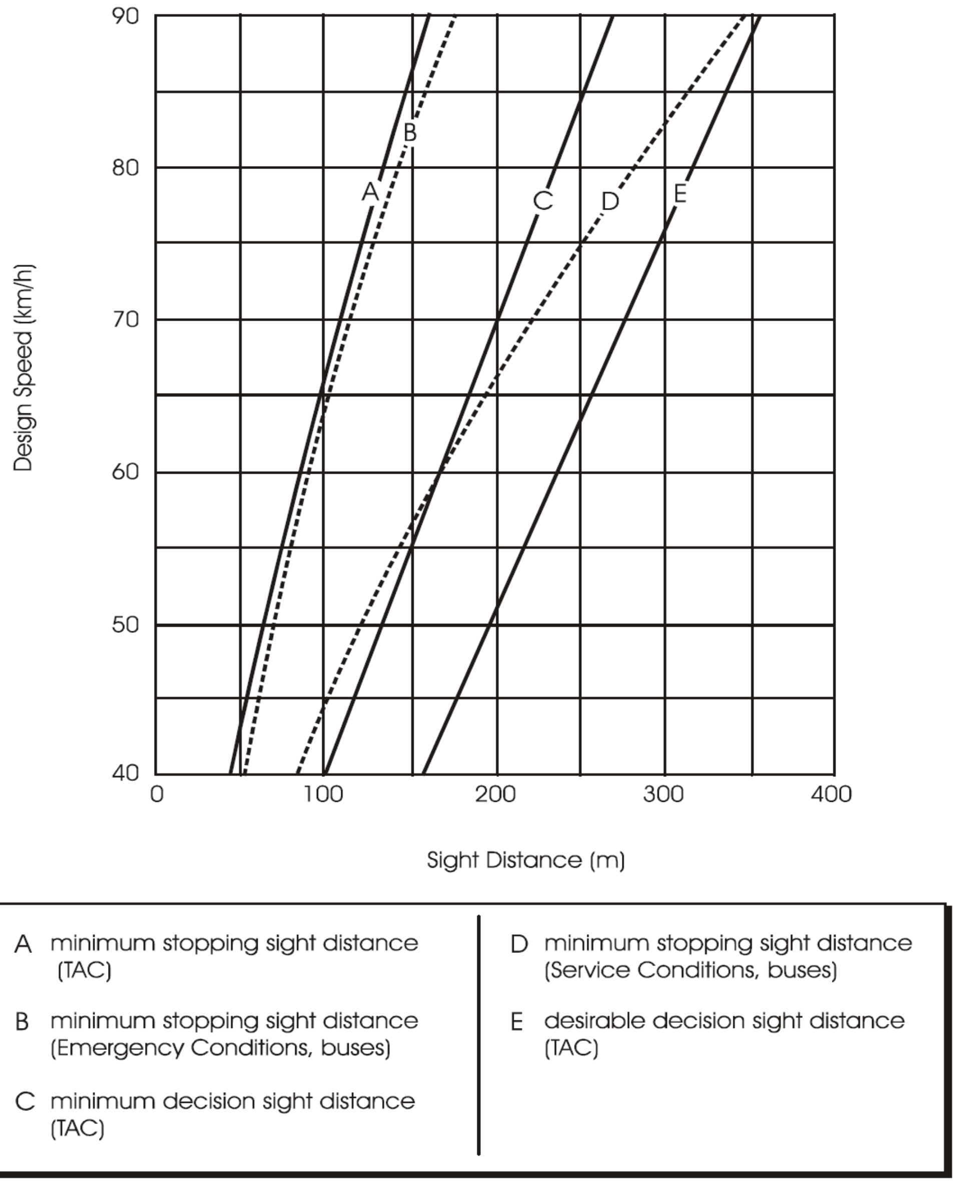
Decision Sight Distance

Sometimes, drivers must complete manoeuvres which require longer perception and reaction times, and actions more complex than a straightforward decision to stop. In these circumstances, use the Decision Sight Distance, a longer measure than the Stopping Sight Distance. According to Section 2.5.5 of the TAC Guide, Decision Sight Distance allows for a greater margin of error to react to unexpected circumstances and maintain safety in such complex situations. Table 2.5.6 (from the TAC Guide) provides the recommended Decision Sight Distance for a range of design speeds, depending on the type of manoeuvre.

Further research may be required to determine the Decision Sight Distance applicable to transit vehicles, particularly due to the fact that:

- The height of the bus operator's eye (1.80 m) is substantially higher than that of a passenger car driver (1.05 m); and
- Deceleration and acceleration rates of buses are significantly lower than those of a passenger car.

Whenever possible, Decision Sight Distance calculations should be used. If it is not possible to provide the Decision Sight Distance because of horizontal and/or vertical curvature, use traffic control devices to give advance warning of conditions ahead. See Figure 4.5 for Stopping and Decision Sight Distances requirements, as well specific Stopping Sight Distance calculations for transit vehicles in Service and Emergency Conditions.



Source: Adapted from TAC Geometric Design Guide for Canadian Roads

Figure 4.5 Stopping and Decision Sight Distances

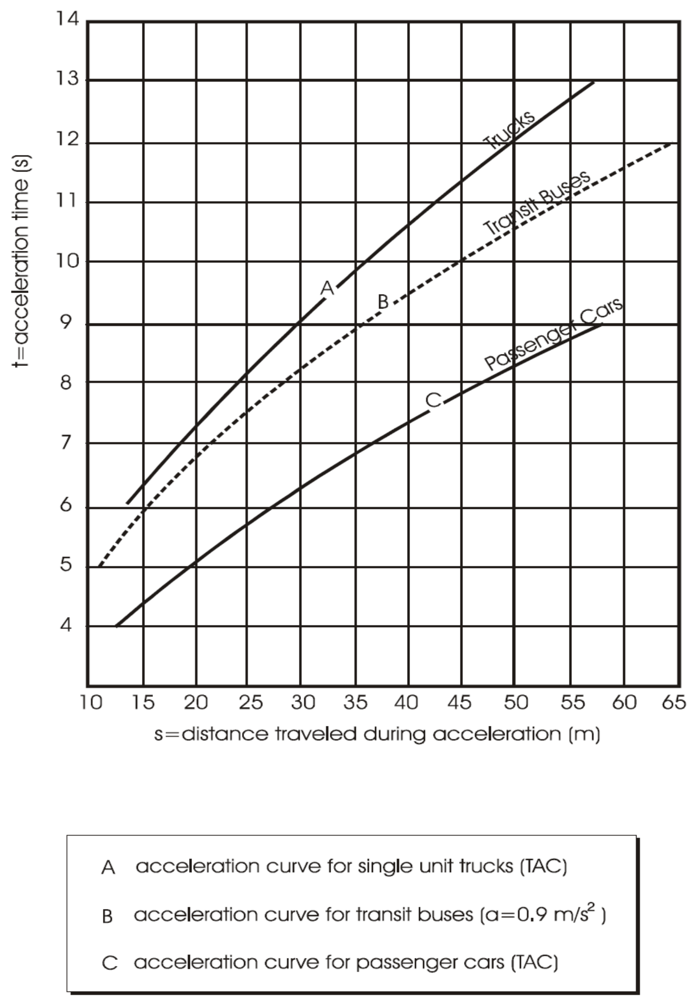
Crossing Sight Distance

The required crossing time depends upon the perception and reaction time of the bus operator, the bus acceleration time, the width of the major roadway, the length of the bus, and the speed of the approaching vehicle on the major roadway.

See Figure 4.6 for the distance travelled by a transit vehicle during acceleration. The minimum Crossing Sight Distance from an intersection along a major roadway can be calculated, as shown in Figure 4.7, based on:

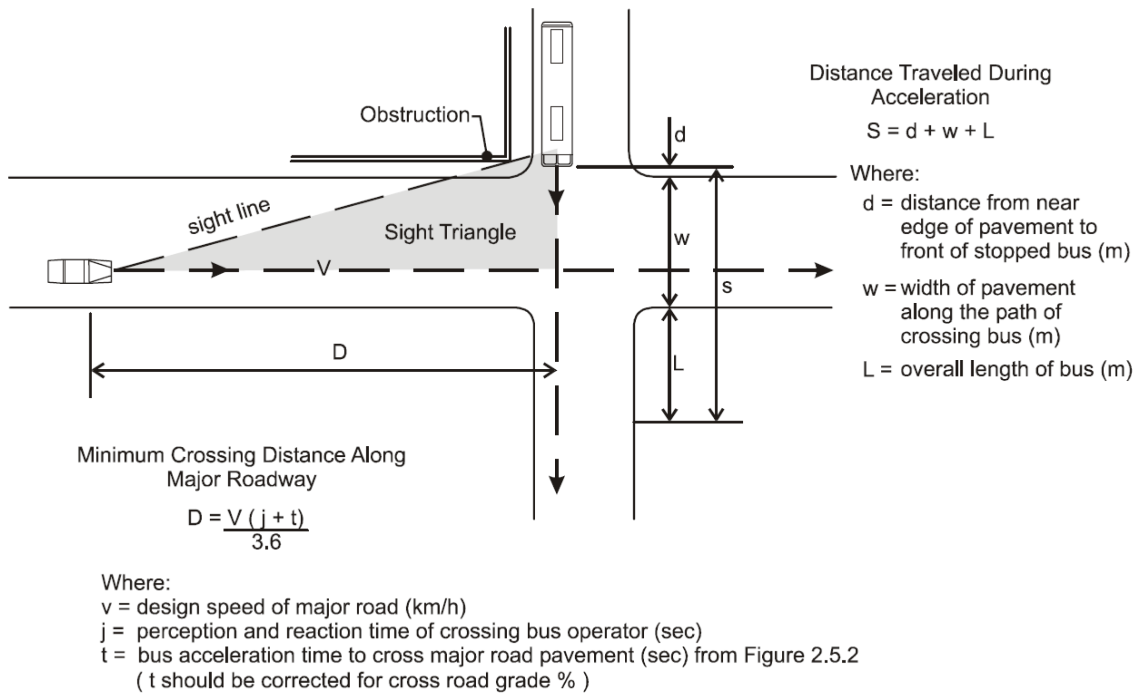
1. The design speed of the major roadway (V),
2. The perception and reaction time of the crossing driver on the major roadway (j), and
3. The length of acceleration time for the bus to cross the major roadway (t).

Sight triangles are used to determine building setbacks at intersections, or if existing obstructions such as parking zones, advertising signs, trees, etc., need to be removed or relocated. The required sight triangle for a crossing manoeuvre at an intersection depends on the minimum Crossing Sight Distance for the bus on the stop approach and the approaching vehicle on the major roadway.



Source: Adapted from TAC Geometric Design Guide for Canadian Roads

Figure 4.6 Acceleration Time for Stopped Buses



Source: Adapted from TAC Geometric Design Guide for Canadian Roads

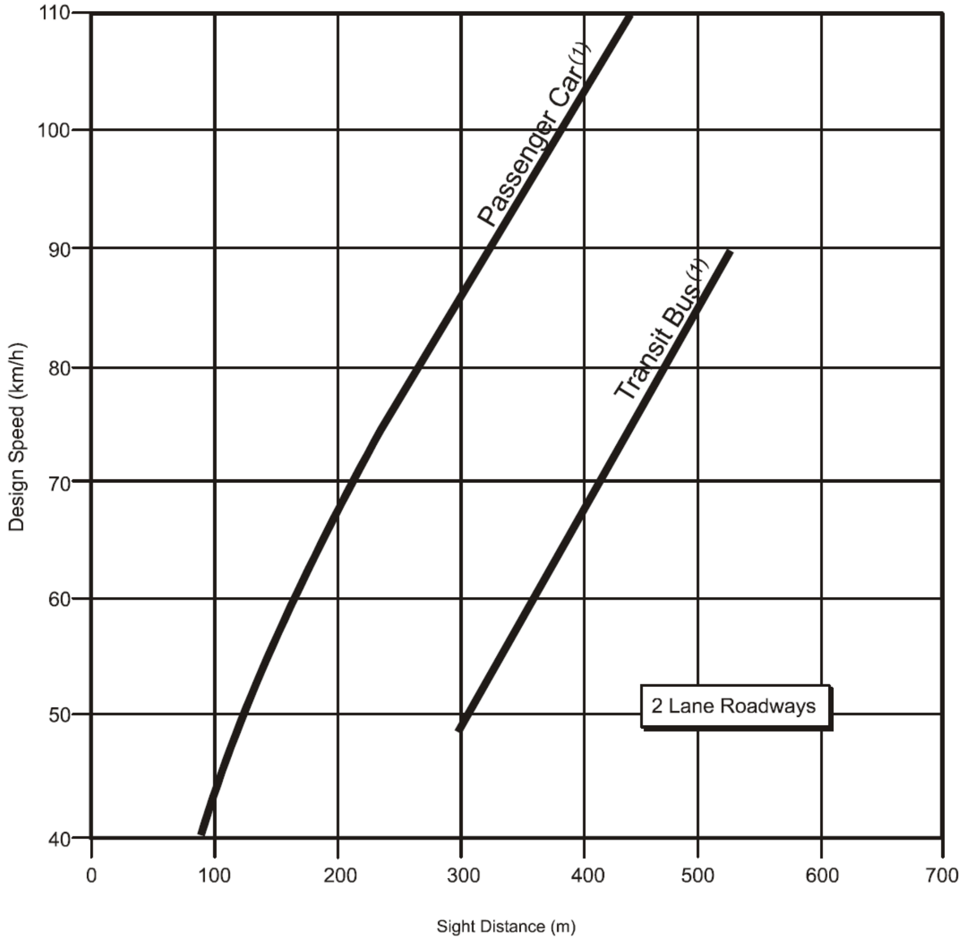
Figure 4.7 Minimum Crossing Distance along Major Roadway

Turning Sight Distance

A vehicle approaching from the right of a left-turning bus, at the instant the turning manoeuvre begins, should be sufficiently far away so that the turning bus can accelerate to a speed that does not significantly interfere with the approaching vehicle.

To determine the required Turning Sight Distance, TAC assumes the approaching vehicle will slow to 85% of the design speed at the intersection, and there will be a gap of at least 2 seconds between the turning bus and the approaching vehicle. Due to their acceleration characteristics, transit vehicles need more time to complete turns.

Figure 4.8 shows the Turning Sight Distance requirements for transit vehicles from a stop control on a minor road. An average acceleration rate of 0.9 m/s^2 for transit vehicles (instead of 1.9 m/s^2 used for passenger cars) is assumed for both left- and right-turning movements.



Note:

(1) Sight distance to a vehicle approaching from the right for a passenger car (or bus) turning left, or for a passenger car (or bus) turning right to a vehicle approaching from the left.

Source: Adapted from TAC Geometric Design Guide for Canadian Roads

Figure 4.8 Turning Sight Distance for Stopped Buses

Merging Sight Distance

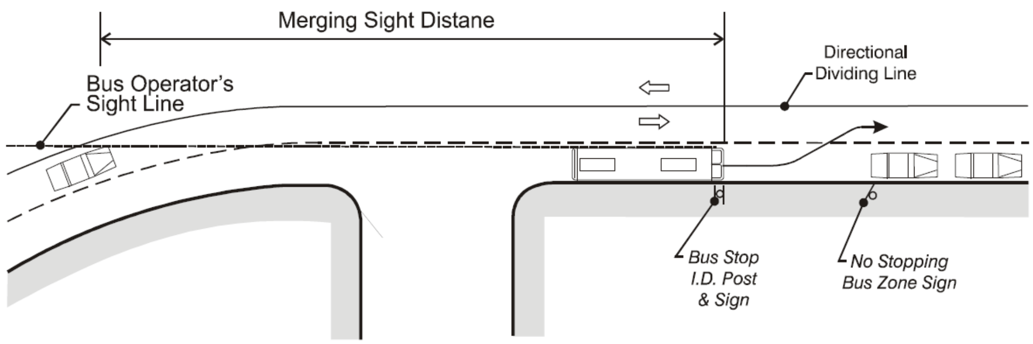
Merging Sight Distance is the distance between a merging bus to a vehicle approaching from behind. It's assumed the driver in the vehicle behind will not know exactly when the bus will start merging.

The minimum Merging Sight Distance for a transit vehicle is the sum of:

- The minimum Stopping Sight Distance of the approaching vehicle in the travel lane,
- The distance travelled by the same approaching vehicle at the design speed during the bus driver's 2.5 seconds of perception and reaction time, and
- The length of the bus.

The minimum Merging Sight Distance for transit vehicles can determine the location of bus stops and other transit facilities, especially on roadways with horizontal curvature and other obstructions such as buildings and trees.

Figure 4.9 illustrates the minimum Merging Sight Distance for transit vehicles leaving a bus stop for a range of vehicle speeds on a through-traffic roadway.



Merging Sight Distance, M.S.D. = S.S.D. + V+L

S.S.D. = Stopping Sight Distance
V = Distance traveled during the (2.5 sec) perception and reaction time of bus operator
L = Length of bus

Source: Adapted from TAC Geometric Design Guide for Canadian Roads

Design Speed (km/h)	S.S.D. (m)	V (m)	L* (m)	M.S.D. (m)
40	45	30	12	87
50	65	35	12	112
60	85	40	12	137
70	110	50	12	172
80	140	55	12	207
90	170	60	12	242

Note: *Assume Standard Bus

Figure 4.9 Merging Sight Distance for Stopped Buses

4.2.9 Pedestrian Sight Lines

Transit Operators have blind spots and visibility impairment zones on both sides of the bus, where they can't see other road users. Pedestrians boarding or alighting from transit vehicles, as well as other people walking near bus stops/facilities, may be unaware of a driver's restricted vision.

Operators need adequate pedestrian sight lines wherever there is any potential conflict between buses and pedestrians, for example where a bus turns right at an intersection or where a merge to the right must be made within a short distance.

Table 4.4 Pedestrian Sight Distance Formula

Pedestrian Sight Distance		
$PSD = 0.278vj + \frac{0.0386v^2}{d}$		
Var.	**Meaning**	**Typically Assumed Value**
v	Speed within Bus Loop (km/h)	20 km/h
j	Perception and Reaction Time of Bus Driver (s)	2.5 s
d	Deceleration Rate (m/s^2)	1.1 m/s^2 (desirable)

Source: TransLink Bus Infrastructure Design Guidelines

Based on assumed values, the typical pedestrian sight distance is 28 m. However, the input values may be different at certain bus stops, and designers are encouraged to validate with BC Transit. It's also important to note that the sight distance is an empirical value under ideal weather conditions. It is reduced or obstructed during adverse weather conditions.

4.2.10 Traffic Calming Measures

Traffic calming measures are often installed in residential neighborhoods to reduce vehicle speeds and volume, and to:

- Improve safety for active travellers;
- Discourage through traffic;
- Reduce collisions; and
- Reduce noise and air pollution.

Most traffic calming measures are physical, such as traffic circles, speed cushions, curb extensions, raised crosswalks and median barriers. In general, they should be avoided on bus routes. If that's not possible, special design considerations must accommodate the physical dimensions and capabilities of transit operations.

For example, speed cushions are a potential alternative to speed humps, and often preferred on transit routes and emergency response routes. Generally, less impactful to bus movement, speed cushions are spaced at a similar distance apart as the wheels of a larger vehicle such as a bus or fire truck. This allows a bus to pass with minimal effect, while still discouraging speeding by other motorists.

Table 4.5 Impact of Traffic Calming Measures

Traffic calming measure	Impact on passenger safety	Impact on bus operational efficiency
Traffic circle	• No adverse impact, but avoid a series of traffic circles to minimize side-to-side movement	• The circulatory roadway width that provides traffic calming for passenger vehicles may result in buses having difficulty going through the traffic circle
Speed hump	• Shorter ramps result in greater passenger discomfort • A speed hump should not be installed immediately before or after a bus stop for passenger safety	• Buses need to reduce speeds significantly to travel over a speed hump • May cause damage to the suspension of the transit vehicle • A series of speed humps should be avoided along a bus route
Curb extensions	• No adverse impact	• The corner radii may impact the ability for a bus to complete a right turn
Raised intersections and crosswalks	• Should not be installed immediately before or after a bus stop for passenger safety	• A series of raised intersections/cross walks should be avoided along a bus route
Diverter	• No adverse impact	• Room must accommodate bus manoeuvre, and without obstruction by parked vehicles

4.3 BUS STOP DESIGN

4.3.1 Bus Stop Location Options

Far-Side Stops

Advantages

Putting a bus stop on the far side of an intersection is generally preferred over the near-side or mid-block configuration because:

- Pedestrians and vehicles travelling in the same direction have a clearer view of intersection traffic controls (for example, a STOP sign or traffic signals);
- Buses pulling in or out of a near-side bus stop can cause queues and delays at a traffic signal or STOP sign;
- Stopped buses are not blocking right-turn vehicles on the near-side, increasing right-turn throughput;
- There is reduced risk of bus passengers stepping in front of the bus to cross the street; and
- Pedestrians cross the intersection behind rather in front of the bus.

Disadvantages

- Slightly increased walking distance to the intersection crosswalk for bus passengers;
- Bus operators have restricted view of passengers approaching from the intersection;
- For a far-side stop sited beyond a channelization island or in an acceleration lane, potential weaving conflicts between buses approaching the stop area and right-turn traffic from the intersecting street; and
- Traffic behind a stopped bus could potentially extend into the intersection, causing delays and potential safety concerns for other road users. This is particularly critical for far-side stops with long dwell time.

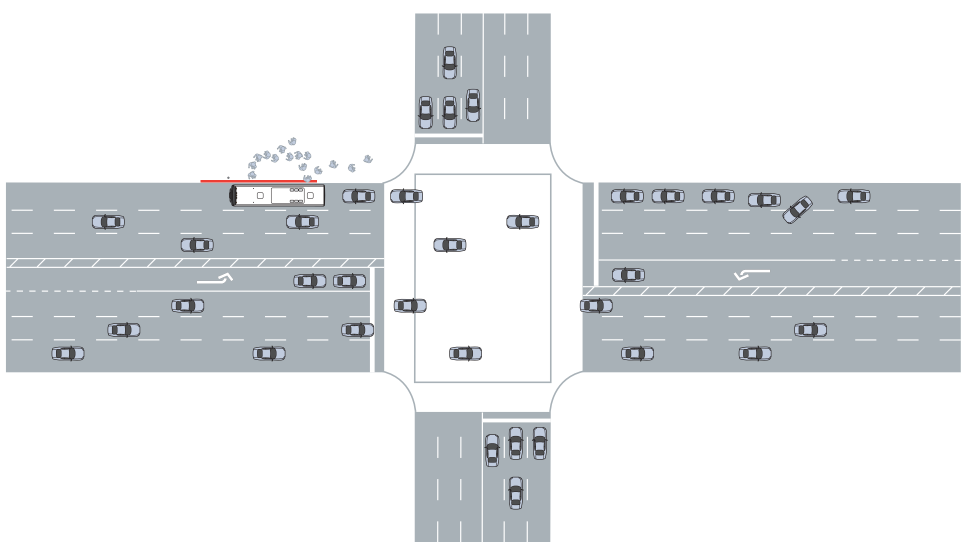


Figure 4.10 Potential Disadvantage of a Far-Side In-lane Bus Stop

Near-Side Stops

Advantages

- When used in combination with a far-side stop, a near-side stop can facilitate passenger transfers between two bus routes (see Figure 4.12); and
- When a quadrant has a significantly higher transit ridership or a distinct demographic that requires increased accessibility, (e.g. schools, hospitals, parks, etc.).

Disadvantages

- If significant, vehicle queues on the curb-lane can delay buses getting to the stop;
- Stopped buses can limit traffic control sightlines for drivers travelling in the same direction; and
- If right-turn vehicle volumes are significant, a stopped bus could block right-turn traffic movements, causing weaving conflicts.

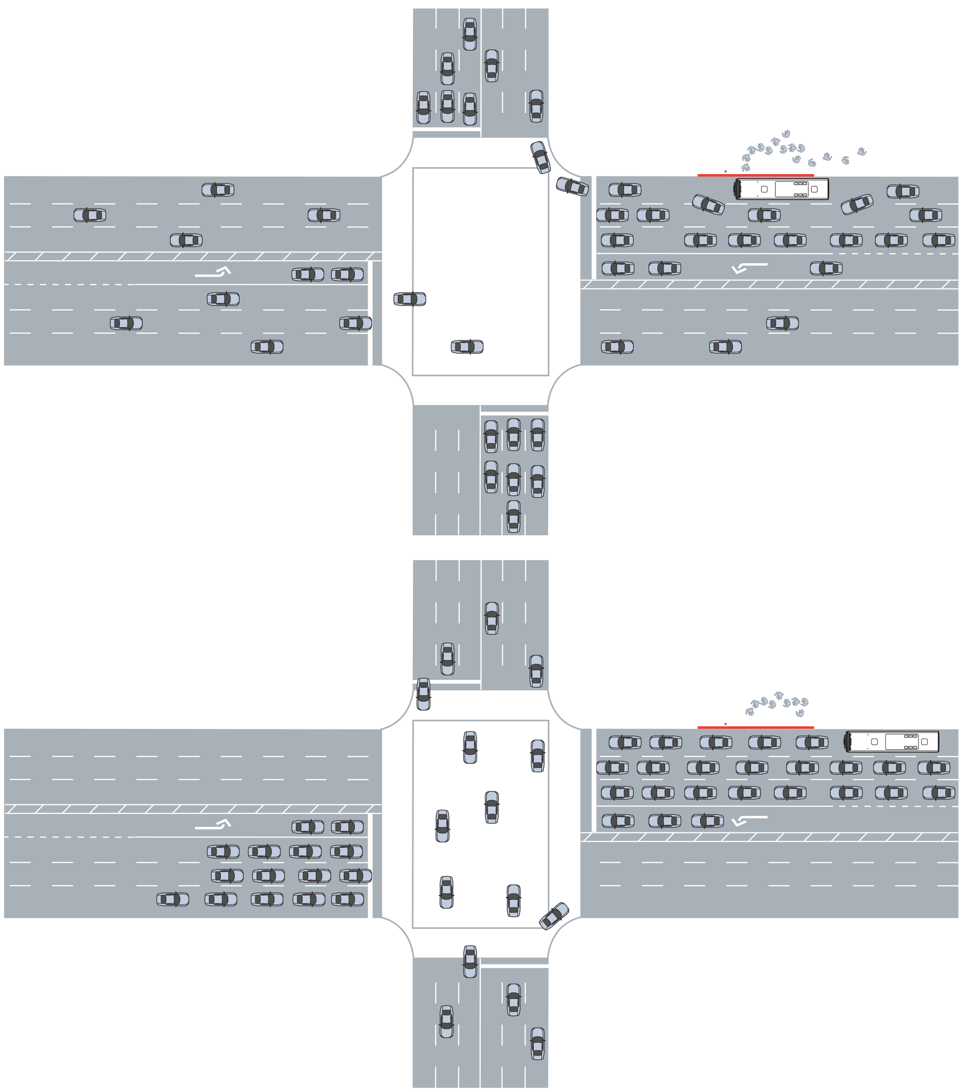


Figure 4.11 Potential Disadvantages of a Near-side Bus Stop

Mid-Block Stops

Advantages

If local trip generators justify its use, mid-block configuration advantages include:

- More available space on the sidewalk to accommodate waiting passengers; and
- The stop location can correspond to particular ridership generator(s) between adjacent intersections.

Disadvantages

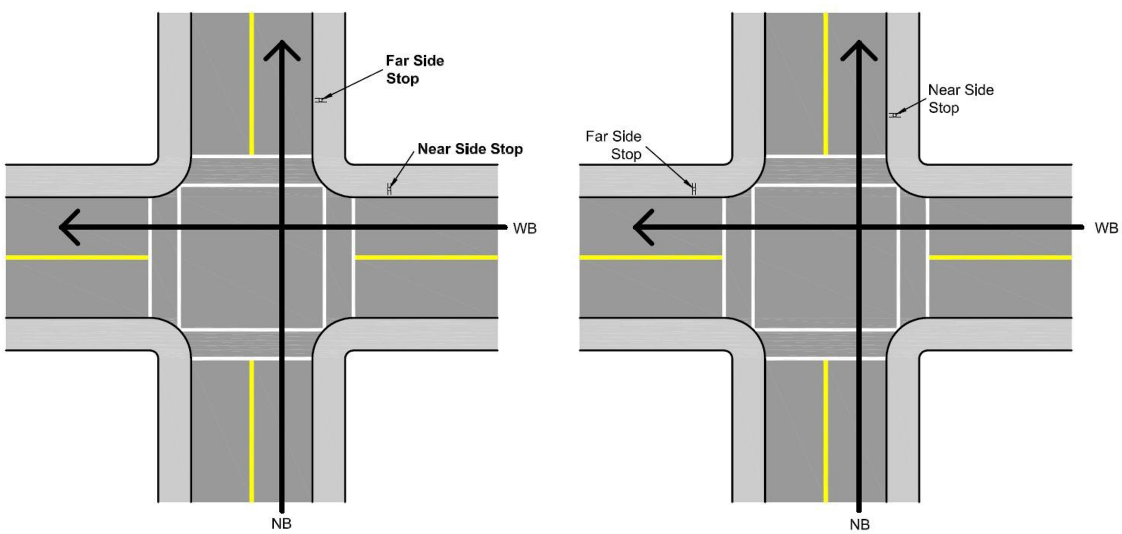
- Crossing the street at an unmarked location near the bus stop; and
- Increased walking distance for passengers making transfers if the connecting bus route is at a different location.

Transit Signal Priority Considerations

Transit Signal Priority (TSP) improves transit travel times and customer experience by altering traffic signal timings to accommodate approaching transit vehicles. TSP is most effective at far-side bus stops and can be inefficient at near-side stops.

Route Transfer Considerations

Bus stops should coordinate with passenger transfer movements (see Figure 4.12, especially when a large transfer volume is anticipated between two transit services. For example, a near-side bus stop can enhance passenger transfers on two intersecting streets.



The diagram (left) illustrates a preferred scenario where convenience is provided for a passenger transferring from a westbound route to a northbound route without having to cross the intersection at the crosswalk. The diagram (right) illustrates a less ideal situation where the same passenger would have to cross the intersection to make the transfer.

Figure 4.12 Bus Stop Placement for Route Transfer Coordination

4.3.2 Configurations

Buses can either stop in their travel lane or pull out of their travel lane and stop in a bus bay / parking lane. In-lane stops are the default bus stop configuration. Removing the need for buses to pull into and out of a general-purpose traffic lane has multiple benefits including:

- More space for passenger amenities and pedestrians.
- More efficient and reliable transit travel speeds.
- More comfortable transit experience.
- Less pavement wear from buses turning out of bus bays.
- Less transit vehicle wear.

Bus bays should only be provided in the following scenarios:

- Streets with high vehicle speeds (60 km/h or higher).
- Stops where buses are expected to dwell for an extended period (e.g. layover locations).
- Incorporated into a bus queue jump lane.
- Allows express buses stopped in their travel lane to pass stopped non-express buses stopped in a bus bay.

4.3.3 In-lane Bus Stop Design (No On-street Parking)

Far-side Bus Stop

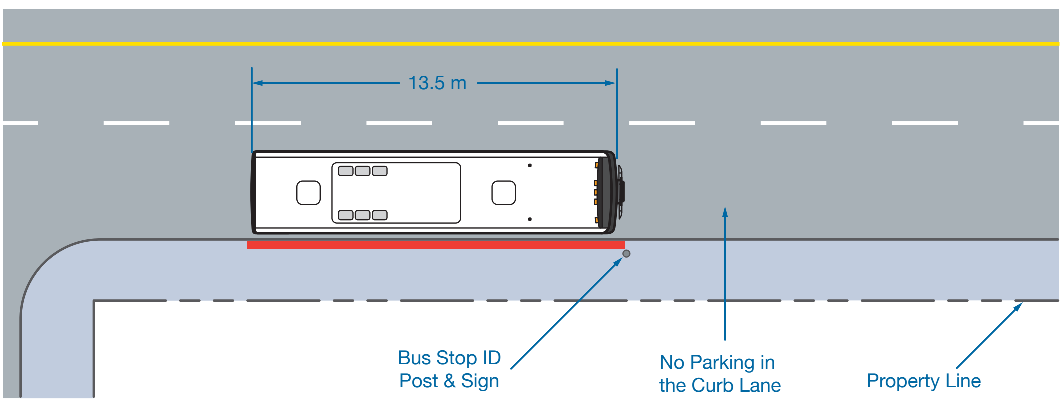


Figure 4.13 In-lane Bus Stop Design

4.3.4 In-lane Bus Stop Design (On-street Parking)

Refer to Figure 4.14 for the layout of a bus bulge which creates an in-lane stop on a street with on-street parking. The depth (D) of the bus bulge is typically equal to the depth of the parking lane. Figure 4.14 illustrates a far-side location; however, bus bulges can also be near-side or mid-block.

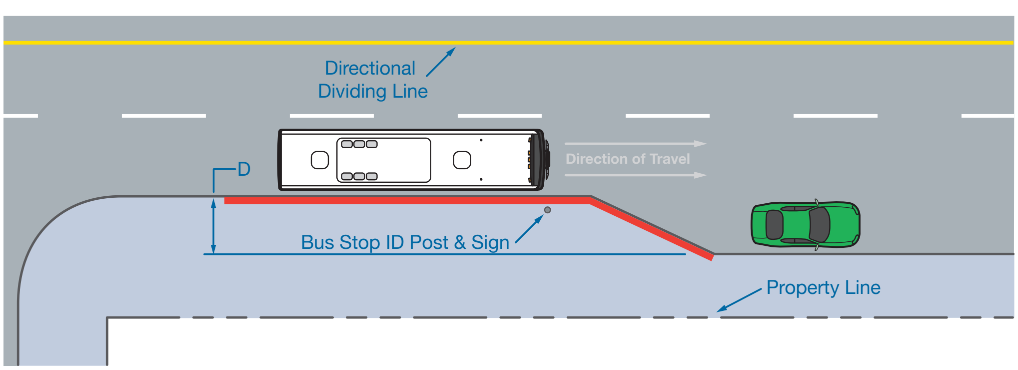
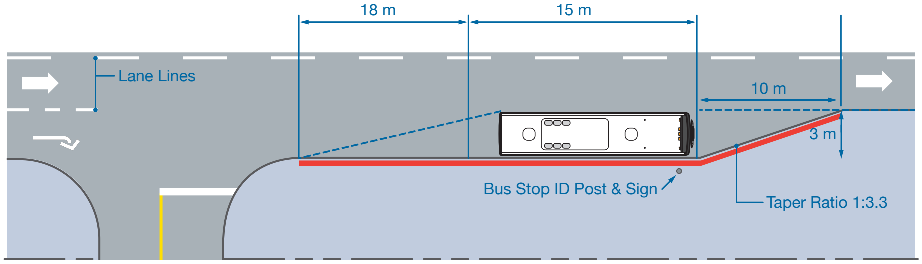


Figure 4.14 Bus Bulge

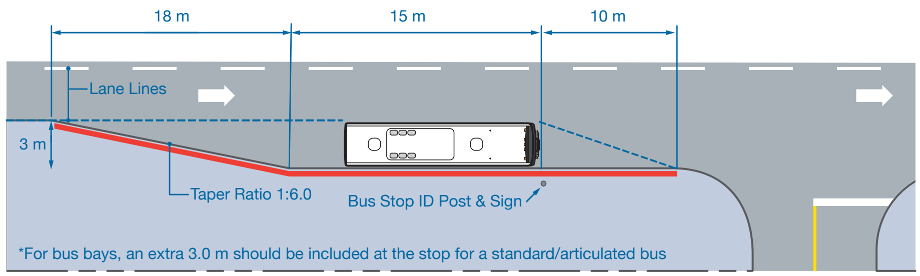
4.3.5 Bus Bay Design (No on-street Parking)

Bus bays are short pull-over zones adjacent to main travel lanes, where buses can stop to pick up passengers without interfering with regular traffic flow. Refer to Figure 4.15 for design details. Bus bays should provide a curve in the transition area as opposed to point to ease maintenance.

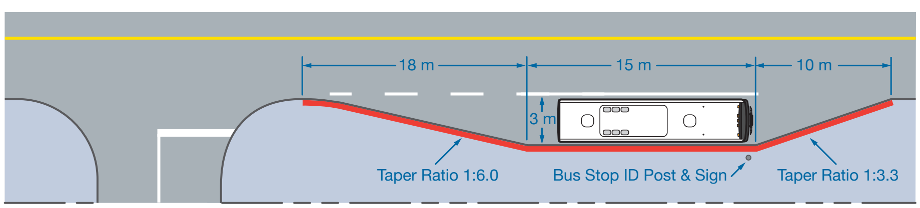
On a typical urban arterial road, operators slow down to about 30 km/h when entering and exiting a bus bay. On exit, bus operators usually accelerate after they have merged back into the adjacent travel lane, not within the taper of the bus bay.



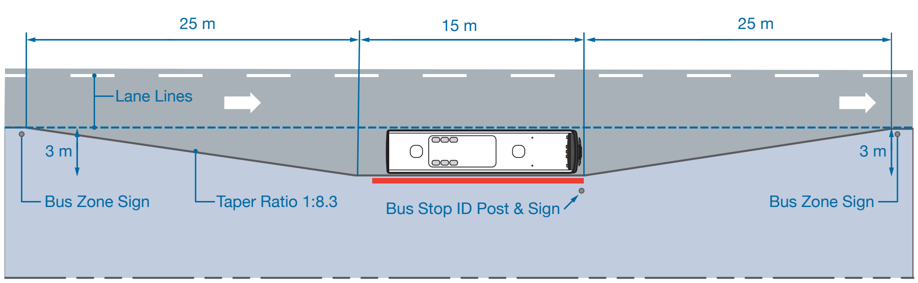
Near Side—Speed Limit < 50 km/h



Far Side—Speed Limit < 50 km/h



Mid-Block—Speed limit < 50 km/h



Mid-Block—Speed Limit > 60 km/h

Figure 4.15 Bus Bay Configurations

4.3.6 Bus Bay Design (On-street Parking)

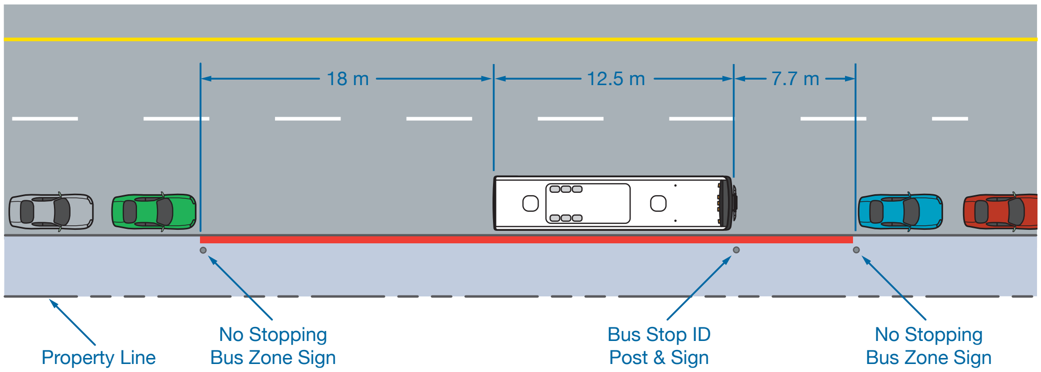


Figure 4.16 Mid-Block Bus Stop Configuration

4.3.7 Bus Bay Design (Highway)

In a highway environment, BC Transit adopts BC Ministry of Transportation and Infrastructure pull-out guidelines for bus bay design.

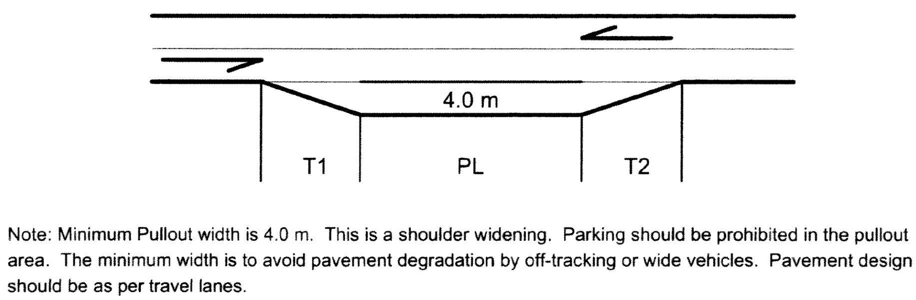


Figure 4.17 Rural/Highway Pullout Design
Source: BC MoTI Supplement

Table 4.6 Rural/Highway Pullout Lengths

Reference Speed km/h	T1 m and (ratio)	Minimum PL (m)	Desirable PL (m)	Maximum PL (m)	T2 m and (Ratio)
50	30 (7.5:1)	30	70	200	30 (7.5:1)
60	40 (10:1)	45	120	300	40 (10:1)
70	50 (12.5:1)	65	190	500	50 (12.5:1)
80	60 (15:1)	85	270	600	60 (15:1)

Note: Use the ratio if Pullout width is other than 4.0 m. Minimum width is 4.0 m. This is a shoulder widening. The minimum width is to avoid pavement degradation by off-tracking or wide vehicles. Pavement design should be as per travel lanes.
Source: BC MoTI Supplement

4.3.8 Bus Stop Locations Near Roundabouts

When locating a bus stop near a roundabout, consider the following:

- **Vehicle speed:** Near-side stops are usually safer as vehicles slow down to enter the roundabout and accelerate exiting the roundabout.
- **Sight line obstruction:** A near-side stop should not obstruct pedestrian sightlines in or near a crosswalk.
- **Distance between near-side bus stop and crosswalk:** At the approach to a multi-lane roundabout, a near-side bus stop can be in the travel lane if it is set back at least 15 m from the crosswalk. Near-side stops should be far enough away from a splitter island in case a vehicle overtaking a stationary bus strikes the island, especially as the bus starts to pull away from the stop. At the approach to a single-lane roundabout, a near-side bus stop can be in the travel lane at least 6 m from the crosswalk.
- **Distance between far-side bus stop and crosswalk:** Far-side stops should be located beyond the crosswalk, so they don't obstruct the view of crossing pedestrians. Bus pull-outs can reduce the risk of vehicles queuing into the crosswalk or roundabout behind a stopped bus but may limit sight lines for bus drivers attempting to merge into traffic. If possible, in a traffic-calmed environment or close to a school, locate the bus stop so other vehicles can't pass a stopped bus.

4.3.9 Multi-position Bus Stops

Sometimes it makes sense to have more than one bus stop at one location, for example where overall transit frequency warrants additional stops, or both local and express transit services operate. See Section 6.2.2 for multi-position stops at off-street transit exchanges.

Tiered Bus Stop

Tiered stops combine bus bulges and bus bays to better serve express and local buses. The bus bay should be placed upstream of the bus bulge so local buses, when pulled into the bus bay, do not impact through traffic and express buses. Tiered stops emphasize service priority and provide opportunity for timed transfers.

1. Bus bay is located before the bus bulge and provides local service;
2. The boarding bulge lets the express bus jump the local bus in the queue, regardless of arrival order. The curb radii at the back of the bulge must be sufficient to accommodate the transition of the local bus back into the travel lane;
3. Stop amenities can be placed on the bulge to preserve sidewalk capacity and throughput; and
4. Concrete bus pads are S-shaped, conform to the curb, and continuous throughout the stop.

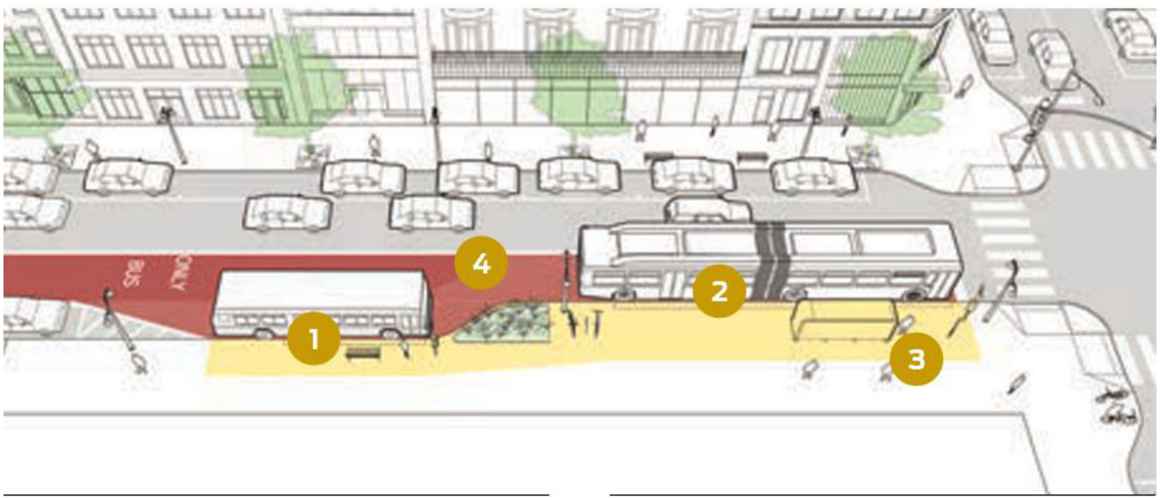


Figure 4.18 Tiered Stop Configuration

Source: NACTO Transit Street Design Guide

Multi-position, In-lane Stops

In a first-in, first-out bus stop layout, the 3 m spacing between each bus stop accommodates bike rack usage.

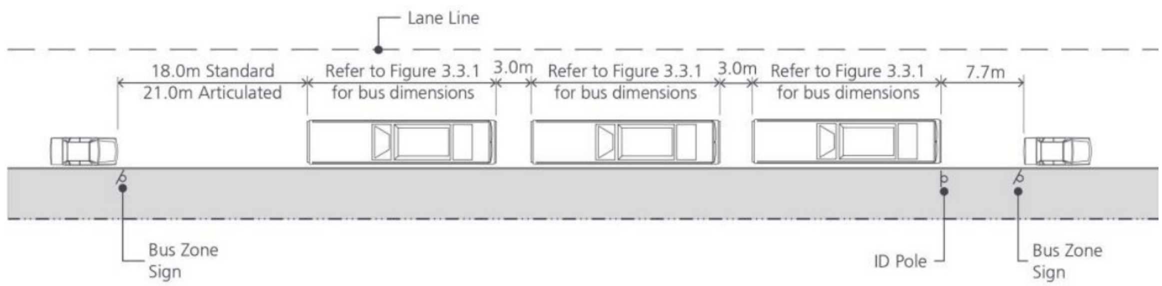


Figure 4.19 First-in, First-out Bus Stop Layout

Source: TransLink Bus Infrastructure Design Guidelines

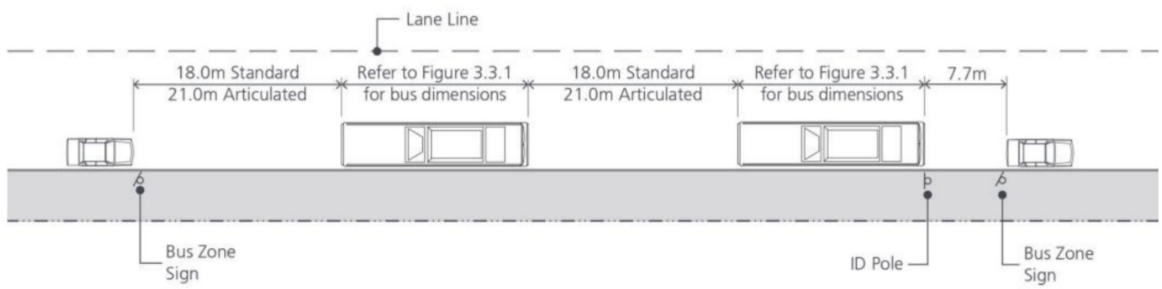


Figure 4.20 Independent-arrival, Independent-departure Bus Stop Layout.

Source: TransLink Bus Infrastructure Design Guidelines

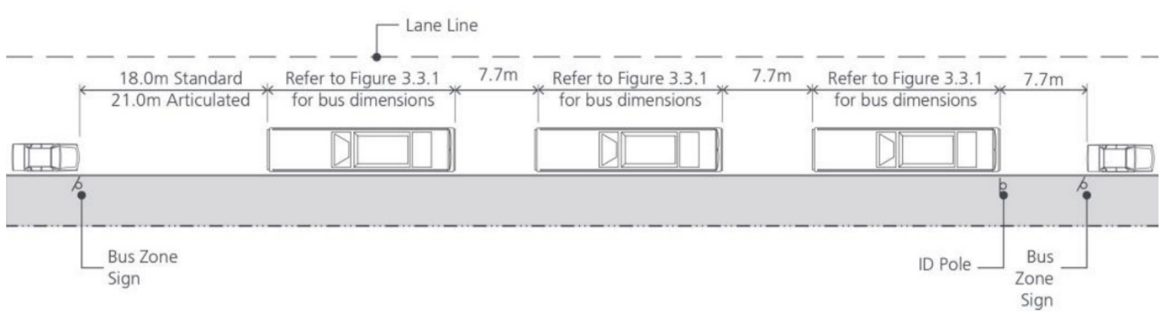


Figure 4.21 Independent-arrival, First-out Bus Stop Layout

Source: TransLink Bus Infrastructure Design Guidelines

4.3.10 Crosswalks

Bus stops should be sited on the far side of a crosswalk to maximize sight distance between approaching vehicles and pedestrians at the crosswalk. The distance between the rear of the bus and the crosswalk should be at least 2 m.

If a near-side stop is provided, the minimum distance between the intersection crosswalk and the bus stop should be 6 m. For a mid-block crosswalk in front of a bus stop, the minimum distance between the front of the bus and the crosswalk should be 10 m.

4.3.11 Bus Stop between Access Driveways

Bus stops should be kept away from driveways whenever possible to minimize conflicts between buses and vehicles. If it can't be avoided, see Figure 4.24 for the minimum requirements, and also consider:

- Turning movement volumes of the driveway;
- Type, spacing and distance between access driveways near the stop;
- Peak usage of the bus stop compared to peak usage of the access driveway;
- Type of buses that use the bus stop;
- Available space to accommodate passengers and amenities;
- Expected service level and customer boarding/alighting volumes at the bus stop;
- Sight line requirements between passengers, bus operators and drivers accessing the driveways; and
- Possibility that traffic queued at the driveway will affect the efficient operation of the bus stop.

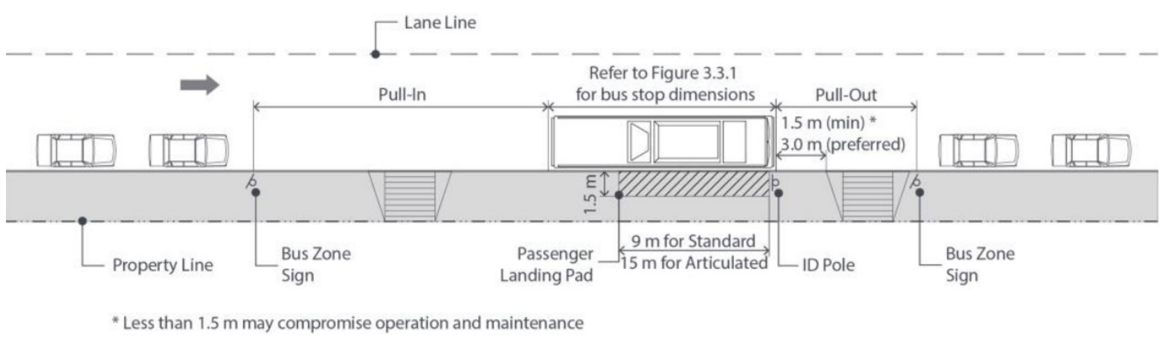


Figure 4.22 Requirements for Bus Stop between Access Driveways

Source: TransLink Bus Infrastructure Design Guidelines

Figure 4.23 Access Driveway Issues

Photo shows a vehicle entering an access driveway (white arrow) adjacent to a bus stop. When a bus is stopped for loading/unloading activities, it could block the view of pedestrians on the sidewalk for a vehicle that needs to turn into the driveway. When a vehicle needs to exit the driveway, the stopped bus would block the view of traffic on the road.

4.3.12 Other Safety Considerations

Regardless of the selected bus stop configuration, consider the following for safe interactions between buses and other traffic:

- Trees, shrubs, poles or buildings should not obscure a bus driver's sight lines on approach to, and at the stop;
- Adequate sight distances are needed for bus pull-in and pull-out movements;
- Stopped buses should not significantly reduce traffic control or crosswalk visibility for other vehicles and pedestrians;
- If bicycle lanes exist, cyclists should have enough distance/time to slow or stop safely for a bus; and
- If possible, don't place stops on horizontal curves as available sight distance can be limited along a curve.

4.4 BUS STOPS ADJACENT TO BICYCLE LANES

4.4.1 Design Considerations

When a bus stop is adjacent to a bicycle lane, careful consideration should be given to minimize conflicts between buses, transit riders and cyclists.

It is not recommended practice to share curb bus lanes with cyclists, as it creates risks and impedes cyclist travel when a bus is pulling in/out or stopped. Separate lanes are preferred.

For one-way roads, the BC Active Transportation Design Guide recommends bicycle lanes be located on the left side of the roadway to eliminate conflicts between cyclists and transit vehicles. When conflicts cannot be eliminated, transit stops should be carefully designed.

At the time of writing this Guide, there was an active BC Human Rights Tribunal complaint being processed from the Canadian Federation of the Blind with respect to the floating bus stops on Pandora Avenue in Victoria, BC. Due to this, BC Transit is not publishing design recommendations for bus stops adjacent to protected bike lanes or multi-use paths where transit riders would need to cross cyclists to access a bus stop. Road authorities considering these arrangements should utilize the recommendations in the Chapter H.1 Supplement of the BC Active Transportation Design Guide and coordinate with BC Transit.

4.4.2 Curb-side Painted Bicycle Lanes

Buses are allowed to stop in painted bicycle lanes as long as the location is signed and marked appropriately. The painted white lane adjacent to the bicycle lane should be dashed where buses are expected to cross.

4.4.3 Stops where Buses cross a Bicycle Lane

For stops where buses need to cross the bicycle lane to enter and exit:

- A minimum 3 m wide bus bay lane next to a bicycle lane is preferred so that the stopped bus doesn't impact the bicycle lane;
- Compared to a bus bay without an adjacent bicycle lane, a longer bus pull-in and pull-out distance should be provided (distance is based on the width of the bicycle lane and either a 1:6 (entering) and 1:3.3 (exiting) taper ratio; and
- In any situation where a bus could encroach into the bicycle lane, the bus stop location should be examined to ensure that the cyclist can pass the stopped bus safely, or make other decisions in a safe and timely manner, e.g. stop behind the bus or make a lane change into the adjacent travel lane.

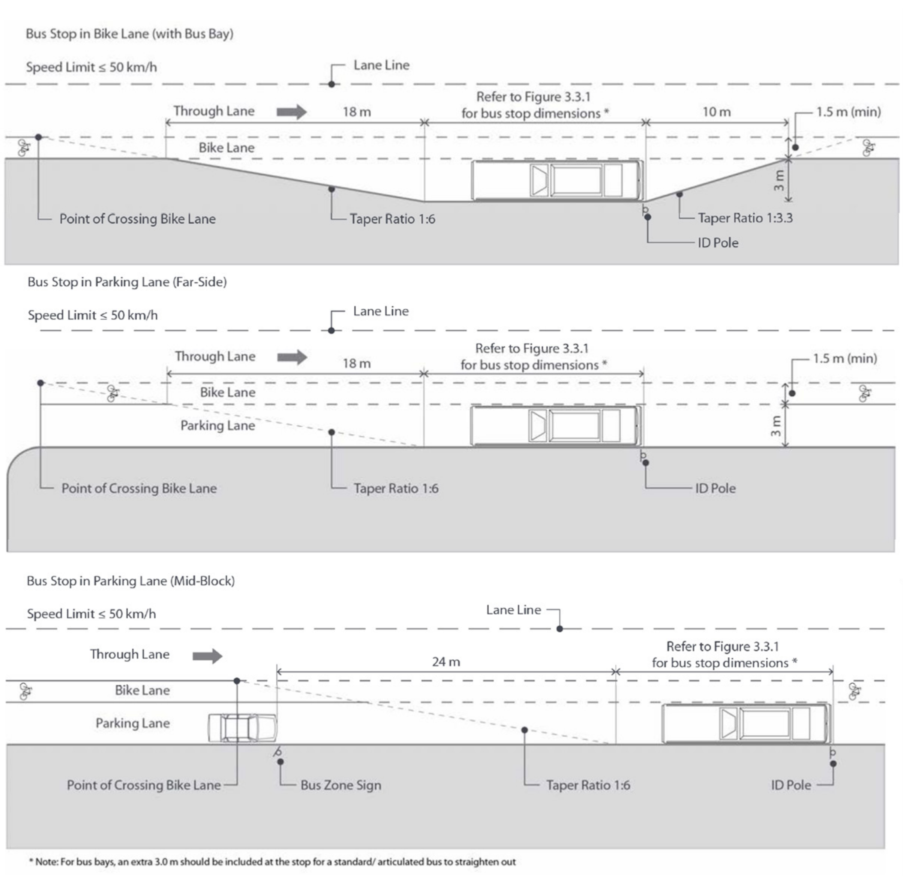


Figure 4.24 Bus Bay next to Bicycle Lane

Source: TransLink Bus Infrastructure Design Guidelines

4.5 TRANSIT LANES AND TRANSITWAYS

NACTO's Transit Street Design Guide is a good source of information regarding the application, benefits and design considerations for various categories of transit lanes and transitways including standard, offset, curbside, centre, time-exclusive, shared bus-bike and contra-flow lanes.

Key transit lane considerations:

BC Transit recommends that transit lanes are dedicated solely to transit unless a vehicle needs to enter the lane to make a right turn.

- Transit lanes can significantly improve on-time performance on streets where transit is delayed by congestion and curbside activities;
- Carefully manage left- and right-turns across transit facilities. Use appropriate signage and markings if turning movements cross or use the transit lane. In some cases, particularly for left turns, turning movements must be prohibited, or operated by fully protected signal phases;
- Continuous markings, signage and enforcement may be required to maintain the integrity of the transit lanes;
- The use of red paint to identify transit lanes should be limited to locations where general traffic is not allowed and where there is a significant concern that general traffic would enter the transit lane;
- For corridors with pronounced commercial and retail activities, on-street parking, loading, parklets, and other curbside uses can be placed on the right side of the transit lane – often called offset, floating, or parking-adjacent transit lanes;
- For corridors with minimal curbside activities, curbside transit lanes are an option, with right-turn movements managed accordingly; and
- For corridors with pronounced goods movement traffic and/or pedestrian traffic, a time-exclusive bus lane can be considered. In this case, buses only have the right-of-way during certain periods. Typically, lanes are designated to buses during peak periods, to goods movements during off-peaks and/or night times, and potentially to other active modes during off-peaks and/or weekends.

Key transitway considerations:

- Transitway corridors are physically separated from general traffic. They can also be transit lanes with transit pre-emption or priority at traffic signals;
- Suitable for streets with consistently poor transit travel speeds and high transit frequency; and
- Often involve large capital investment but offer the most benefit by reducing overall run-time and improving on-time performance.

Figure 4.27 Example of Street with Centre Transit Lanes and In-lane Island Stops

Source: NACTO Transit Street Design Guide

4.5.1 Transit Lane Pavement Markings

The following are lane painting details that are specific to transit lanes (see Figure 4.26). The recommendations are based upon the assumption that transit lanes will be in the right-hand lane.

- **Reserved Diamond:** 1.0 m wide by 4.0 m long, with a line width 200 mm. The distance between the Reserved Diamond and BUS is 10 m for speeds of 60 KM/H and below, 15 m for speeds above 60 KM/H.
- **Bus Lane:** The BUS dimensions are 2.40 m long by 1.9 m wide. The distance between BUS and LANE follows the same rules between Reserved Diamond and BUS. The LANE dimensions are 2.40 m long by 2.7 m wide, with 0.2 m spacing between each letter.
- **Thick White Dashed Line:** This line is used on the left side of transit lanes throughout standard traffic flow. 6 m segments of 200 mm wide white with 3 m gaps.
- **Thin White Line:** This line is used on the left-hand side of transit lanes at intersections (dashed) and on the right side of the transit lane if there is no curb (solid). Dashed lines are comprised of a 0.5 m line and 0.5 m gap. See example in Figure 4.27.

- **Angled Taper Line After Right Turn:** Where there is a right turn into a transit lane, there must be an angled white dashed line as further action to avoid regular vehicles turning into the transit lane (see example in Figure 4.30). A 2:1 taper ratio is required, with a 1.5 m gap, centered in the middle of the transit lane.

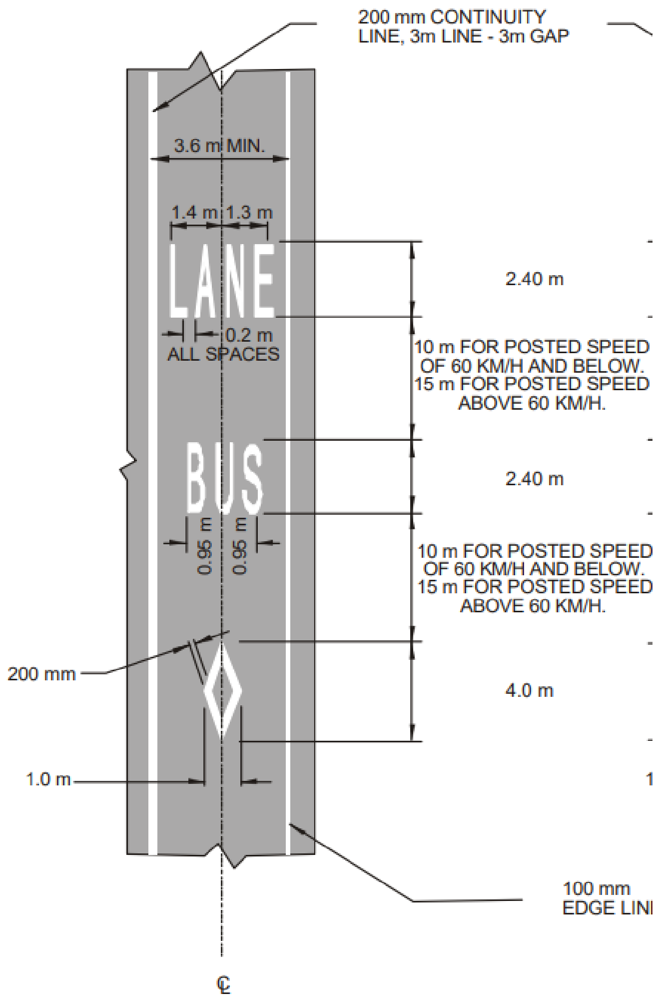


Figure 4.26: Transit Lane Pavement Marking

Source: MoTI Manual of Standard Traffic Signs & Pavement Markings

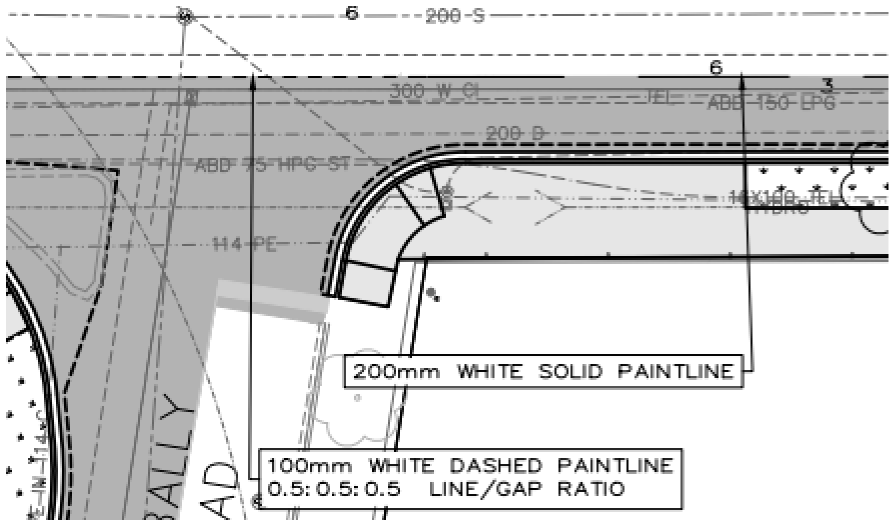


Figure 4.27: Dashed Line Usage for Transit Lanes (Douglas Corridor Phase 2B)

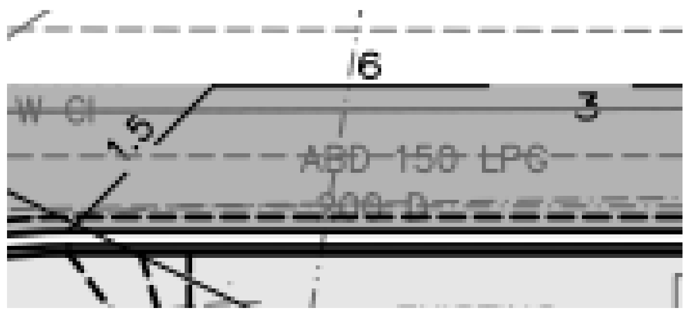


Figure 4.28: Right-hand Turn Taper (Douglas Corridor Phase 2B)

The in-lane painting for transit lane is spaced every 200m for roadways with a speed limit of 50 km/h. Use the following rule for the in-lane painting spacing:

$$\text{SPACING (m)} = \text{SPEED}\left(\frac{\text{Km}}{\text{H}}\right) * 4$$

4.5.2 Transit Lane Signage

W-321: HOV Lane in Right Lane after Turn symbol. The purpose of this sign is to inform drivers who are turning right onto a street with a transit lane to go past the lane and to turn into the all-purpose traffic lane. The sign needs to be located on the right-hand side of the intersecting street. Best practice is to place the sign on a pole with the sign a minimal distance of 2.0 m above the ground.

0.081 Aluminum

Sign Item Number	Dimensions (W x H) mm	Reflectivity ASTM Type	MoT Approval	Typical Application
W-321	750 x 750	9	-	Local Road / Low Speed or Arterial
W-321-x	900 x 900	9	-	Expressway

Figure 4.29: W-321 Signage

Source: MoTI Catalogue of Standard Traffic Signs

R-200-1D: There are different types of R-200 signs, all of which are variations of overhead transit/HOV lane designation signage. Project specific discrepancies between the different R-200 signs may occur, depending on the purpose of the transit lane. However, the standard signage is R-200-1D. All R-200 signage is overhead, with the following spacing between signs:

$$\text{SPACING (m)} = \text{SPEED}\left(\frac{\text{Km}}{\text{H}}\right) * 4$$

16 mm MDO PLY
or Ext Aluminum

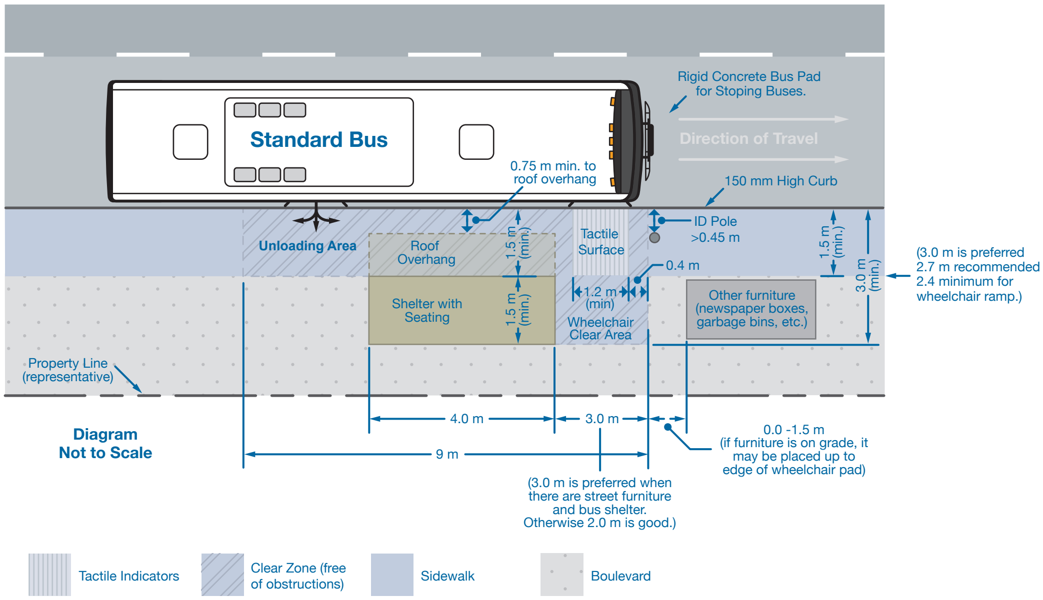
Sign Item Number	Dimensions (W x H) mm	Reflectivity ASTM Type	MoT Approval	Typical Application
R-200-1D	915 x 1220	3	-	Arterial or Expressway
R-200-1Dx	1220 x 1525	3	-	Freeway

Figure 4.30: R-200-1D Signage

Source: MoTI Catalogue of Standard Traffic Signs

4.6 TYPICAL BUS STOP LAYOUTS

4.6.1 Urban Locations



**3.0 m width is preferred when there are street furniture and bus shelter.*

Figure 4.31: Urban Bus Stop Layout

The landing pad should be 9 m to cover the front and rear door. Refer to Appendix C for tactile surface details.

Rapid Transit stops should also consider
- Live bus schedule;
- Level door boarding is not advised due to mixed fleet types;
- Bus stop platform and access facilities to service the expected number of riders without overcrowding or spillback to accommodate future growth;
- Concrete bus pad for stopping buses;
- Orange bus lollipop sign indicating rapid transit.

4.6.2 Rural Locations

Rural roads do not always have sidewalks. In these locations, a landing pad can be constructed to create an accessible bus stop. The pad should have a minimum depth of 3.0 m if a shelter is provided. The pad should have a curb ramp (maximum 8% slope) at each end to direct passengers away from the road.

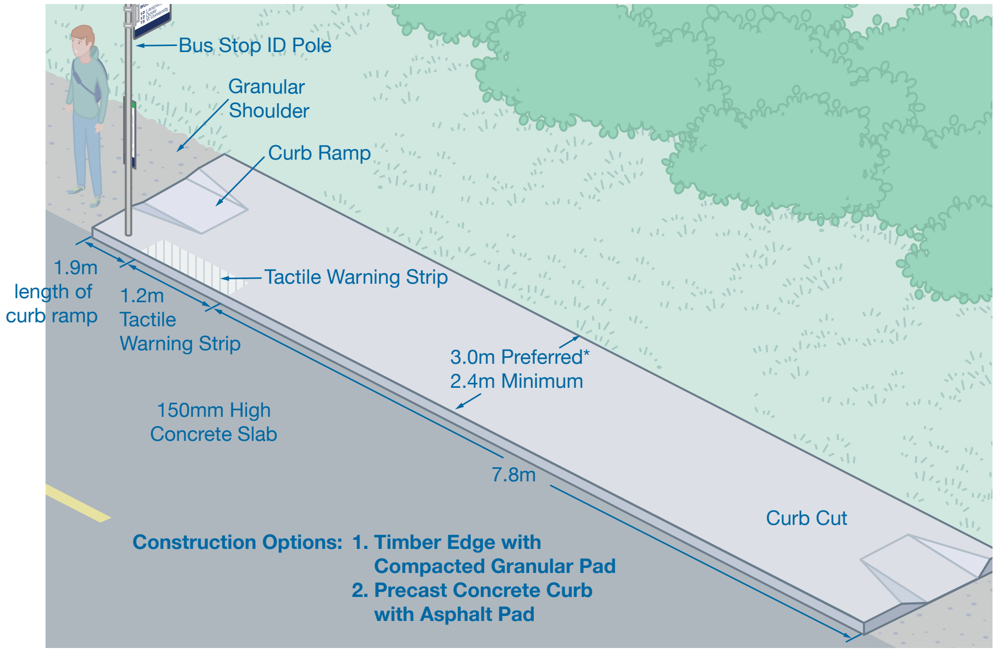
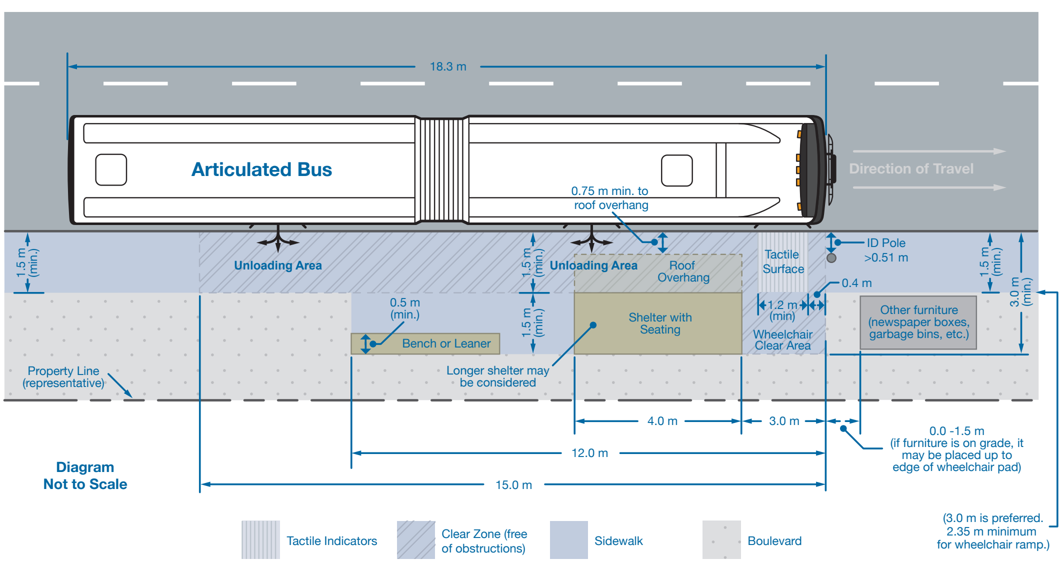


Figure 4.32: Rural Bus Stop Layout

4.6.3 Articulated Buses

Articulated buses are not currently operated by BC Transit, but as ridership grows and service improvements are made, it is important to consider the future use of a bus stop and the range of different vehicles that might service the location.

- Bus bay length must be at least 20 m.
- Taper into bus bays must be at least 21 m
- Distance between the sign pole and curb face must be no less than 0.51 m; and
- Landing pad to cover all three doors.



**3.0 m width is preferred when there are street furniture and bus shelter.*

Figure 4.33: Articulated Bus Stop Layout

4.7 BUS STOP DESIGN CONSIDERATIONS

This section provides additional design notes and discussion regarding the typical bus stop layouts previously shown in Section 4.6.

4.7.1 Curbside Clearance Zone

The number of objects within the curbside landing area should be minimized to provide accessible access. The bus stop sign as well as other objects near the front of the bus can be placed up to 0.30 m from the curb face. All objects within the rear curbside area should be at least 0.45 m back from the curb face.

The rationale behind these requirements is based on the following.

Curbside Sweep

The Nova Bus has the longest front and rear overhangs of any bus in the BC Transit fleet, and the greatest sweep as it pulls out of a bus stop. At the extreme, the Nova Bus sweeps an additional 0.40 m from its at-rest position. However, if a 0.18 m clearance between the curb and the bus wheel is assumed, the result is a 0.22 m curbside sweep (see Figure 4.34). The rear of a bus is usually 0.36 m away from the curb face, so allowing for 0.18 m clearance errs on the side of caution.

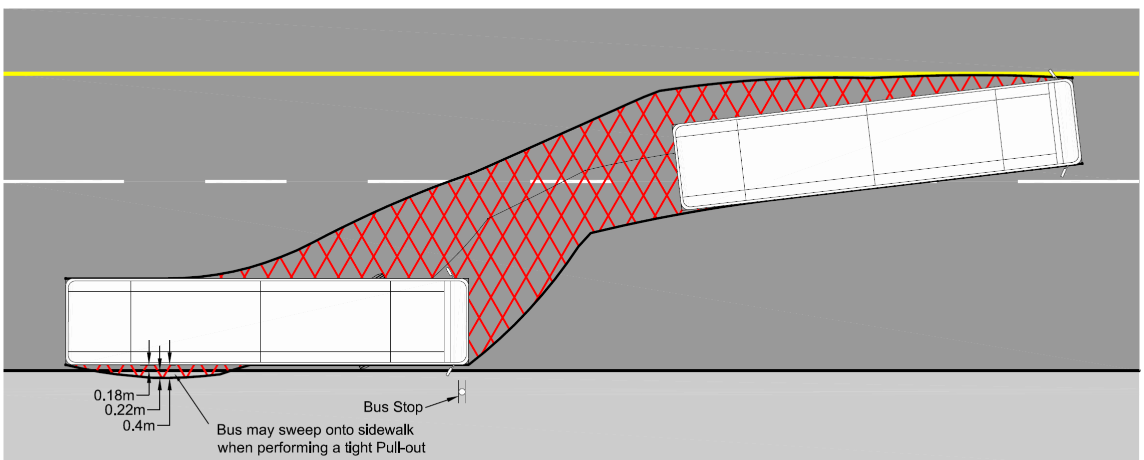
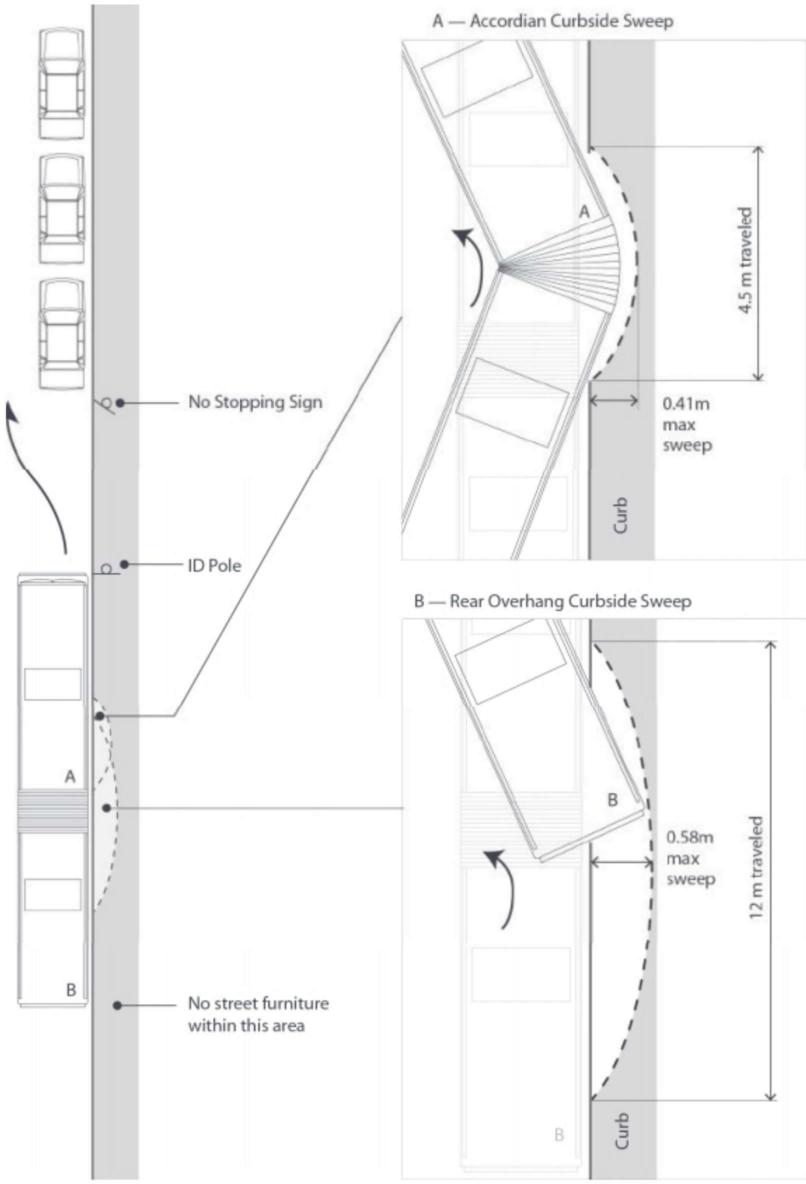


Figure 4.34 Curbside Clearance Zone

Figure 4.35 below shows the design dimensions of the articulated bus from the TransLink Guidelines.



DISTANCE TRAVELED (m)	SWEEP (m)
0	0
0.5	0.13
1.0	0.23
1.5	0.27
2.0	0.32
2.5	0.41 (max)
3.0	0.26
3.5	0.20
4.0	0.10
4.5	0

DISTANCE TRAVELED (m)	SWEEP (m)
0	0
2.5	0
3.5	0.15
4.5	0.25
5.5	0.37
6.5	0.43
7.5	0.47
8.5	0.58 (max)
9.5	0.44
10.5	0.27
11.5	0.05
12.0	0

Figure 4.35 Lateral Sweep of Articulated Bus

Source: TransLink Bus Infrastructure Design Guidelines

Mirror Protrusion

The right mirror of the Nova Bus protrudes 254 mm from the edge. It's okay if the mirror hangs over the sidewalk as the bus pulls into a stop, provided there are no obstructions. Clearance should be allowed for the worst-case scenario, where the front of the bus pulls up immediately adjacent to the curb, rather than allowing for the more typical gap of 180 mm.

4.7.2 Door Clearance Zones

Figure 4.36 illustrates specific door clearance zones to allow for unimpeded passenger movement. Distances are measured from the bus stop ID post.

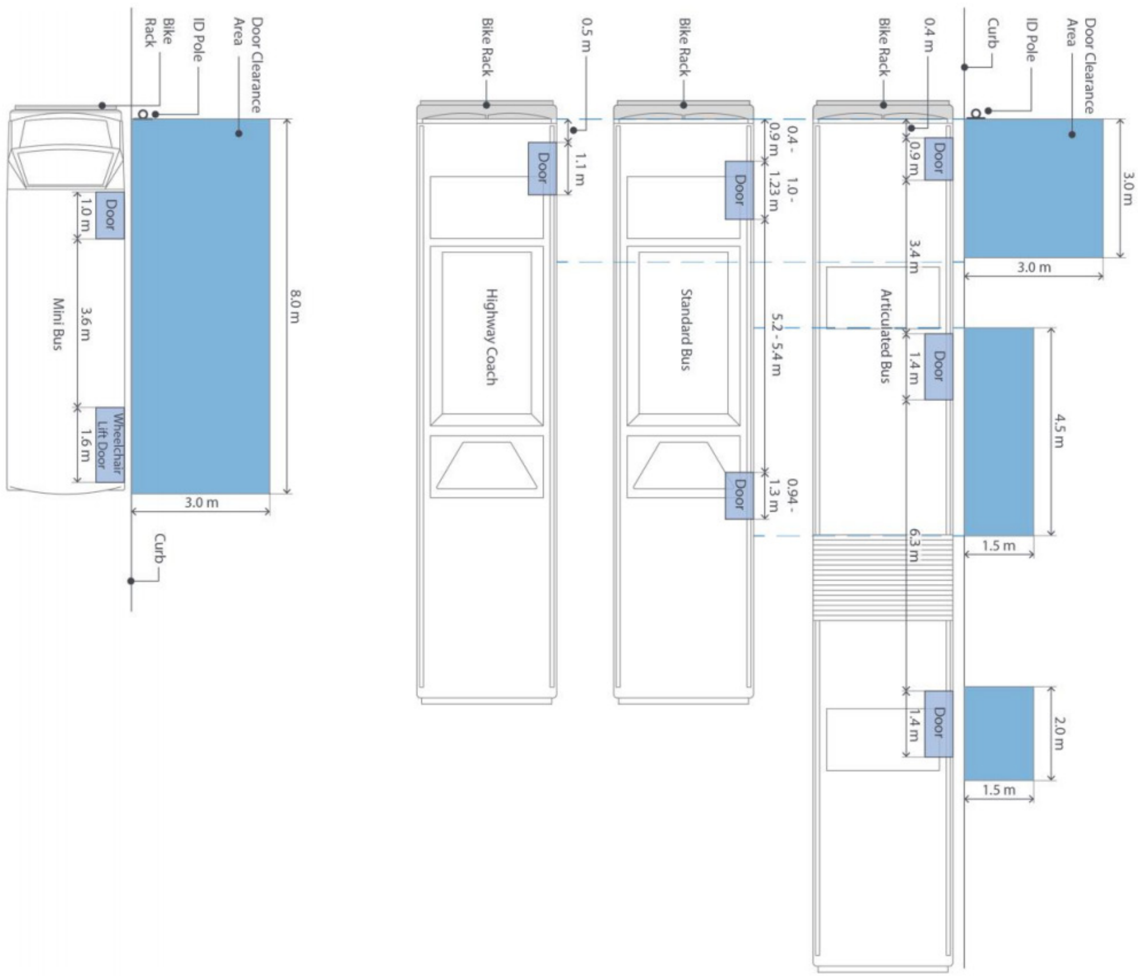


Figure 4.36 Door Clearance Zones

Source: TransLink Bus Infrastructure Design Guidelines

4.7.3 Passenger Landing Pad

A passenger landing pad is the surface at a bus stop where passengers wait to get on and off the bus. Landing pads are firm, even and slip resistant. When feasible, they should connect to sidewalks that lead to adjacent intersections. When there isn't a sidewalk, the landing pad should be raised with connecting ramps on each end to the road shoulder.

A 9 m long by 3 m wide passenger landing pad with a maximum 2% cross slope is recommended. Passenger landing pads may have amenities such as shelters or garbage receptacles, but they should not prevent riders from accessing the bus doors.

4.7.4 Wheelchair Clear Area

A wheelchair pad is a designated area within the passenger waiting area, located where the front of the bus is likely to stop. They are obstruction-free areas where the bus deploys its ramp or lift, and the mobility device user manoeuvres as needed between the sidewalk and the bus (or vice-versa).

Depending on site-specific conditions, the wheelchair pad may be located outside the bus shelter, within the shelter with the sidewalk behind the shelter, or within the shelter with the sidewalk in front of the shelter.

The minimum clearance area for a wheelchair pad either within or outside a shelter is 2 m (parallel to the roadway) by 2.75 m (perpendicular to the roadway) with 3m preferred in both directions. See Figures 4.37 and 4.38. The wheelchair pad requirements exceed those of the American Disability Act (ADA) Standards for Accessible Design.

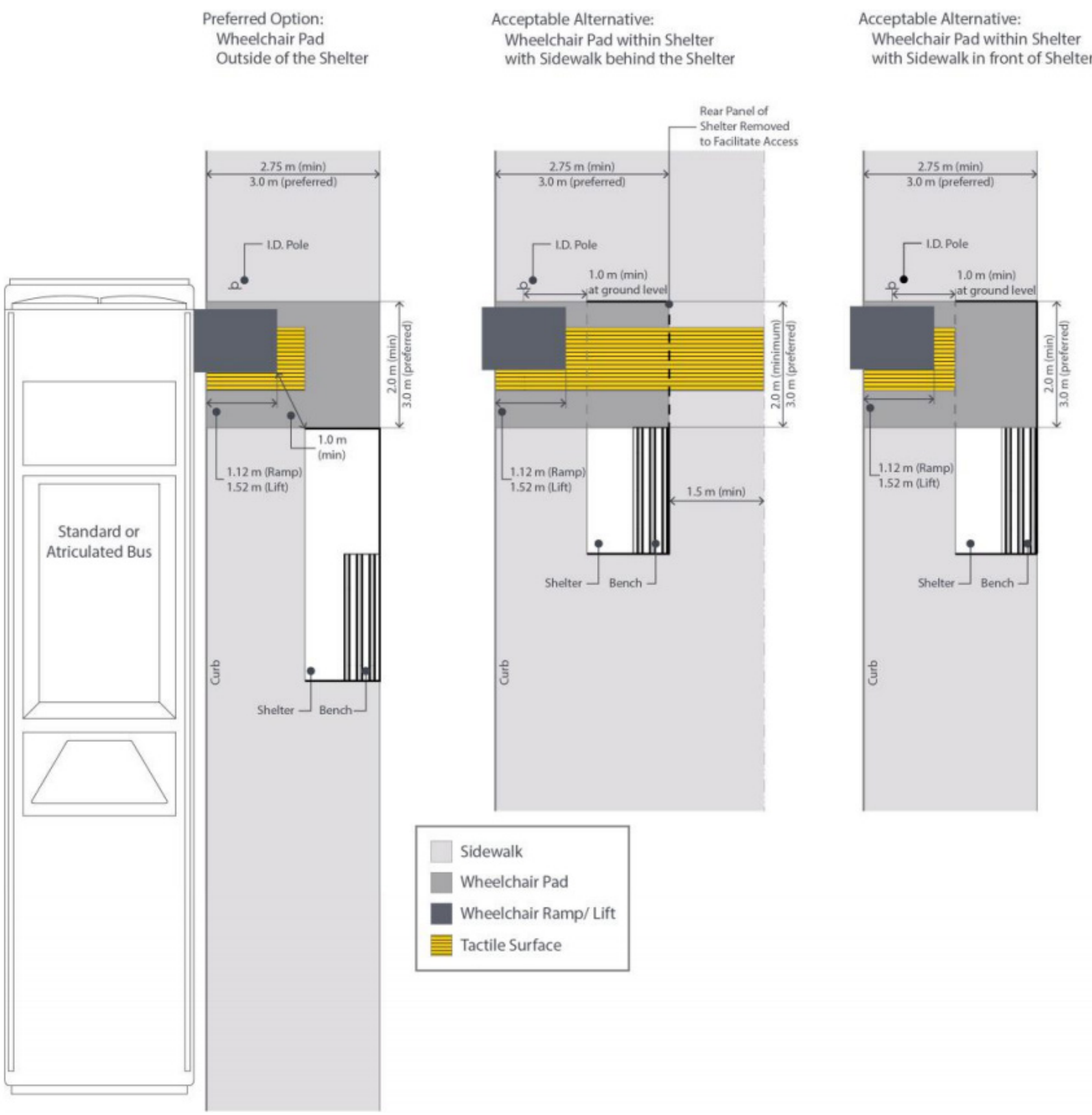


Figure 4.37 Wheelchair Pad Location and Dimensions (Standard or Articulated Buses)

Source: TransLink Bus Infrastructure Design Guidelines

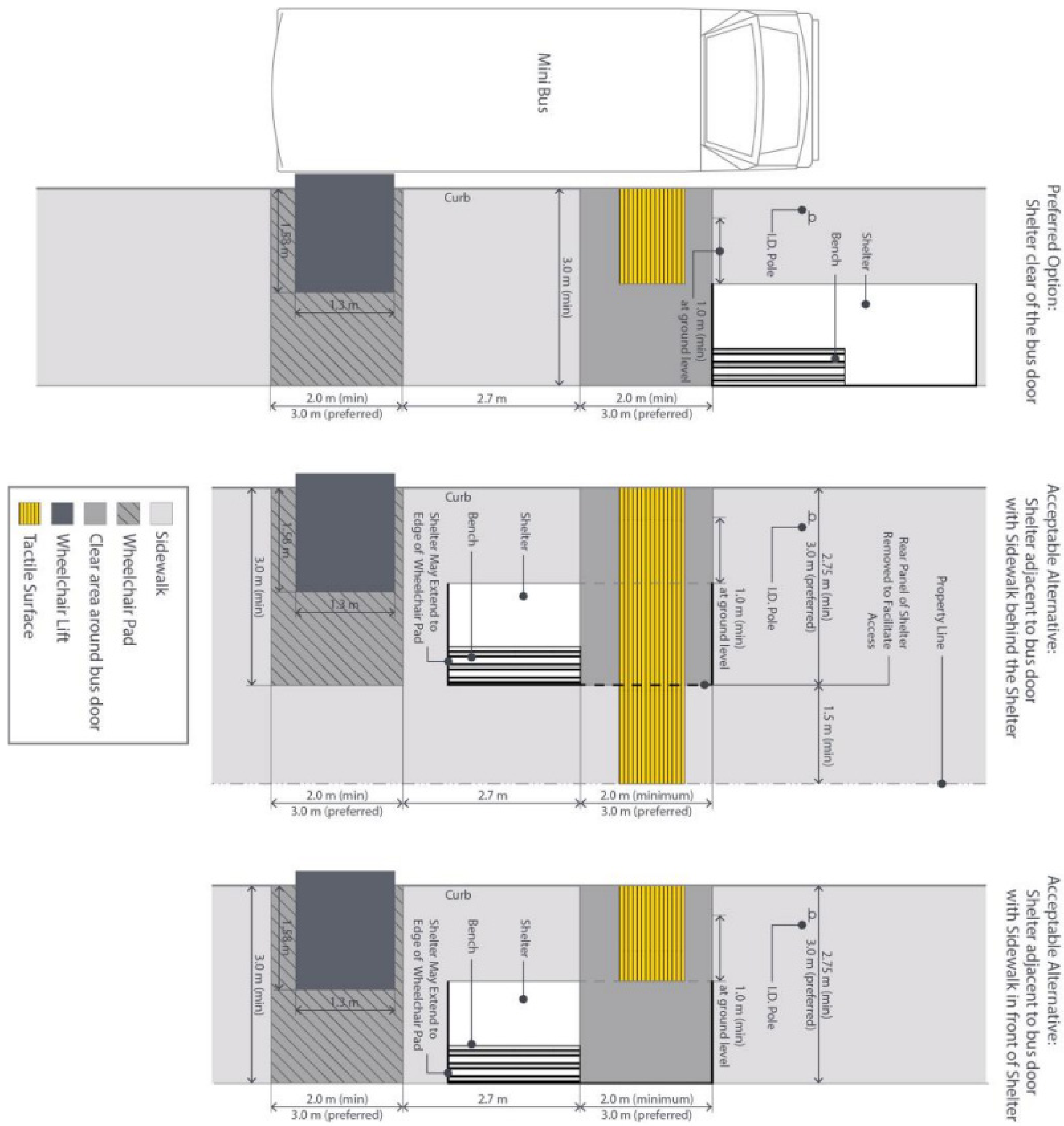


Figure 4.438 Wheelchair Pad Location and Dimensions (Light Duty Bus)

Source: TransLink Bus Infrastructure Design Guidelines

4.7.5 Bus shelters

Bus shelters are partially enclosed waiting areas that protect waiting passengers from the weather and contain important information such as route maps and schedules. Clearly identified BC Transit shelters are preferable.

Bus shelters are warranted when more than one of the following conditions is met:

Table 4.7 Bus Shelter Warrant

Condition	Bus shelter
Bus service	Frequent services are provided and/or there are a number of transfers at a stop, hence more passenger activities.
Adjacent land use	Shelter can be made compatible with the adjacent land use (for example, a bus stop in a busy commercial area or modal interface with rail, boat or air transit) and space is available for construction such that the shelter can be sited on level ground and without obstructions by trees, utility poles, etc.
Passenger demographics	There are relatively high percentages of seniors and/or people with physical disabilities using the bus stop.
Passenger request	The request is supported by the conditions above.

Shelters should be located:

- Parallel to curb. Usually the shelter faces the curb, but can be rear-facing to accommodate winter conditions;
- Where the transit operator can easily see waiting passengers;
- Clear of the passenger landing area or pedestrian path; and
- Clear of steps between the sidewalk/bus pad and the shelter.

Some municipalities and transit systems have agreements in place with companies to acquire shelters at no cost in return for the right to display advertising. Regardless, the same location criteria and design considerations apply.

Figure 4.39 BC Transit Branded Shelter

While shelters are available in various configurations, the BC Transit recommends:

- Four-sided shelters must have a minimum 1 m wide opening;
- Not typically installing glass panels due to high maintenance costs, but if used, they should be marked with a contrasting horizontal stripe minimum 75 mm wide, located approximately 140 to 160 cm above ground level. Glass panels are recommended where other materials would otherwise create a sight line issue;
- Sides are transparent;
- Seating is oriented to view oncoming transit and pedestrians; and
- Lit shelters are preferred to improve shelter safety and visibility.

No component of the bus shelter should be closer than 75 cm to the curb to avoid a potential collision with the right mirror of the bus.

BC Transit also offers the Transit Shelter Program which provides an overview of standardized bus stop shelter designs across the province for all operating conditions, including harsh winter weather.

4.7.6 Seating

Even without a bus shelter, seating is a beneficial amenity. Benches should be located away from access driveways, using nearby trees for shade and wind/rain protection. Benches should also not obstruct the accessible path of travel. Materials should be resistant to weather, water retention and vandalism.

Benches should have a seat height of between 430 mm and 486 mm and, where possible, offer backrests. Ideally, if a variety of seating is offered, it is recommended to offer seating with and without armrests. An adjacent firm and level area of at least 830 mm x 1350 mm should be provided for wheelchair users or parents with strollers to wait out of the path of travel.

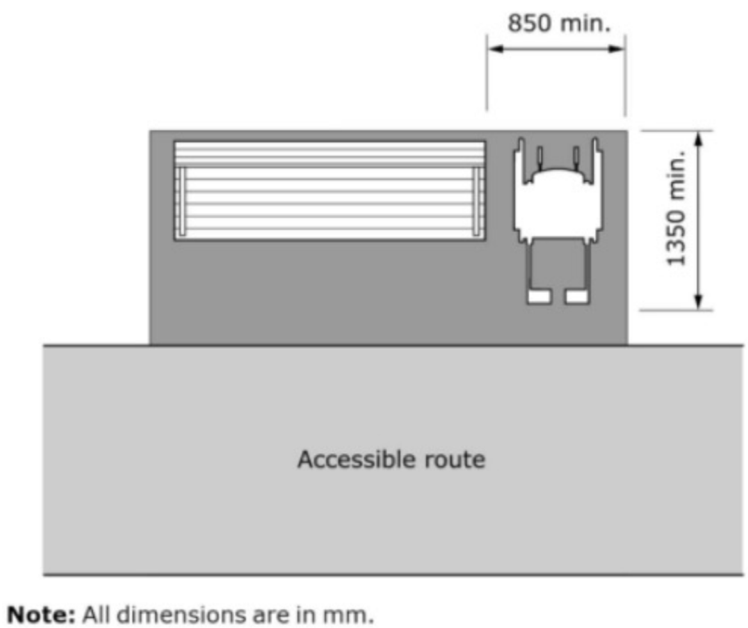


Figure 4.40 Bench Area

Source: CSA B651-18 (Figure 55)

4.7.7 Bicycle Parking

All high-activity bus stops and transit exchanges, especially those with a Park & Ride, should consider bicycle parking. Safe, organized, well-lit and conveniently located short- and long-term bicycle parking deters damage and theft, and may encourage more transit users to cycle to access transit service.

The BC Active Transportation Design Guide provides detailed bicycle parking best practices.

4.7.8 Passenger Information Display System and Wayfinding

Providing clear and simple transit information improves customer satisfaction. The Passenger Information Display System (PIS or PIDS) can be deployed at rapid bus corridors to give real-time transit arrival information. Wayfinding maps are often offered in high-density areas, transfer stops or areas with local attractions. PIS/PIDS and wayfinding should:

- Present information in a manner that is clear, simple and universal, particularly helpful when transfer stops are some distance apart;
- Carefully consider level of detail to avoid confusion and information-overload;
- Present key information, particularly frequency, running time (throughout the week), and accessible destinations so transit users can make well-informed decisions;
- Use universal design principles, including audible and tactile resources;
- Make signs visible and recognizable from all corners of an intersections; and
- Maintain BC Transit's brand.

4.7.9 Passenger Queue Management

Passenger queue management is used at rapid transit stops where an exceptionally high number of boarding passengers can block the sidewalk. Queue management is particularly useful at locations where all-door boarding is permitted. A well-managed queuing system reduces crowding at doors and can lower the overall stop dwell time.

- Alighting passengers must be able to exit the bus first. This should be communicated to boarding passengers through signage;
- Stops serving multiple routes should provide a separate boarding and queuing area for each route;
- The marked queue lines should have sufficient clearance for a pedestrian through-zone; and
- Use lean bars where there are long queues.

4.7.10 Physical Protective Measures

Physical protective measures, such as barrier curbs, bollards, fences, guardrails, concrete roadside or low barriers can enhance passenger safety and protect infrastructure at multi-position bus stops and transit exchanges.

While not mandatory, protective measures should be considered at locations where there have been incidents in the past, or where the following potentially hazardous situations may exist:

- Bus stop is at a downward slope, with a passenger waiting area/infrastructure in front of the transit vehicle. Transit vehicle may roll forward;
- Bus stop is at an upward slope with a passenger waiting area/infrastructure behind the transit vehicle. Transit vehicle may roll backward;
- Bus stop with a high-density passenger waiting area in front or behind the stopped transit vehicle;
- Bus stops along high-speed routes where transit vehicles operate with high deceleration or acceleration rates; and/or
- A structure is located near the curb face, e.g. within 2 m.

Bollards or barriers can be concrete, steel, wood or a combination of these materials. If barrier curbs are continuous and high, they can interfere with bus entry and exit, as well as passenger boarding and alighting. If the decision is to use bollards at a bus stop, it's preferable to use fixed bollards. However, if vehicle access is required, use removable or retractable bollards.

Bollard design considerations include:

- Use at least two bollards and ensure the space in between is less than the width of transit vehicles using the stop;
- Fixed bollards designed against a defined level of threat and installed permanently in a foundation capable of resisting the threat;
- Removable bollards installed in a sleeve or mount buried underground. Usually flush with the ground surface so the bollard can be removed to allow access. They are generally designed to resist low impact loads in comparison with fixed bollards, and may be installed temporarily at locations where there is a possibility of access change; and
- Retractable bollards that may be automatically or manually operated to retract underground. Retractable bollards may use lift assistance mechanisms to deploy.

Position protective measures behind the curb within the potential trajectory of transit or vehicle movements.

While physical protective measures can improve safety, they also reduce the usable passenger waiting area and may be problematic for those with limited eyesight. Furthermore, if a bus carrying passengers collides with the protective measure, injuries could occur. Before installing bollards of other protective barriers, conduct a careful analysis and risk assessment.

4.7.11 Concrete Bus Pads

Buses are heavy and cause deformation in asphalt pavement – especially in locations where they start, stop or turn. Bus stops, in particular, are susceptible to pavement damage. To minimize pavement wear, a concrete bus pad should be considered for all high bus volume locations. Although concrete bus pads are more expensive than normal asphalt paving, they will reduce long-term maintenance costs and help to retain roadway surface shape, drainage and skid resistance.

Concrete bus pads should be a minimum of 3 m wide, stretch across the entire lane or bay where a bus stops, and be long enough to cover the entire wheelbase of a bus.

- Standard Bus and Double Decker = 10 m
- Articulated Bus = 16 m
- Light Duty Bus = 6 m
- handyDART = 10 m

In the case of a multi-stop bay, the concrete area should span from the front wheel of the first bus to the rear wheel of the last bus, including pull-in/pull-out zones.

Minimum concrete bus pad thicknesses should be as follows:

- Portland Cement Concrete: 225 mm
- Base Course: 150 mm
- Sub-base Course: 300 mm

4.7.12 Lighting

Lighting at bus stops and other transit facilities improves passenger visibility, promotes personal security and deters unwanted activities. Lighting levels at transit facilities should be no less than adjacent street lighting. Supplemental lighting may be required at isolated bus stops, transit exchanges or Park & Rides.

TransLink's Universally Accessible Bus Stop Design Guidelines recommend a lighting level of 20 to 50 lux at all ground level bus stops. For transit exchanges and bus stops, TransLink Guidelines recommends a lighting level of 50 lux.

CHAPTER 5 Transit Hubs

5.1 INTRODUCTION

Transit Hubs allow for a greater degree of passenger transfer movement (both bus-to-bus and intermodal) than at a typical curbside stop. Transit hubs can consists of the following components:

- Transit Exchange;
- Park & Rides; and
- Passenger Pick-Up and Drop-Off Facility (also known as a Kiss-and-Ride)

5.2 TRANSIT EXCHANGES

A transit exchange has multiple transit stops, allowing passengers to transfer from one bus to another. Transit exchanges are commonly the terminal stops for many bus routes and can be on- and off-street.

Figure 5.1 Example of an On-street Transit Exchange

Figure 5.2 Example of an Off-street Transit Exchange

5.2.1 Location Considerations

A bus transit exchange is often at the end of a route to maximize transfer opportunities and minimize any detours a bus must take to access it.

Major trip generators like shopping centres and institutional facilities are also good locations for a transit exchange, acting not only as an exchange but also as a hub of concentrated activities.

Another candidate location for a bus transit exchange is where multiple bus routes pass by in the vicinity, creating high demand for transfer movements between routes.

5.2.2 Design Considerations

The size of a transit exchange depends on land availability, local operating conditions, the number of bus routes served by the site, as well as:

- Bus access (to and from adjacent roadways);
- Bus circulation within the transit exchange;
- The type and number of buses;
- Bus layover space;
- Pedestrian access routes to and from the transit exchange;
- Passenger amenities;
- Bicycle parking;
- Accessibility within the transit exchange, and the surrounding area;
- Measures to reduce bus-auto-pedestrian conflict;
- Bus operator restrooms;
- Integration with nearby parking or drop-off zones; and
- Signage within the layout to direct users to appropriate bay.

Passenger platforms vary in size and configuration depending on the number and types of buses, as well as expected passenger volumes and profile. The two most common transit exchange configurations are the parallel loading platform and the sawtooth loading platform.

A combination of these configurations is often used in actual design. All designs should consider the typical design considerations for on-street bus stops.

Parallel Loading Platform

A parallel loading platform typically consists of multiple bus stops aligned one after another along a curb, with spacing in-between to accommodate bus pull-in and pull-out movements. To accommodate the same number of buses, a parallel loading platform usually requires a longer platform length than the sawtooth platform.

The right-of-way between the platform and the edge of the bus transit exchange should be 6.5 m to allow buses to pass a stopped bus. There should be 30.5 m between individual stops: 18 m for the pull-in zone and 12.5 m for the stopped bus. To minimize space requirements, the pull-out zone shares road space with the pull-in zone of the next stop. These calculations are based on the New Flyer Hybrid bus requirements.

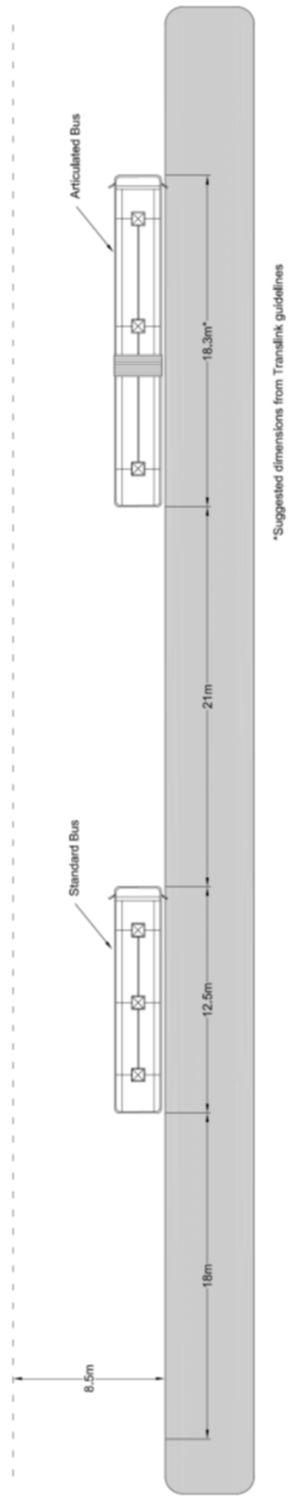


Figure 5.3 Parallel Loading Platform

Sawtooth Loading Platform

Sawtooth loading platforms are characterized by the jagged edges of the pedestrian platform area, which allow buses to pull in at an angle. They require a shorter platform length than a parallel loading platform.

Figure 5.4 Sawtooth Loading Platform

The platform teeth should protrude 1.3 m from the rest of the platform, and taper over a 14 m pull-in/ stopping zone and a 6 m pull-out zone. It is preferred that all jagged edges are rounded with a radius of 8 m (minimum 6 m) for easier maintenance (see Figure 5.5).

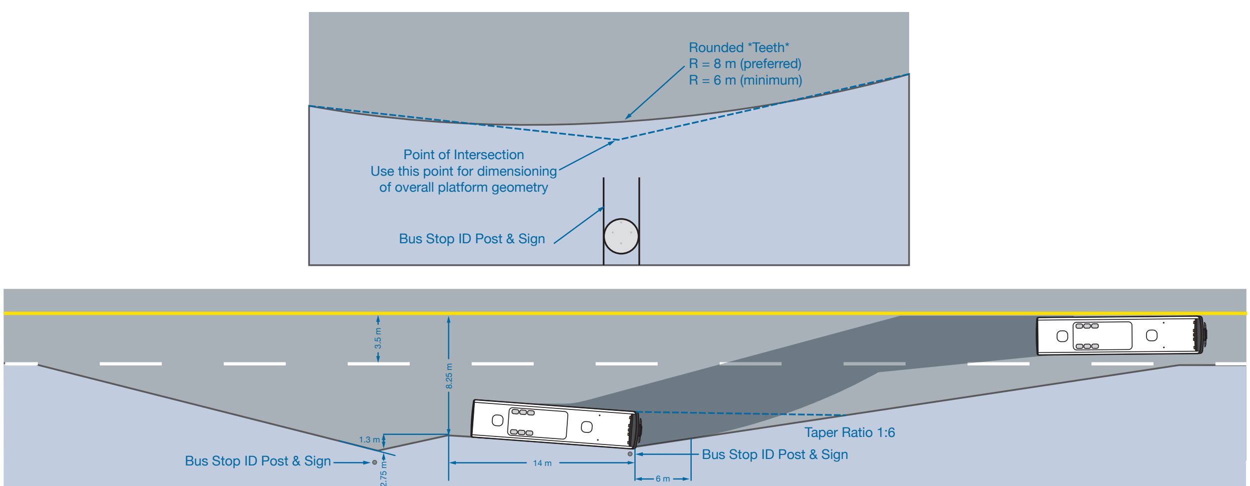


Figure 5.5 Sawtooth Loading Platform Reference Points

Sawtooth platforms can be used at curbside stops, and as part of an island platform at a bus transit exchange. Depending on the set-up, there are several key layout dimensions to consider.

i) Curbside sawtooth stop

The length of the platform requires a 2.75 m minimum platform clear width (excluding the teeth). Additionally, the roadway space for bus parking should be at least 4.75 m from the tip of the teeth (e.g. 6.05 m including teeth width) to the nearest travel lane. This allows buses to safely pull in and out of their stops without interfering with traffic. At either end of the bus layover space, there should be a taper to and from the adjacent travel lane. A 1:6 taper ratio is recommended.

Based on all these criteria, a rough approximation of the area required for this type of bus stop is as follows:

- Land width: 8.8m measured from the left edge of nearest travel lane
- Land length: 77 m (including tapers) for a single bus stop, plus an additional 20 m for each additional bus stop

Note that calculating an area using these values includes two triangular wedges of land at either end (where the tapers are located) that is not actually required for use. Depending on the nature of existing site conditions, it may be possible to reduce the total land area required by excluding these sites.

Figure 5.6 illustrates an example of a 4-bay curbside sawtooth stop, using the New Flyer Hybrid Bus as the design vehicle.

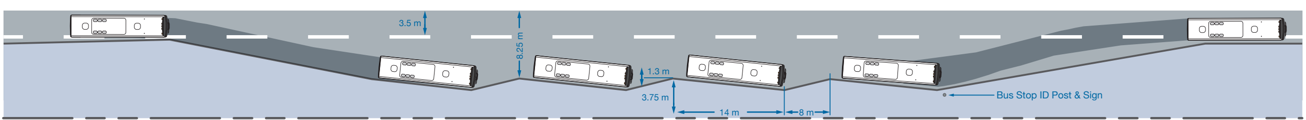


Figure 5.6 Multi-Bay Curbside Sawtooth Stop

ii) Island platform at transit exchange

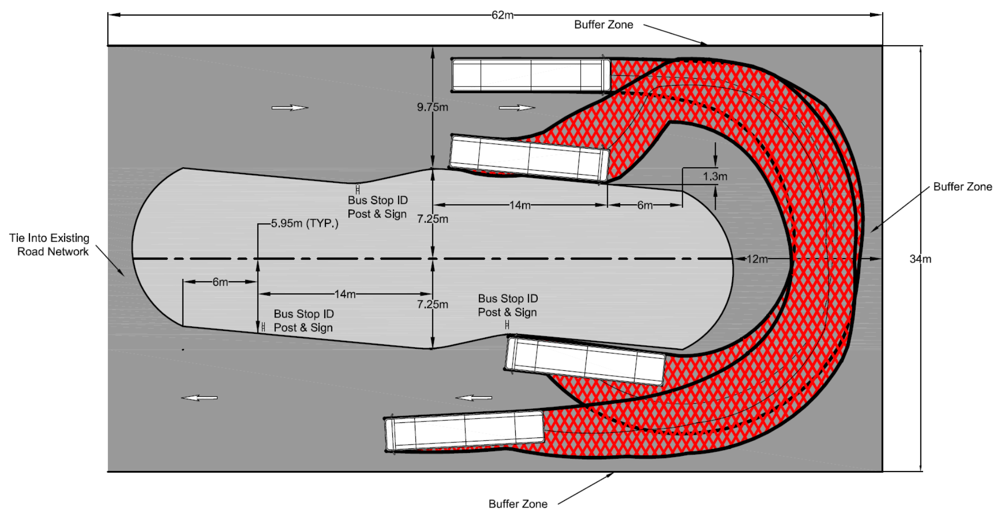
An island platform may feature sawtooth bus stops on both sides. This set-up is typically used at a major transit exchange, which is assumed to be off-road with prohibited access by general traffic. There are two major design considerations for an island platform: the accommodation of pedestrians (ensuring the platform is large enough to handle expected pedestrian volumes), and making sure buses have sufficient space to move around the exchange.

Island platforms should be at least 5.5 m wide (excluding the teeth) to allow for pedestrian circulation. Wider platforms are recommended if high passenger volumes are anticipated or there are amenities such as benches and landscaping. In terms of road space, a minimum of 9.75 m (from the tip of the teeth) is required for effective bus circulation and adequate layover space.

At the end of an island platform, buses must make a 180-degree turn. To accommodate this sweep path, the transit exchange must be wide enough, with a minimum distance from the stops closest to the end of the turn area. There is some degree of trade-off between these two parameters. A narrower platform needs more space past the end of the platform for a bus to make a turn, while a wider platform needs less.

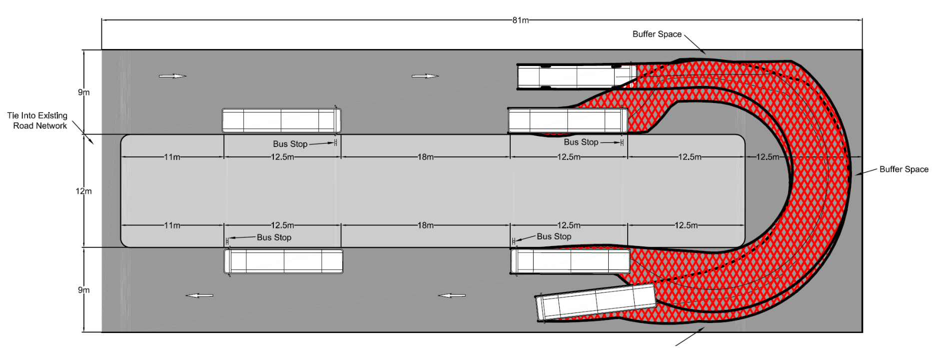
Figure 5.7 illustrates two sample bus loop designs: a 4-bay wide sawtooth platform and a 4-bay parallel platform. It's assumed that all buses enter and exit the loop in a clockwise manner. The vehicle sweep paths are based on the New Flyer Hybrid Bus.

a) Sawtooth Platform



62m
x 34m
2,108m^2

b) Parallel Platform



81m
x 30m
2,430m^2

Figure 5.7 Platform Size Requirements (For Illustrative Purpose Only)

Other Considerations in Transit Exchange Design

- Provide buffer room at the edge of the bus loop because drivers do not execute turns in exactly the manner shown in the sweep path analysis. The exact amount depends on site conditions at the end of a transit exchange, and the severity of consequences if the bus exceeds them. For example, if the transit exchange has a large gravel shoulder beside it with no major obstructions, it's not an issue if a bus drives on it occasionally. But if there is a major vertical surface at the edge of the site, such as a fence or wall, there should be a buffer – up to 2 m depending on conditions – to allow for bus mirrors and bike racks. It's not safe or efficient if a driver has to back up and try again after an improperly executed turn;
- Where there is very limited space, paint lines on the pavement to reflect the outer front wheel sweep path. This will help bus drivers complete the turn;
- With exceptionally complicated manoeuvres, field test the layout at a bus depot; and
- Include layover space if a bus transit exchange is a timing point or a terminus loop, and multiple routes are scheduled to arrive at the same bay. This might require additional land around the outer edges of the loop.

5.2.3 Bus-Pedestrian Conflicts within a Transit Exchange

Properly designed transit exchanges minimize conflicts and collision risks between buses and pedestrians. Painted crosswalks, handrails and/or wayfinding signage are used to guide pedestrians to areas of high visibility.

Pedestrians in a crosswalk should never have their backs to oncoming buses. As a result, locate crosswalks to maximize available sight distance between drivers and pedestrians: either behind a bus stop, before a point where a bus starts to turn, or at a point after the bus has turned. Curb extensions can enhance pedestrian visibility at a crosswalk in front of a bus stop.

If there are potential shortcut routes with limited visibility, use handrails to funnel pedestrians to a specific path and/or crosswalk.

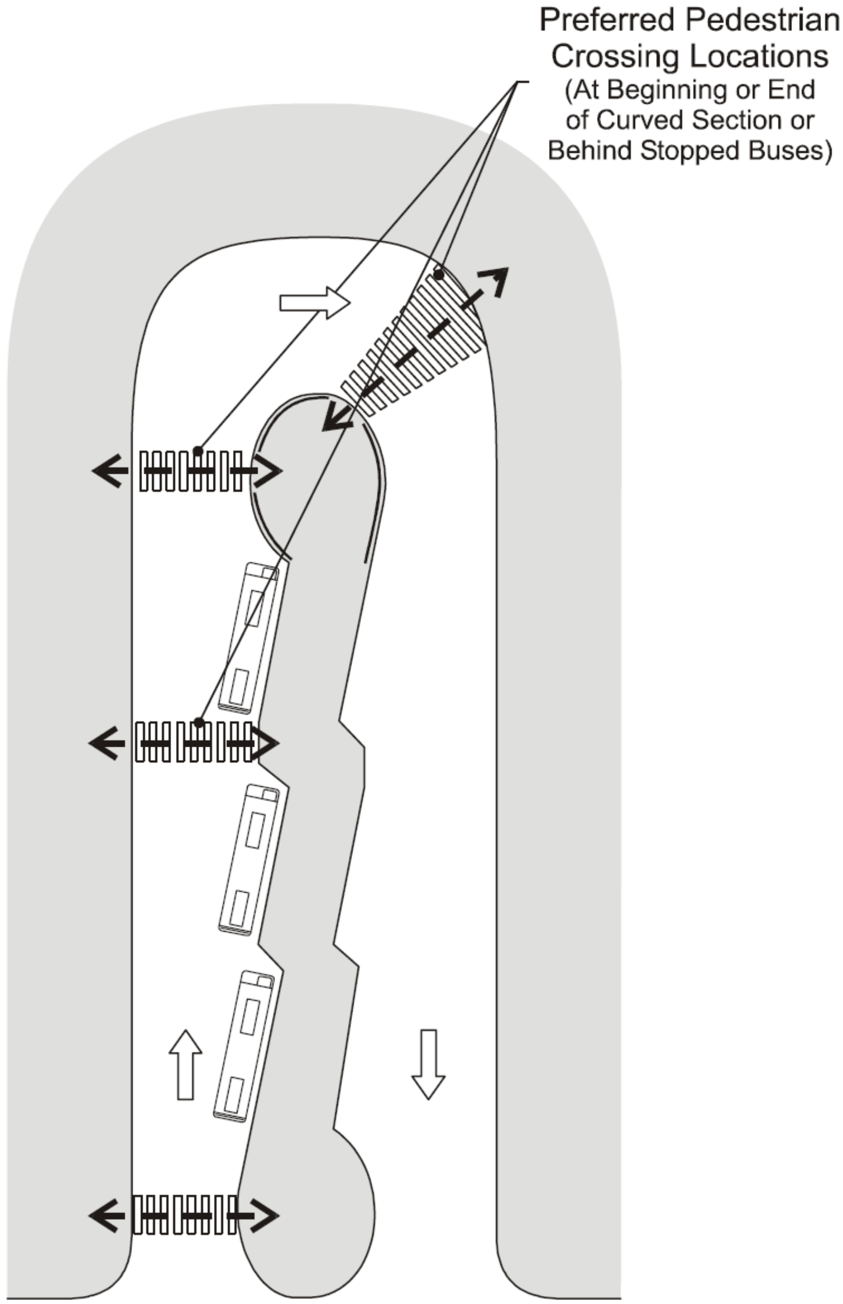


Figure 5.8 Pedestrian Crossing Within a Transit Exchange

Source: TransLink Bus Infrastructure Design Guidelines

5.2.4 Passenger Access, Boarding and Alighting Activities

Pedestrian access both within a bus transit exchange and to the surrounding area are important considerations in the design process. Walkways to surrounding areas should be as direct as possible and wide enough to accommodate pedestrian flows.

The Highway Capacity Manual (Transportation Research Board) describes the relationship between effective walkway width and passenger flow rates using Level of Service (LOS) (see Figure 5.9). Effective walkway width is what's available to pedestrians after discounting lateral restrictions such as a grass boulevard, trees and other fixed objects.

Eighty pedestrians per minute per metre is maximum capacity for a walkway (LOS E). For design purposes, LOS C is recommended. Using figure 5.9, the required walkway width can be determined based on the expected pedestrian flow rate, if it is known.

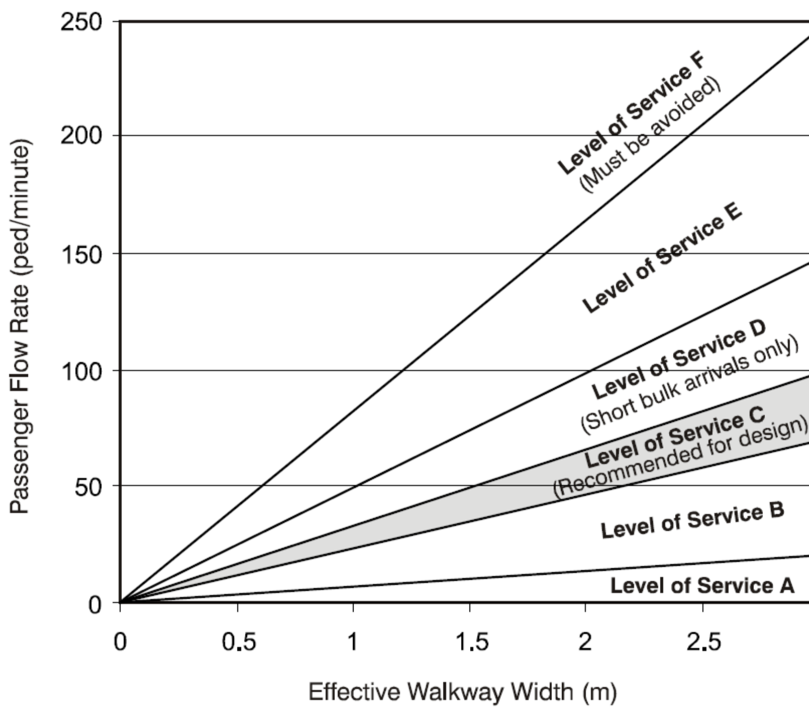


Figure 5.9 Relationships Between Pedestrian Flow Rate and Effective Walkway Width

Source: Highway Capacity Manual, Transportation Research Board

Effective walkway width (see Figure 5.10) may be lower than the total width, depending on what is adjacent to the walkway.

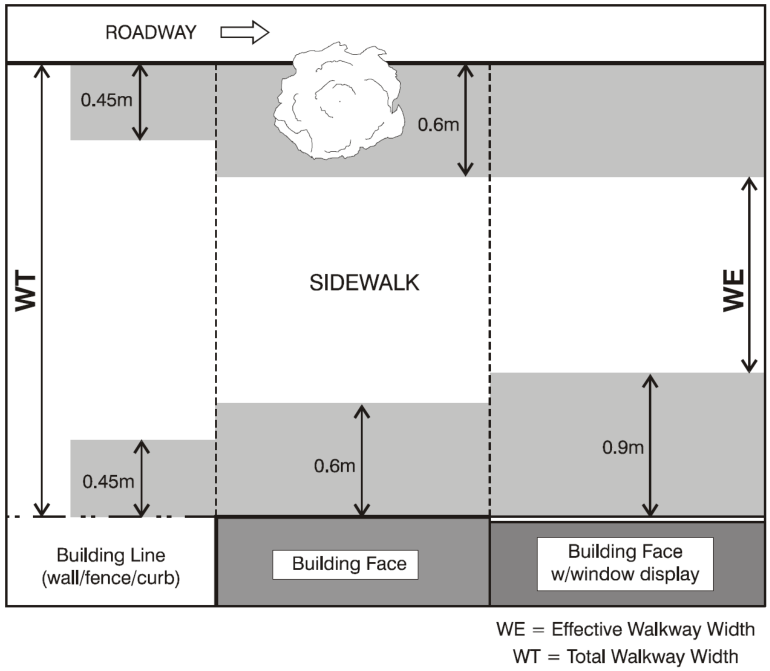


Figure 5.10 Effective and Total Walkway Widths

Source: Highway Capacity Manual, Transportation Research Board

To accommodate a pedestrian and a person using a mobility device, the suggested minimum effective walkway width (WE) is 2 m. To accommodate three pedestrians abreast, between 2.25 m to 3 m WE is recommended.

Use a directional line or physical barrier if pedestrian flows are heavy and even in both directions. For routes with heavy boarding and alighting activities, offer separate unloading and loading areas to minimize pedestrian conflicts and reduce dwell times.

5.2.5 Loading Area Estimation

According to the Transit Capacity and Quality of Service Manual - 2nd Edition (TCQSM), the capacity of a linear loading area in buses per hour is*:

$$B_l = \frac{3{,}600 * (g/c)}{t_c} + t_d * \left(\frac{g}{c}\right) + Z * c_v * t_d$$

Where:

B_l	=	Loading area bus capacity (bus/hour)
3,600	=	Number of seconds in 1 hour
g/c	=	Green time ratio (the ratio of effective green time to total traffic signal cycle length, equals 1.0 for unsignalized streets and bus facilities
t_c	=	Clearance time (seconds)
t_d	=	Mean dwell time (seconds)
Z	=	Standard normal variable corresponding to a desired failure rate (assume to equal (1 – failure rate), where failure rate is 0.25)
c_v	=	Coefficient of variation of dwell times (assume 0.6)

**Refers to linear stops (as in parallel loading) as opposed to a sawtooth or other loading configuration.*

The resulting capacity (B_l) is then compared to the desired provision of buses per hour (typically derived from the arrival headway). Site characteristics and desired access and circulation patterns determine the length and arrangement of the various loading areas. Additional loading areas might be necessary if the route terminates at the transit exchange and/or vehicles are stored overnight.

In a transit exchange, linear stops are usually separated by the required pull-in zone (see Figure 5.3). However, when multiple stops are arranged in a linear manner without the pull-in zone, efficiency may be reduced due to the following:

- Rear-loading areas are used less because an arriving bus typically stops at the front-loading area;
- Dwell times are higher in rear-loading areas compared to front-loading because passengers waiting near the front need time to walk to the rear; and
- Depending on the gaps between buses, sometimes a bus can't leave until the bus in front departs.

To account for this reduced efficiency, the TCQSM - 2nd Edition applies an equivalent efficiency factor:

$$B_s = N_{el} * B_l$$

Where:

B_s = Bus stop bus capacity (bus/hour)

B_l = Loading area bus capacity (bus/hour), as calculated from the previous formula

N_{el} = Estimated capacities as shown in Exhibit 4-14 (Table 5.1) of the TCQSM - 2nd Edition (reproduced below)

Table 5.1 Estimated Capacities of Transit Exchanges

Dwell Time (s)	Number of on-line loading areas									
	1		2		3		4		5	
	g/C 0.5	g/C 1.00	g/C 0.5	g/C 1.00	g/C 0.5	g/C 1.00	g/C 0.5	g/C 1.00	g/C 0.5	g/C 1.00
30	48	69	84	120	118	169	128	182	133	189
60	27	38	48	66	68	93	74	101	76	104
90	19	26	34	46	48	64	52	69	54	72
120	15	20	26	35	37	49	40	53	51	55

Note:Assumes 10-second clearance time, 25% failure rate, 60% coefficient of variation of dwell times, and random bus arrivals. To obtain the vehicle capacity of non-linear on-line bus stops, multiply the one-loading area values shown by the number of loading areas provided.

5.3 PARK & RIDES

Park & Rides are usually located in suburban and rural areas, adjacent to transit connections to regional centres. Physical size is based on anticipated demand. Park & Rides have ample parking and may contain other amenities such as short- and long-term bicycle storage.

5.3.1 Park & Ride Design

To support transit ridership, a successful Park & Ride must be designed for use by cars, pedestrians and cyclists. Specific considerations are given to adjacent road network traffic operations, the interaction between various modes of travel and:

- Number of access driveways, driveway geometry and traffic control;
- Parking supply;
- Parking stall type, dimensions and configuration;
- Site circulation;
- Site security; and
- Interaction between modes.

5.3.2 Access driveways

Surrounding street traffic conditions determine the most appropriate location for Park & Rides access driveway(s). Avoid putting access driveways along exclusive turn lanes to reduce conflict between vehicles slowing to turn into the facility and exiting vehicles crossing traffic lanes to merge into the traffic stream. They also shouldn't be in the middle of a vertical crest curve as sight distance is limited for exiting vehicles, resulting in an increased risk of angle or crossing-type collisions.

The number of access driveways is based on peak arrival/departure volumes and adjacent road network geometry and traffic conditions.

If traffic volume is relatively high on an adjacent street, multiple access driveways can minimize delays for exiting vehicles. At the same time, driveway locations must be considered in the context of the surrounding road network, to ensure convenience and maintain traffic operations.

Typically, an access driveway is 8.5 m wide for a 2-lane access and 11.0 m wide for a 3-lane access. Simulation software can be used to assess the appropriate traffic control needed at the driveway intersection. Geometric design should also consider anticipated traffic volumes, movements at individual driveways, the number of lanes, traffic control with the intersecting public road, and available storage length for the anticipated queue in the exiting direction.

5.3.3 Parking supply

Designers must think long-term and consider land use, population growth, demographic, social and economic trends, auto and transit travel networks, and future increase in transit ridership.

The Trip Generation Manual (Institute of Transportation Engineers) Land Use 090 can be used to determine the relationship between vehicle trip ends and number of parking spaces. In the early planning stages, a survey of similar facilities can help identify trip patterns and parking utilization.

At least 5% of the stalls should be accessible parking.

5.3.4 Parking Stall Dimensions and Configuration

Municipalities typically set requirements for parking stall dimensions. The best practice for accessible perpendicular parking is to have a minimum stall width of 2.6 m with an adjacent, shared, access aisle of 2 m wide (see Figure 5.11). The access aisle should connect to a curb ramp and sidewalk or designated walkway allowing for safe and direct passage from the parking stall to the transit facilities.

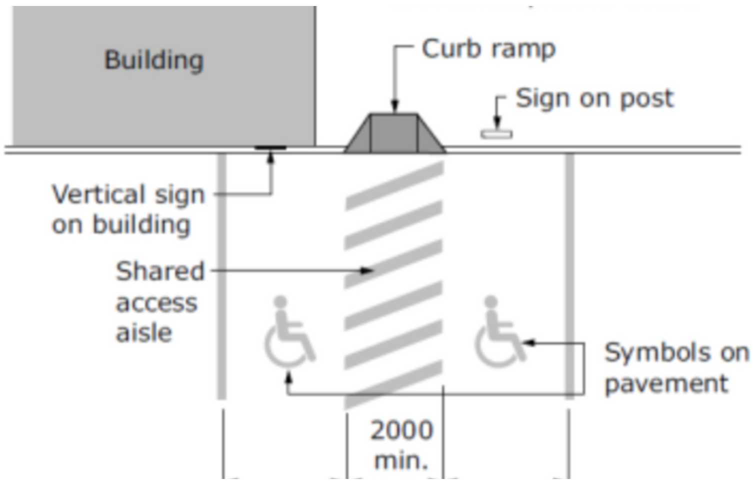


Figure 5.11 Accessible Perpendicular Parking

Source: CSA B651-18 (Figure 67)

Accessible parallel parking stalls should have a width of 2.6 m and length of 5.5 m with an adjacent, shared, access aisle with a minimum width of 2 m. The access aisle should connect to a curb ramp and sidewalk or designated walkway allowing for safe and direct passage from the parking stall to the transit facilities.

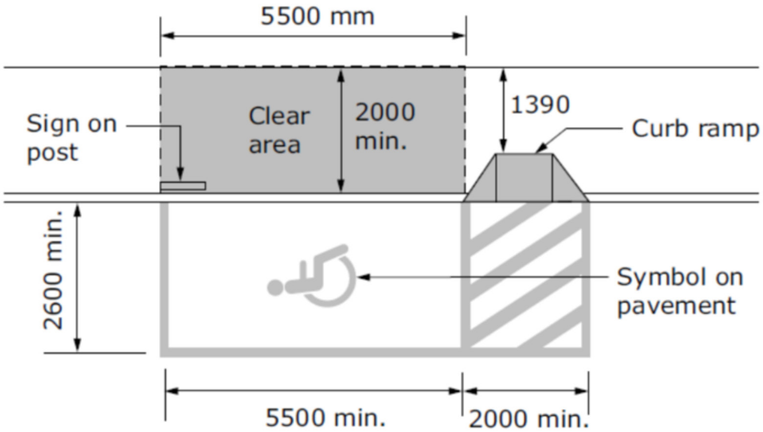


Figure 5.12 Accessible Parallel Parking

Source: CSA B651-18 (Figure 68)

Where possible, an accessible drop-off stall is recommended. The stall should have an access aisle adjacent and parallel to the accessible route and of at least 1.5 m and 7 m long and feature either a curb with a curb ramp or a tactile attention indicator (see Figure 5.13).

Unless the entire drop off area is curbed or level (requiring tactile indicators), the access aisle is located on the pavement to allow for a ramp to be lowered from a side-loading van and to ensure that someone exiting a vehicle has sufficient level maneuverability without impeding access to the sidewalk for other pedestrians.

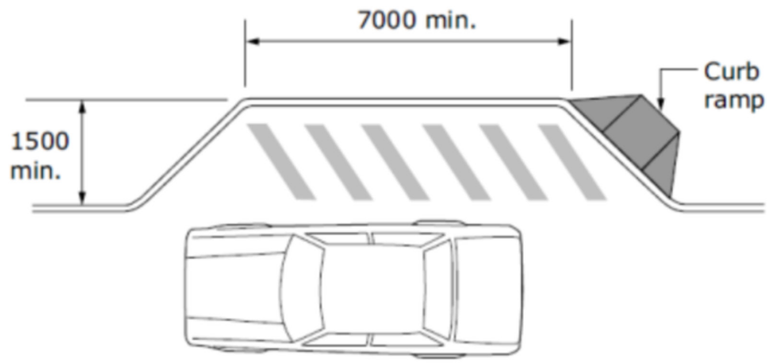


Figure 5.13 Accessible Pick-up / Drop-off

Source: CSA B651-18 (Figure 65)

5.3.5 Site Circulation

Parking should be easy to find in a Park & Ride. A single, continuous path from the street to a parking space is ideal. Clear signage at major access points as well as within the lot (pavement arrows and STOP signs for example) will assist in site circulation.

5.3.6 Site Security

A safe and secure environment is important for all facility users. Measures to minimize unauthorized activities include:

- Natural surveillance;
- An enforcement policy;
- Signage to indicate the enforcement policy;
- Lighting;
- Remote surveillance; and
- Fencing and pathway bollards to control pedestrian and vehicle access.

5.3.7 Interaction between Travel Modes

Key considerations to improve the interaction of travel modes include:

- Safe pedestrian connections between the parking lot and the transit stops. For example:
  - Use wayfinding to direct pedestrians to follow desired paths rather than cut through parked vehicles;
  - Keep the walking distance reasonable (300 metres or less, equivalent to travel time of 5 minutes or less) to reduce shortcuts;
  - Use marked crosswalks and appropriate signage to minimize pedestrian/vehicle conflicts;
  - If possible, use raised pedestrian pathways to further enhance visibility;
- Separate access for transit vehicles and cars to minimize conflicts; and
- Separate access and secured/protected storage for cyclists.

5.4 PASSENGER-PICK-UP AND DROP-OFF FACILITIES

Passenger pick-up and drop-off (PPUDO) facilities, also known as kiss-and-rides, are short-term parking areas where passengers are picked up or dropped off. They can consist of a designated series of parking stalls or a pull-up zone alongside a designated pedestrian area. Parking times are usually restricted to around 5 minutes. Between one and five PPUDO stalls are typically sufficient.

PPUDOs are typically included in Park & Rides or adjacent to transit exchanges. Specific considerations are as follows:

- PPUDOs should be easily accessible from the adjacent road network, and not create conflicts with adjacent road traffic. For example:
  - Because there is high turnover during specific periods (typically in the morning for drop-off and in the late afternoon for pick-up), PPUDO design must account for the surge to avoid queues encroaching onto the adjacent road;
  - Conversely, access points should be located away from any vehicle queues entering and exiting the facility;
- PPUDOs should be located close to the transit exchange entrance (at the least the drop-off spaces); and
- Pick-up spaces can be separate and slightly farther away; however, passengers shouldn't have to cross more than one street. Otherwise, they will use unofficial pick-up locations that are more convenient and closer to the transit exchange.

CHAPTER 6 Transit Priority Measures

6.1 INTRODUCTION

Transit Priority Measures (TPMs) aim to improve transit safety, travel time and reliability, leading to additional benefits such as mode shifts, reduced carbon emissions, reduction in fleet size and increased customer satisfaction.

There are three TPM categories: regulatory measures, physical measures and transit signal priority (TSP). Often, a combination is used. For example, pairing a queue jump lane with a queue jump signal phase to improve transit flow and minimize traffic conflict.

TPMs are an extensive, technical subject. Designers should consult with BC Transit and conduct a detailed cost-benefit analysis prior to implementation.

Table 6.1: Criteria for Provision of Transit Priority Measures

TPM Types	Criteria for Provision			
	Rapid Transit	Frequent Transit	Local Transit	Targeted and Custom Transit
Regulatory Measures	Desirable for peak hours	Depends on local conditions	Not required	Not required
Physical Measures	Transit lanes are desirable in areas of congestion where vehicle queues typically exceed 75 m or when the number of buses exceeds 25 per hour Queue jump lanes are desirable at key areas of congestion	Queue jump lanes are desirable at key areas of congestion	Not required	Not required
Transit Signal Priority	Desirable at all signalized intersections along rapid transit corridor where delays typically exceed 40 seconds	Desirable in areas of congestion or when the number of buses exceeds 25 per hour	Desirable at intersections with significant delays	Not required

6.2 REGULATORY MEASURES

Regulatory measures are road management rules that prioritize transit movement or impose restrictions on private vehicles. Common regulatory measures include:

- Movement restrictions on private vehicles at all times or during certain time periods;
- Parking restrictions at all times or during certain time periods; and
- Exemption of transit movements from existing movement restrictions.

6.3 PHYSICAL MEASURES

Physical measures designate a portion of the roadway to transit operation, either by new infrastructure or reallocation of existing roadway usage. Common physical measures include:

- Dedicated transit lane (curbside, median, contraflow, etc.) and transitways; and
- Queue jump lane and queue by-pass lane. Generally, the length of the queue jump lane is a function of the anticipated queue length during peak periods.

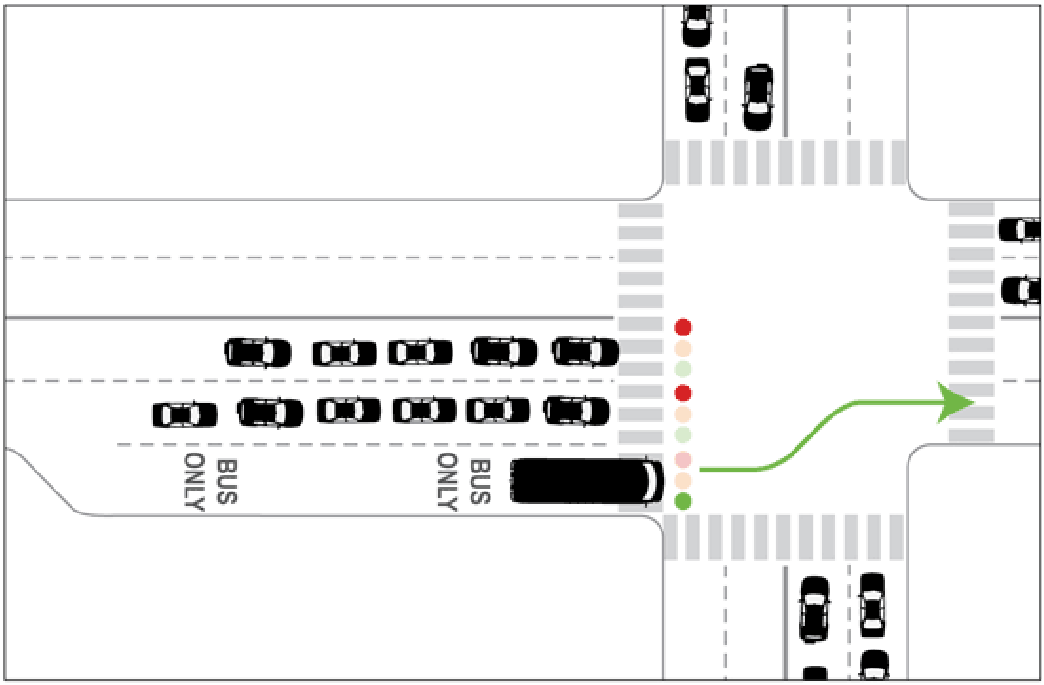


Figure 6.1 Queue Jump Lane

Source: MoTI Transit-Supportive Guidelines

Physical measures require careful planning and potential consultation with involved stakeholders, as they can disrupt existing road conditions, enlarge an intersection footprint and increase pedestrian crossing times.

6.4 TRANSIT SIGNAL PRIORITY

TSP is the practice of adjusting traffic signal timing to improve transit vehicle movement through intersections. It is worthwhile to note the difference between TSP and pre-emption:

- TSP is a short extension or reduction in a traffic signal's overall timing sequence, more commonly used at locations where only a minor signal timing adjustment is required; and
- Pre-emption can be an infinite amount of all-red time for all other traffic, until the vehicle requesting the pre-emption clears the intersection. Pre-emption implies that the transit vehicle always arrives in a green window, which is not the case for TSP. It is less commonly used for buses, as opposed to rail and light-rail crossings.

Because of the above differences in meaning and execution, documents should clearly identify TSP or pre-emption to avoid misinterpretations of the technical standards.

TSP is an extensive subject, but there are two general types, passive and active:

- **Passive TSP** is a pre-programmed signal timing plan based on known transit arrival times, most applicable at locations where arrivals are consistently reliable, such as at intersections next to the transit terminal, or along dedicated transit lanes;
- **Active TSP** is the most common application used by BC Transit. Through detection and communication, traffic signal controllers make real-time active TSP decisions based on transit arrival information. Depending on the pre-programmed TSP logic, the traffic signal controller may grant an extension, reduction or reject the TSP request. Active TSP has two sub-categories:
  1. Conditional – Priority is granted only when certain conditions are met, typically if a bus is a certain number of minutes behind schedule or carrying more than a specific number of passengers.

Conditional TSPs are less disruptive to general traffic, but more expensive because technically they require an additional exchange of information between the transit vehicle and the traffic signal controller; and

2. Unconditional – More common, less expensive. The traffic signal controller only knows that a bus is approaching. Unconditional TSPs can lead to unnecessary provisions on buses well ahead of schedule, causing bunching and traffic disruption. While active unconditional is the default, other TSPs should be considered depending on local traffic performance and the TSP objective.

Active TSPs need sophisticated detection and communication systems. Inductive loop detectors are an option, but their pavement intrusive characteristics are costly and not ideal for maintenance. GPS, infra-red and Wi-Fi are less intrusive alternatives, but aren't as precise or reliable as inductive loops. The exact detection and communication system depends on location-specific needs. Designers should consult with BC Transit and the jurisdiction that operates the traffic signal.

An active TSP request must be communicated to the traffic controller at a reasonable upstream distance. This distance is a function of travel speed and the green extension time that can be granted. If a maximum green extension is granted, the bus must be able to clear the intersection given the distance and the operating speed. This is why TSPs are not compatible with near-side stops.

For the inductive loop detection method, the upstream detector is called the check-in detector (see Figure 6.2). Designers should consult with BC Transit and the relevant jurisdiction to determine optimal check-in detector locations.

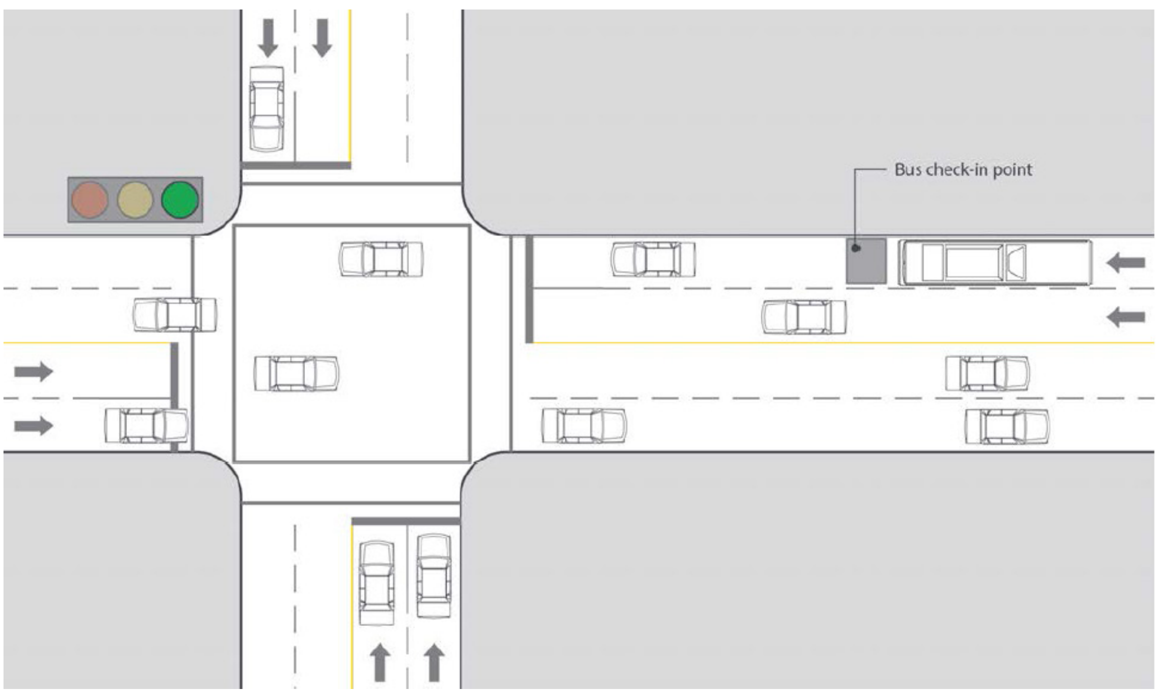


Figure 6.2 Active Transit Signal Priority Check-In Point

Source: TransLink Bus Infrastructure Design Guidelines

CHAPTER 7 Signing

7.1 DESIGN STANDARDS

Pavement markings, sign design and placement should meet the standards of the TAC's Manual of Uniform Traffic Control Devices for Canada (MUTCDC) and other relevant jurisdictions.

Consistent, concise signs and pavement markings reduce confusion for passengers and the general public. Regular maintenance ensures signs and pavement markings are visible during the day and at night.

7.2 BUS STOP SIGNS

Bus stop signs should comply with section 810.4 of the American Disability Act (ADA) Standards for Accessible Design regarding text font, size, spacing and sign height.

Add the following bullet points:

- Signs should have a non-glare finish and have a minimum contrast of 70% between the characters and the background;
- Characters should be uppercase, lowercase or a combination of both (with a combination being the most accessible);
- Characters should be written in a sans serif font, not be italic, oblique, script or have unusual forms;
- Characters should have a width-to-height ratio of between 3:5 and 1:1;
- Character height should be relative to the expected viewing distance.

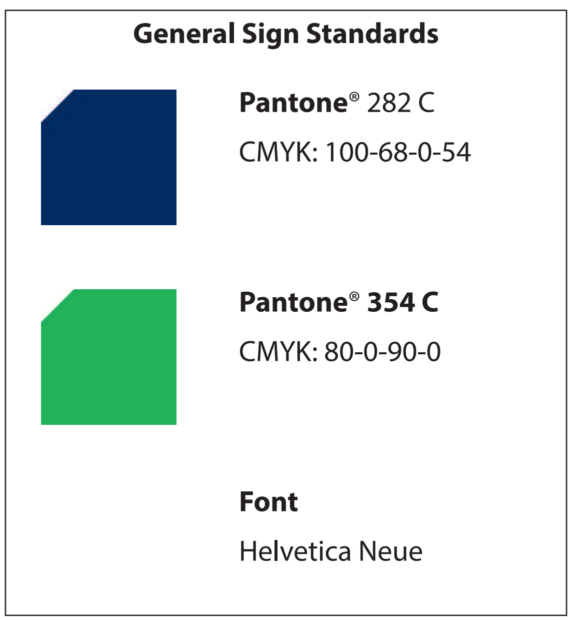


Figure 7.1 General Sign Standards

Strip Sign

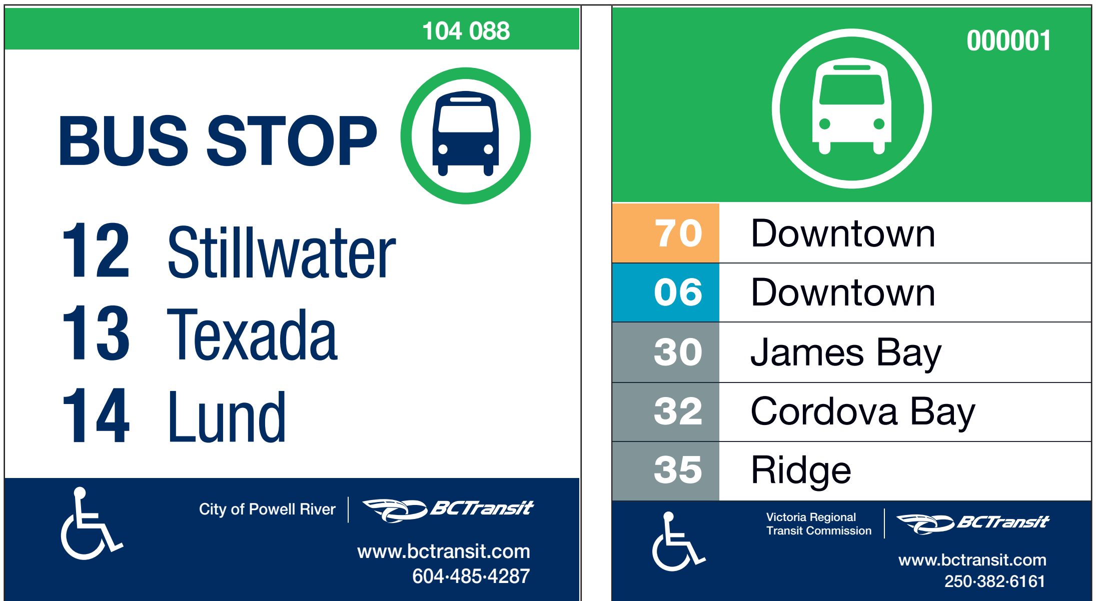
Size: 4.5" wide by 30" tall

Reflective Grade: Diamond

Required Information

- Stop ID Number
- Words "Bus Stop"
- Universal Symbol
- BC Transit Logo
- BC Transit Website
- Transit System Phone No.
- Funding Partners
  - Provincial
  - Municipal System(s)
- Wheelchair accessible decal (only on stops that meet accessible criteria)

Figure 7.2 Strip Sign



Size: 16" w (height varies depending on # of routes listed)

Reflective Grade: Diamond

Required Information:

- Stop ID Number
- Universal Symbol
- BC Transit Logo
- BC Transit Website
- Transit System Phone No.
- Funding Partners (Municipal System)
- Wheelchair Accessible decal (only on stops that meet accessible criteria)
- Route numbers and names (and frequency on System Signage (see right)

Figure 7.3 Flag Sign

7.3 OTHER SIGNS

Park & Ride Sign

Size: 8′ wide x 4′ high

Reflective Grade: Hi-Intensity (HI)

Required Information

On white area:

- BC Transit Logo
- Tag Line (Linking Communities, Businesses & Lifestyles)

On blue area:

- Universal Symbol
- "Park & Ride"
- Location (address)
- Funding Partners
  - Provincial
  - Municipal System(s)

Figure 7.4 Park and Ride Sign

Building Sign

Size: 6′ wide x 4′ high

Reflective Grade: Hi-Intensity (HI)

Required Information

On white area:

- BC Transit Logo
- Tag Line (Connecting People and Communities)

On blue area:

- Location (address)
- Funding Partners
  - Provincial
  - Municipal System(s)

Figure 7.5 Building Sign

GLOSSARY

Accessible Pedestrian Signal	Pedestrian signals that communicate information about the state of the signal (Walk, Flashing Don't Walk, Don't Walk) in non-visual formats.
Articulated Bus	Segmented bus that has rear portion flexibility but is permanently connected to a forward portion and has no interior barrier to hinder passenger movement between the two portions.
AutoTURN	Transoft Solutions Inc. software that analyzes and visualizes vehicle-turning swept paths.
Bollard	A short post on the street or sidewalk that acts as a boundary marking or protective barrier.
Bus Bay	A bus stop where a bus pulls off the roadway to a designated area (which typically consists of tapers and a loading area), picks up and drops off passengers, then re-enters roadway.
Bus Bulge	A bus stop used a passenger zone, where a widened piece of sidewalk extends into the parking lane of a roadway.
Bus Fleet	BC Transit vehicles, such as: conventional bus, double-decker bus, handyDART, light duty bus, low floor bus, community bus or alternative technology bus.
Bus Pad	An overlay of concrete at a transit facility, used to minimize pavement wear.
Bus Shelter	A building or other structure that provides protection from the weather, sometimes with seating and other passenger convenience amenities.
Bus Stop	An area where passengers wait for, board, alight and transfer between transit vehicles, usually identified with a bus stop sign (RB-58) and red painting along the road curb, where a road curb is available.
Bus Stop Sign	A bus stop sign is a pole-mounted rectangular plate with the stop's identification number, the words BUS STOP, and other information such as other bus routes, or a wheelchair accessible decal, if applicable.
Bus Sweep Path	The horizontal distance taken up by a transit vehicle when it turns. The width increases when a bus begins to turn and decreases as the bus completes the turn.

Conflict Zone	Area where different modes of travel intersect.
Crime Prevention through Environmental Design (CPTED)	A proactive crime prevention strategy that uses proper design and the built environment to reduce crime and improve safety.
Curb letdown	Also known as a curb ramp or curb cut. A short ramp cutting through a curb or built up to it to provide continuous and accessible access between the road and a sidewalk or raised concrete/asphalt pad.
Detector	A device used to indicate the presence or passage of vehicles.
Dwell Time	The scheduled time a vehicle or train should discharge and take on passengers at a stop, including opening and closing doors.
Far-Side Bus Stop	Located after an intersection, in the same direction as bus travel.
Flag Stop	When a pedestrian flags or signals a bus to stop.
Hybrid Bus	A hybrid electric bus combining conventional and electric propulsion systems.
Layover	Layover may either be recovery time for the schedule to ensure on-time departure for the next trip, or break time between trips for bus drivers. Regardless of the situation, layover space is required for transit vehicle parking.
Mid-Block Bus Stop	Located midway between two adjacent intersections.
Near-Side Bus Stop	Located before an intersection, in the same direction as bus travel.
In-Lane Bus Stop	Located on the curb travel lane to load and unload passengers.
Parallel Loading	A type of transit platform configuration parallel to a roadway.
Park & Ride	An area where passengers park their personal cars or bikes and then use the transit system.
Passenger Information Display System	An automated system that provides transit status and arrival information.
Passenger Landing Pad	A stable, level, raised and slip-resistant surface for passenger boarding and alighting.

Passenger Pick-Up and Drop-Off Facilities	Designated spaces for taxis or private cars to pick up or drop off passengers using public transit. Usually with limited parking duration.
Passenger Zone	Where passengers wait for, get on and off buses. May be bounded by the road curb, adjacent property lines or boulevards. Consists of a variety of amenities, such as the passenger landing pad, wheelchair pad and bus shelter, etc.
Pull-In and Pull-Out Zones	Areas where transit vehicles either decelerate to stop at, or accelerate to leave, a bus stop.
Queue Jump Lane	A geometric Transit Priority Measure (TPM) used at a signalized intersection. An auxiliary or right-turn lane where through movement is allowed for transit vehicles, but not general traffic. Transit vehicles can use this lane to bypass through-traffic queues.
Real-Time Information	Accurate arrival information electronically displayed at a bus stop, either on a pole or under the roof of a shelter.
Right-of-Way	The legal right of a pedestrian, cyclist or transit vehicle to proceed first, ahead of others.
Sawtooth Loading	A platform configuration characterized by jagged edges for buses to pull in at an angle.
Sight Distance	Sight distance is the length of roadway ahead visible to the driver.
Sight Line	A line of sight from the eye to a perceived object. In transportation, a sight line typically refers to the ability of a road user to detect an object or another road user.
Timing Point	A location, usually a bus stop, where a transit vehicle arrives at a set time.
Traffic Calming	According to the Transportation Association of Canada, traffic calming is used to alter motorist behaviour on a street or on a street network. Can involve changing traffic routes or flows within a neighbourhood.
Transit Exchange	A focal point for passenger transfers between transit modes (for example, between bus and rail) and/or transit routes.
Transit Infrastructure	All fixed components in an environment where transit operates, including areas where passengers wait to get on and off transit vehicles, as well as roadways used by transit vehicles.

Transit Priority Measures (TPMs)	Measures that give transit vehicles priority over other road users, such as exclusive bus lanes.
Transit Signal Priority (TSP)	The alteration of normal signal phasing or sequence to provide preferential treatment for transit vehicles.
Universal Access	The ability of all people (including people with disabilities and other mobility challenges) to have equal opportunity to access transit service.
Visibility Impairment Zones	Bus drivers have blind spots on both sides of the vehicle.
Wheelchair Landing Pad	Located in the passenger waiting area near the front door of the bus. Allows persons in wheelchair to use the wheelchair ramp safely and without any obstructions.

APPENDIX A Design Checklist for Bus Stop Facilities

Refer to this checklist at the onset of the design process and/or towards the end to ensure all aspects have been considered.

	Design Aspect	Relevant Section(s)
☐	Far-side, near-side or mid-block configuration • Advantages and disadvantages	4.3.1
☐	Bus stop visibility • Signing	7.2
☐	Passenger amenities • Passenger landing pad • Wheelchair pad • Bus shelter • Miscellaneous amenities	3.6, 4.6
☐	Universal access • Minimum requirements	3.2, 4.6
☐	Pedestrian safety • Interaction with pedestrian crosswalks	4.3.8
☐	Bus stop layouts/dimensions • Curbside stop • Bus bay • Bus bulge • Multi-position stop	4.3.2 to 4.3.7
☐	Maintenance • Preferred conditions • Frequency of on-site checking	3.7

APPENDIX B Tactile Walking Surface Indicators

Tactile Walking Surface Indicators (TWSIs), are used by people with low vision or who are blind to locate bus stops and other changes in the environment. They are required to be detectable underfoot when walking or by a white cane. They also must be contrasted with the surrounding surface.

In alignment with the Canadian Standards Association, TWSIs at the front of bus stops shall consist of flat-topped, parallel, elongated bars having:

- A height of 4 mm to 5mm;
- A top width between 17 mm and 30 mm and a base width of 10 +/- 1mm greater than the top width;
- A centre-to-centre distance between adjacent bars of 57 mm to 85 mm;
- A top length of not more than 270 mm and the base length 10 +/- mm greater than the top length;
- A spacing of 20 mm to 30 mm between the ends of the parallel bar;
- A height of base plate of not more than 3 mm;
- Slip resistant material.

Table C.1 Bar Width and Spacing Combinations

Top Width of Elongated Bars (mm)	Base Width (mm +/- 1 mm)	Centre-to-centre Distance between Elongated Bars (mm)
17	27	57-78
20	30	60-80
25	35	65-83
30	40	70-85

Source: CSA B651-18 (Table 3)

At the front of bus stops, TWSIs should be:

- Placed perpendicular to the curb;
- Aligned with the front door of a bus;
- Have a minimum length of 1.2 m along the sidewalk and be the entire width of the sidewalk;
- A contrasting colour to surrounding surfaces – yellow is preferred;
- Only be provided at bus stops that provide a hard-surfaced passenger zone and wheelchair pad.

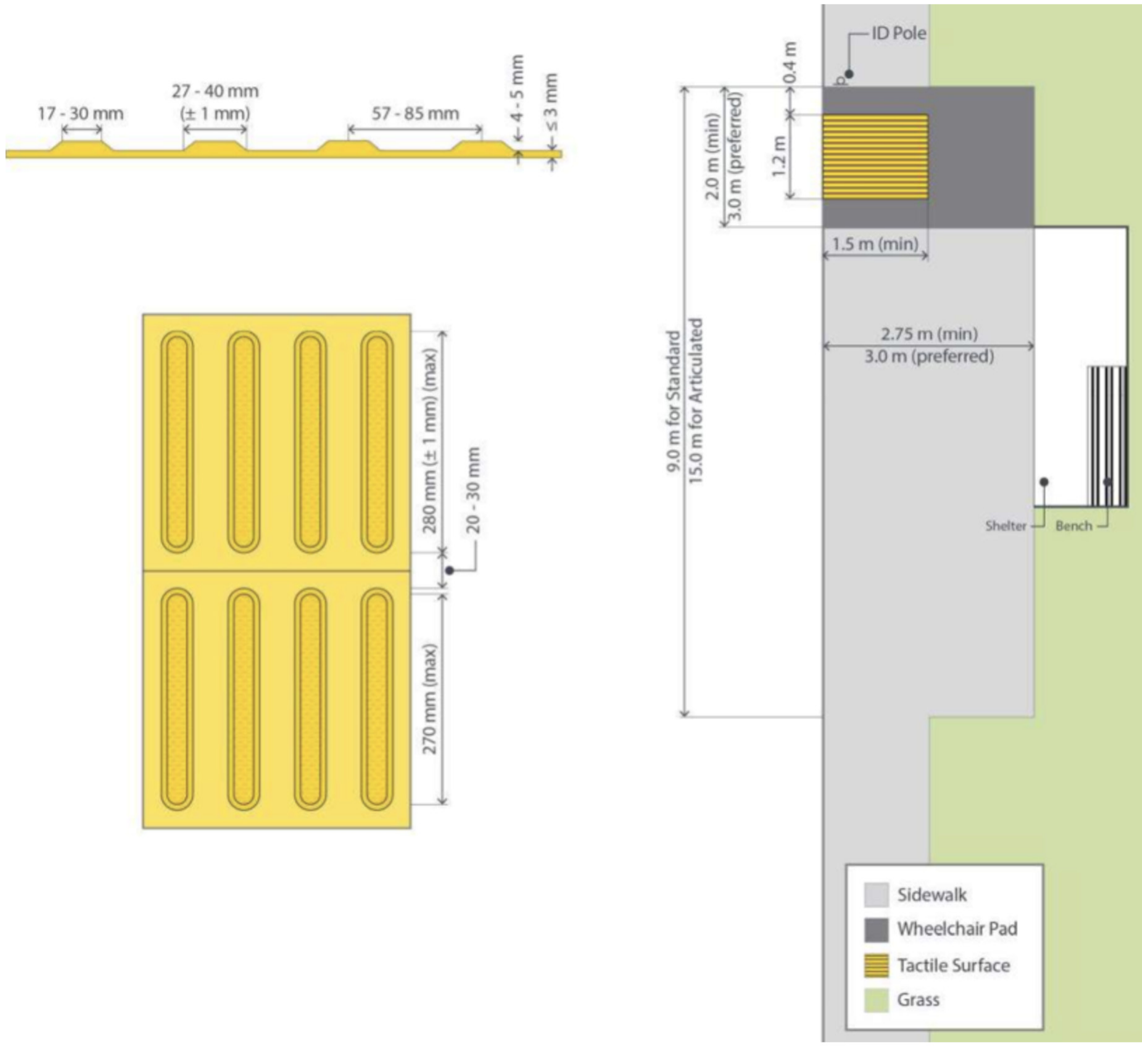


Figure B.1 Typical Layout of TWSIs at Bus Stops

Source: TransLink Bus Infrastructure Design Guide (Figure E2)

APPENDIX C Worked Examples

C.1 TRANSIT LANE

Project #1

Highway 99 Transit Lane Project, Richmond, B.C.

Overview

To design a 4 m wide by 3 km long dedicated transit lane along the shoulder of Highway 99 between the northbound off-ramp to Highway 91 and the south approach at the intersection of Bridgeport Road and Highway 99 northbound off-ramp.

Design includes widening the existing shoulder for at-grade bus operation with signalized metering at on-ramps.

Project Images

Figure 8.1 Highway 99 Transit Lane

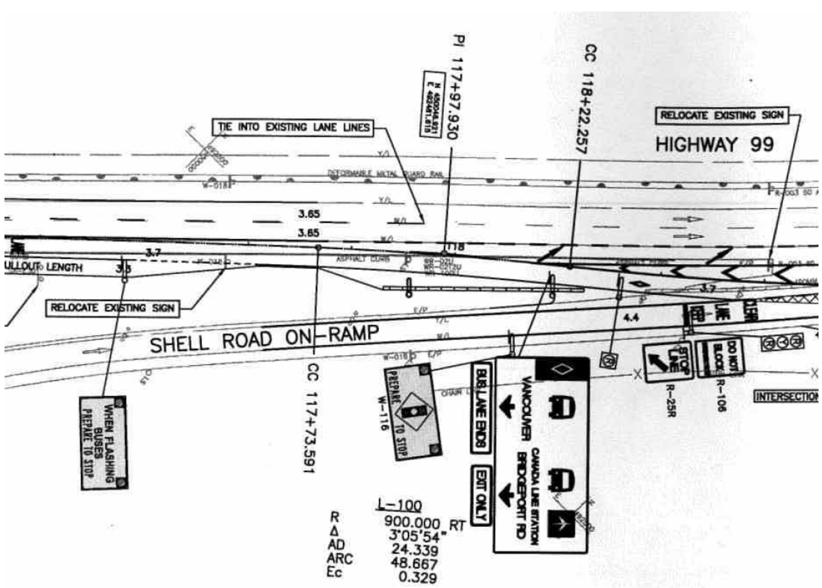


Figure 8.2 On-Ramp for Transit Lane

Key Design Elements

For optimal design, collision history, weaving and ramp operations for the current and future horizon years were analyzed. Proposed design includes location of bus check-in and check-out detectors, ramp and bus signals, advance warning flashers and intersection detectors.

Stop Bar Locations

Within the project limits, the existing on-ramps located along Highway 99 were designed as parallel lane entrance (see Figure 8.1). A driver entering on a parallel lane is expected to accelerate to close to through-traffic speed on the parallel section of the terminal before making a lane change into the adjacent through lane. The length of acceleration lane (L_a) excluding the taper length (L_t) is the distance required to accelerate from speeds as controlled by the ramp, to speeds required to safely merge with through traffic. The length of acceleration lane (L_a) is measured to the beginning of the taper (L_t).

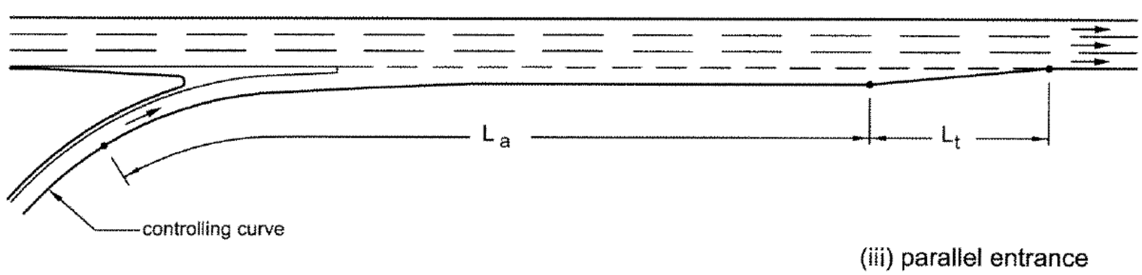


Figure 8.3 Parallel Lane Entrance

This project proposes metered ramps, so the location of stop bars must: 1) Provide available queue storage space on the ramp, and 2) Provide sufficient distance for vehicles to accelerate to freeway speeds from stop condition and merge safely with freeway traffic.

Table 8.1 Design Length for Acceleration

Speed of Roadway (km/h)		Length of Taper (m)	Length of Acceleration Lane Excluding Taper (m) L_a							
Design	Assumed Operating	L_t	Stop Condition	Design Speed of Turning Roadway Curve (km/h) 20	30	40	50	60	70	80
60	55-60	55	85-115	70-100	60-80	45-60	20-35			
70	63-70	65	120-160	115-150	100-135	80-115	50-85	15-40		
80	70-80	70	160-225	150-215	130-200	115-185	85-160	40-100		
90	77-90	80	215-325	200-310	180-300	160-285	140-250	50-200	40-145	
100	85-100	85	275-450	250-440	240-420	225-405	200-375	140-325	100-285	40-230
110	91-110	90	330-650	320-645	305-630	290-600	260-575	210-525	150-475	100-410
120	98-120	95	410-730	400-725	375-710	370-690	340-660	285-590	250-515	195-430
130	105-130	100	550-885	540-880	510-870	500-850	470-820	400-745	340-655	300-550

Notes: 1. The selection of ramp design speed as discussed in Subsection 2.4.6.2 should be referred.
2. The acceleration distance curves in 1994 AASHTO are used in developing the design domain.

Source: TAC Guide (Table 10.6.5)

The posted speed limit along Highway 99 is 90 km/h. Under this criterion, the design domain for length of acceleration lane under stop condition ranges from 215 m to 325 m. Section 10.6 of TAC's 2017 Geometric Design Guide for Canadian Roads states that longer entrance terminals (e.g. the higher values of the design domain in the above table) are desirable on higher volume roads to enable entering traffic to merge with through traffic safely and conveniently.

Based on this guideline, it is proposed that the stop bar at the Highway 91 eastbound on-ramp be located 215 m upstream from the beginning of taper due to its low volumes. For the Highway 91 westbound on-ramp, the proposed stop bar location is 325 m upstream from the beginning of taper. For the Shell Road on-ramp, since the existing acceleration lane exceeds the 325 m upper domain, the proposed stop bar location is 10 m upstream from the beginning of the gore nose to maximize storage space.

Vehicular Clearance Periods

The vehicular clearance period is the sum of the yellow and red time at the end of a green interval. It allows approaching motorists to either stop or enter and clear the intersection before a conflicting traffic stream enters. For this project, using the same guideline as for a signalized intersection, the vehicular clearance period is the clearance time that allows ramp vehicles approaching the intersection of the bus lane and the ramp entrance lane, to either stop at the ramp signal or enter and completely clear the intersection before a bus arrives at the advanced warning sign.

Vehicular clearance periods are calculated using the following equation:

$$I = t_{pr} + \frac{V_a}{2(f + AG)g} + \frac{D_c}{V_c} - \frac{D_b}{V_b}$$

where

T_{pr} = perception/reaction time (s).
V_a = approach speed (m/s).
f = friction factor on wet pavement (varies depending on speed. See *Table 18*
AG = approach grade (m/100 m), positive if approach traffic is climbing: negative if approach traffic is descending.
g = 9.81 m/s^2
D_c = clearance distance (m)
V_c = clearance speed (m/s)
D_b = conflict distance (m).
V_b = conflict speed (m/s).

The following assumptions were incorporated into the above equation to determine the vehicular clearance periods in this project:

- Perception/reaction time of 1 second;
- Approach ramp speed of 50 km/h;
- Friction factor of 0.36 under the posted speed limit at 50 km/h;
- Approach gradients of -3.7% for the Highway 91 eastbound on-ramp, -5.2% for the Highway 91 westbound on-ramp, and 0% for the Shell Road on-ramp; and
- Clearance distances for the on-ramps (see Figure 8.4). Clearance distance is measured from the stop bar location to the intersection point where on-ramp vehicles are completely clear of the bus travelling path, and the body of the on-ramp vehicle is completely inside the downstream accelerating lane;
- Clearance speed of 50 km/h assumed to be the same as the approach speed; and
- Conflict distances between the on-ramp vehicle path and bus path are small and assumed to be zero.

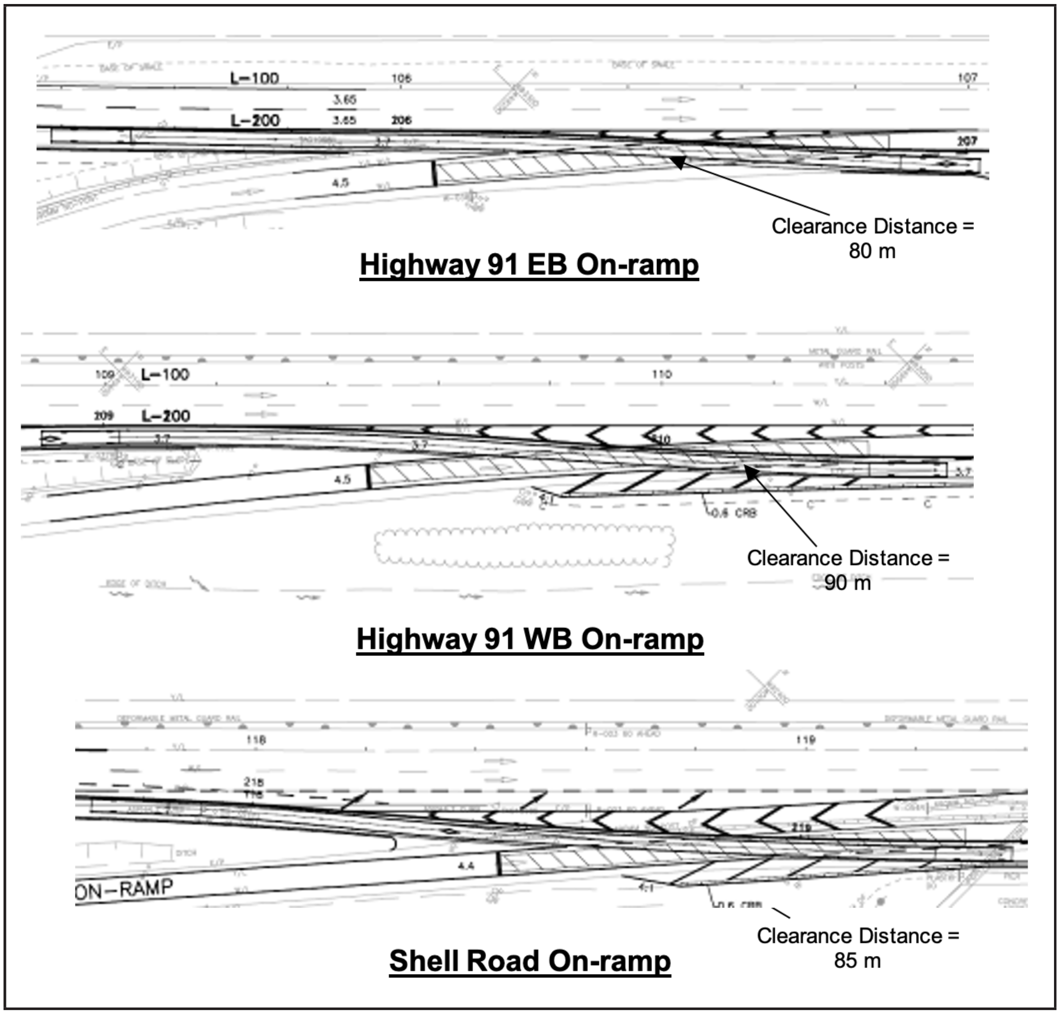


Figure 8.4 On-ramp Clearance Distances

Based on the above assumptions, the vehicular clearance periods are 9 seconds for the Highway 91 eastbound on-ramp, 9.8 seconds for the Highway 91 westbound on-ramp, and 9.1 seconds for the Shell Road on-ramp. According to MoTI Electrical & Traffic Engineering Design Guidelines Clause 4.2.5.4, the maximum allowable yellow time is 5 seconds. This project proposes only 3 seconds yellow time to reduce the risk of drivers running a yellow light.

Advanced Warning Sign

Advanced warning sign locations for the on-ramps and bus lane were determined based on MoTI Design Guidelines Clause 4.2.6.8. Using the grade percentage and approach speeds assumptions as stated above, the advanced warning sign locations for the on-ramps were calculated to be: 45 m for the Highway 91 eastbound on-ramp, 46 m for the Highway 91 westbound on-ramp, and 41 m for the Shell Road on-ramp. The location of the advanced warning sign for the on-ramps is measured upstream from the stop bar location.

The advanced warning sign locations on the bus lane were determined based on the assumptions that bus speed is 90 km/h and bus lane grade is 0%. As a result, advanced warning signs should be located 131 m upstream from the beginning of the gore nose.

Bus Check-In and Check-out Detector Locations

Bus check-in detector locations are based on vehicular clearance periods and advanced warning sign locations, calculated in the above sections. The time it takes a bus to travel from the check-in detector location to the advanced warning sign should allow for on-ramp vehicles to enter and clear the intersection. If a bus arrives at the advanced warning sign and there are vehicles travelling inside the intersection, the advanced warning sign will start flashing and the distance between the sign and the beginning of the gore nose should allow buses to come to a complete stop before the intersection.

The check-in detector location should be measured from the farthest point on the upstream approach lane just before the bus enters the intersection. The check-out detector should be located at the middle of the intersection. The distances should include the clearance interval periods plus the advanced warning sign distances. Note that the check-in detector for the Highway 91 westbound on-ramp will be located upstream of the Highway 91 eastbound on-ramp intersection due to the short distance between the two ramps.

If an approaching bus reaches the check-out detectors and another bus hasn't activated the upstream check-in detectors, the on-ramp signal will immediately switch to green. When more than one bus is approaching at the same time, the on-ramp signal will switch to green after the last approaching bus reaches the check-out detectors.

Intersection Detectors

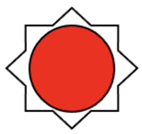
Due to heavy through volumes on Highway 99 during peak periods, the intersection of the bus lane and the on-ramp lane could be blocked by on-ramp vehicles trying to merge with through traffic. Detectors should be placed at the intersections to detect vehicle presence.

It's proposed a bus signal be installed on the bus lane in conjunction with the advanced warning sign. It should be located upstream from the intersection just before buses enter. The detection of vehicles in the intersection can trigger both the advanced warning sign and bus signal to warn bus drivers about possible downstream conflicts, and also trigger the ramp signal to stop releasing vehicles to the intersection. The detectors need to be able to distinguish stopping vehicles from travelling vehicles.

Ramp and Bus Signals Display

On-ramp and bus lane signals were also proposed to improve intersection safety. The signal at the on-ramp is a standard signal head with red, amber and green displays. For the bus lane, a customized advanced warning sign and a flashing red signal at the intersection are recommended.

Table 8.2 On-ramp and Bus Lane Signals

Displays	Descriptions
	When flashing, to inform bus drivers they may have to come to a complete stop before entering the intersection.
	When flashing, to inform bus drivers they must come to a complete stop before entering the intersection. They can then approach the intersection with caution.

C.2 TRANSIT EXCHANGE

Project #2

Capilano College Transit Exchange, North Vancouver, B.C.

Overview

To develop various conceptual and functional layouts of a proposed temporary transit exchange at Capilano College, the candidate site was a parking lot on Monashee Drive.

Project Images

Before

After

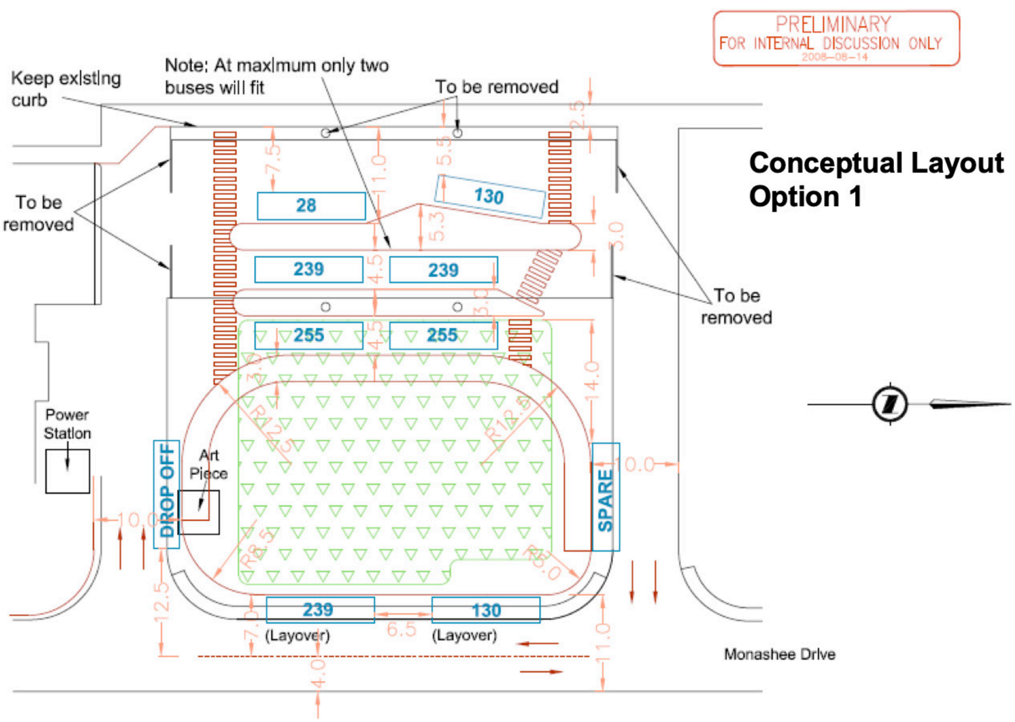
Figure 8.5 Capilano College Transit Exchange

Key Design Elements

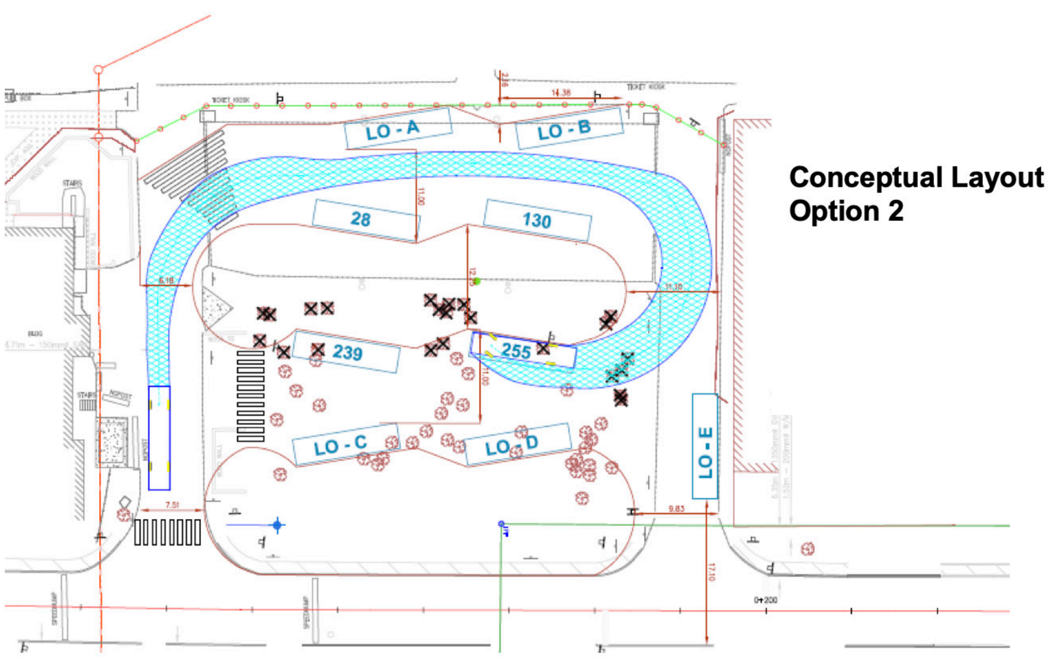
High pedestrian activity was anticipated at the proposed transit exchange, so it was important to locate bus stops to maximize the sight distance to pedestrian crosswalks for bus drivers turning around the upper part of the transit exchange.

Handrails were installed to funnel pedestrians to specific paths and/or crosswalk(s), and not use potential shortcuts.

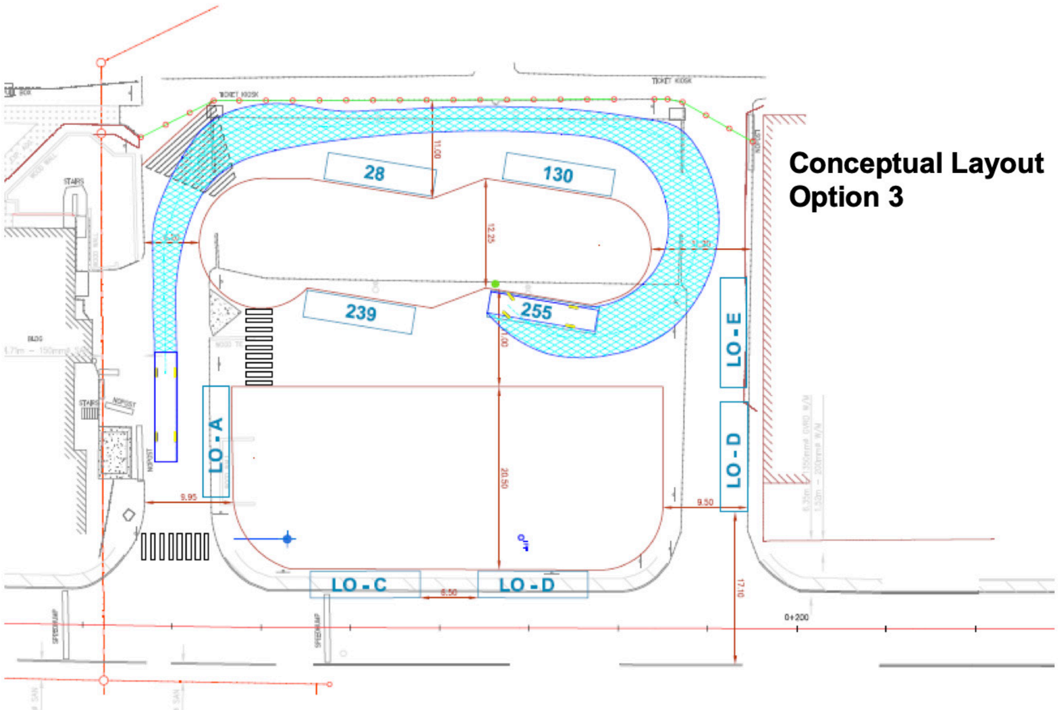
Using AutoTURN, swept path analyses were conducted and then confirmed by a field test, resulting in three conceptual layouts:



Conceptual Layout Option 1



Conceptual Layout Option 2



Option 1 was selected as the preferred layout. After conducting the field test, the drop-off bay at the entrance of the loop was removed. Although tests confirm the spare layover bay at the bus loop exit (with the widening of the exit driveway to 10 m) is adequate for the swept paths, it could create some sight distance issues between the pedestrian crossing and the exiting buses. In addition, according to the Motor Vehicle Act, vehicles are not allowed to park within 6 m of the approach side of a crosswalk or stop sign. As such, the spare layover position was also removed. The transit exchange was constructed in November 2008 and is now in operation.

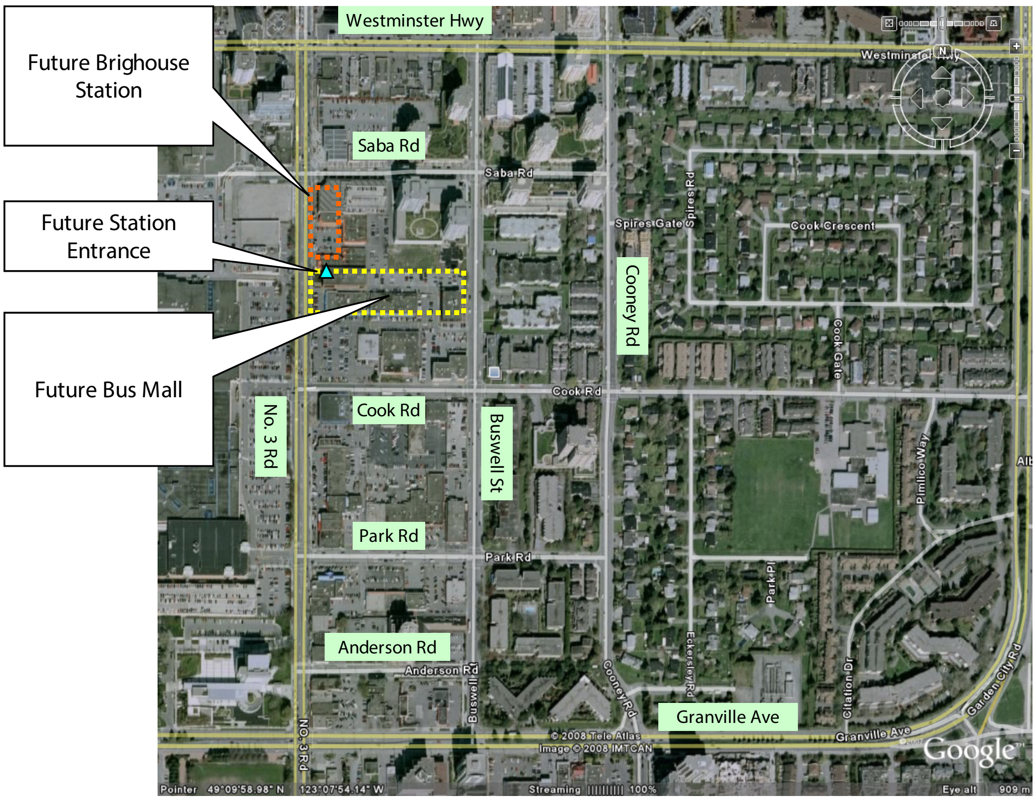
Project #3

Review of Transit Exchange Operations at Brighouse Station, Canada Line, Richmond, B.C.

Overview

Review conducted and alternate arrangements identified to minimize the number of buses stopping on No.3 Road northbound, and to maximize the number of buses using the new bus mall.

Bus Mall Location



Key Design Elements

A review of proposed future bus services determined layover bus requirements. Bus routing options were assessed to determine the impact of access and egress on each route terminating at the station. Upon consultation with TransLink's Planners, the following principles were used to reassign routing and bus bay locations:

- handyDART drop-off and pick-up locations should be as close to the station entrance as possible;
- Local route stops should also be located near the station entrance, since they have the most transfers to/from the Canada Line; regional routes can be located a bit further away;
- Bus routes with higher passenger loading should be assigned to bays with larger passenger queuing areas;
- Bus routes going to the same place and serving parallel corridors (or intersecting with each other) should share stops in the same bay or nearby to give customers more options;
- Minimize bus travel time and delays to the designated stop;
- Eliminate unnecessary routing inside the mall;
- Minimize the distance between drop-off and layover position of each terminating route;

- Offer dedicated drop-off and pick-up positions for terminating routes; and
- Keep bus layovers on side streets to a minimum.

The proposed number of bus storage units at each bus bay was reviewed to ensure adequate operation during peak hour passengers loading. The required bus bay lengths were subsequently identified using the formula as discussed in Section 5.2.5 of these Guidelines. In estimating the bus bay lengths, an average bus clearance time of 10 seconds was assumed for a bus to start up and travel its own length when departing from the bus bay. Apart from the above assumptions, a 25% failure rate, 60% coefficient of variation of dwell times and random bus arrivals were also assumed.

Bus Bay	1	2	3B	4	5	6	7	8
Total Number of Buses per Hour	39	20	12.	4	7	19.5	19	34
Green Time Ratio	0.6	0.6	1.0	1.0	1.0	1.0	1.0	0.6
Average Arrival Headway (s)	55	108	288	900	514	185	189	64
Average Dwell Time per Bus (s)	70	70	70	70	70	70	70	70
Assumed Clearance Time (s)	10	10	10	10	10	10	10	10
No. of Bus Storage Unit* (raw)	1.5	0.7	0.4	0.1	0.2	0.6	0.6	1.3
No. of Bus Storage Unit* (rounded)	2	1	1	1	1	1	1	2

*Note: *Assumes 25% failure rate, 60% coefficient of variation of dwell times and random bus arrivals*

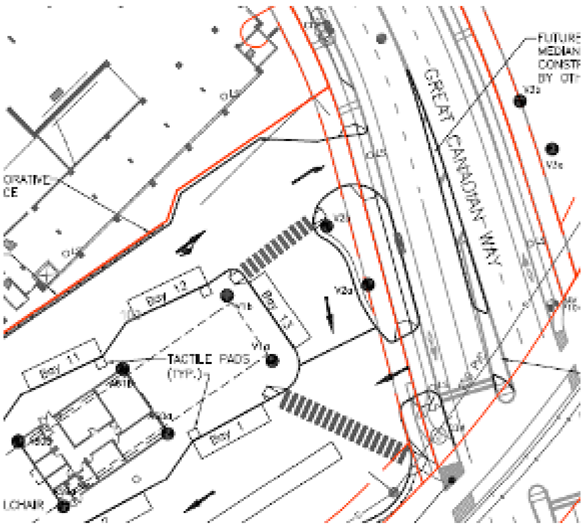
Project #4

Review of Pedestrian Crosswalks at Bridgeport Transit Exchange, Richmond, B.C.

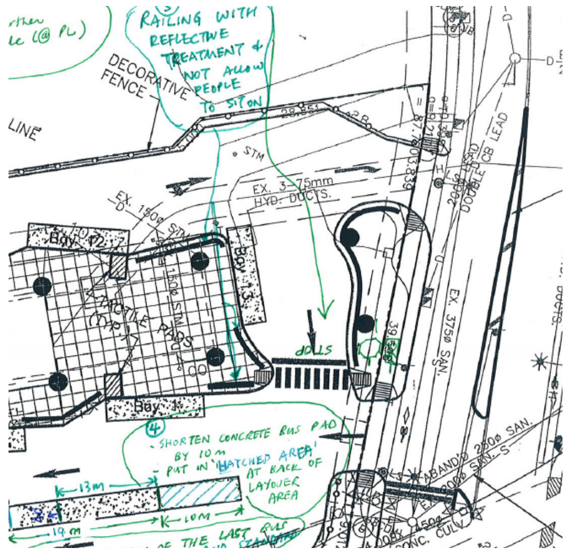
Overview

Determine proposed crosswalks in the vicinity of the Bridgeport bus loop. Improve the design. Identify potential issues related to pedestrian safety and bus operation. Identify other mitigating measures.

Original and Final Crosswalk Layout Designs



Original Design



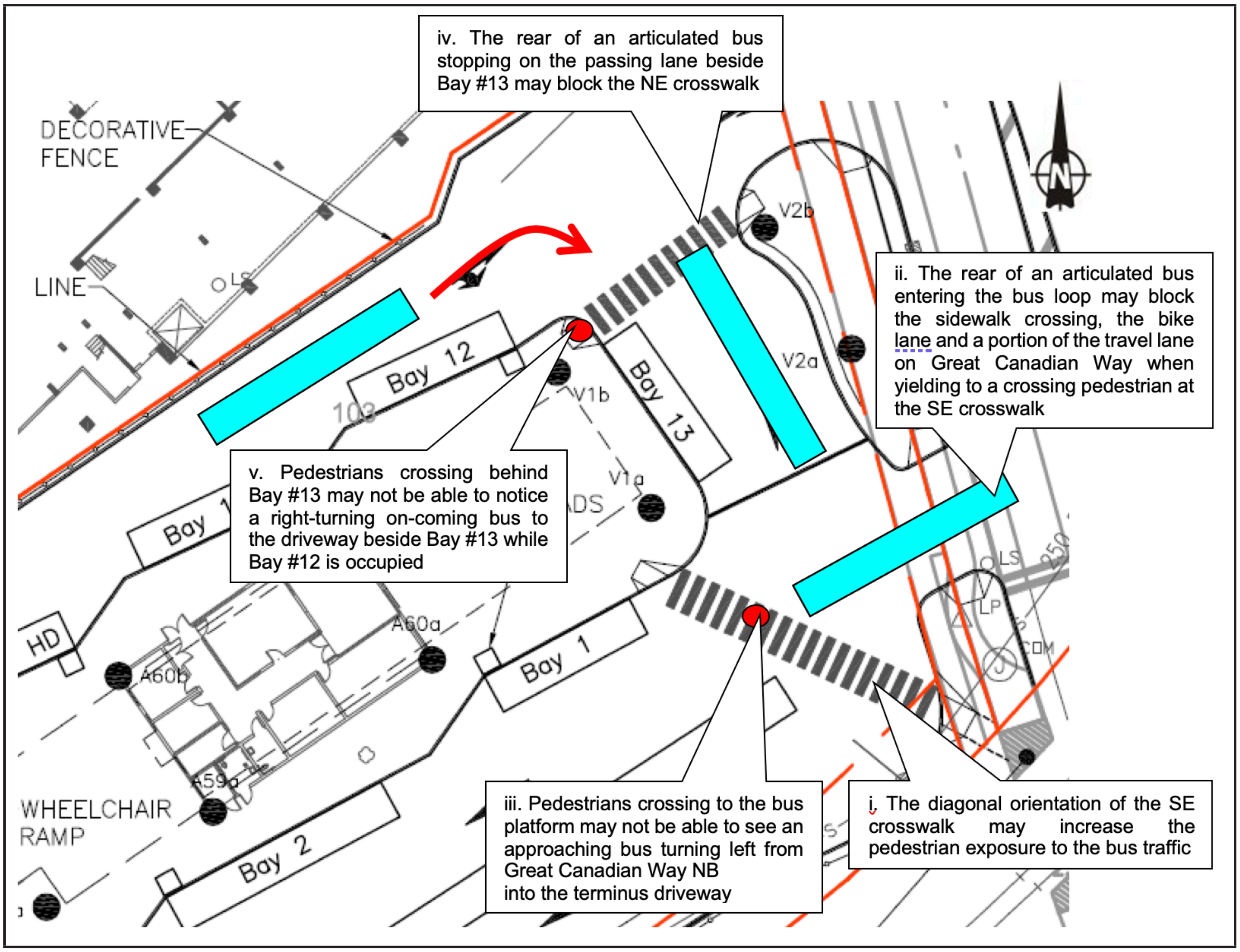
Final Design

Key Design Elements

The review involved identifying pedestrian desire lines, potential conflict points between pedestrian and bus movements, and potential signage and physical measures to funnel pedestrians to cross at the designated location. Design guidelines in Section 5.2.3 were followed.

Originally, there were supposed to be two crosswalks at the Bridgeport bus loop for pedestrian access to/from Great Canadian Way, located at the northeast and southeast corners. However, the following issues were identified (see diagram below):

- Diagonal orientation of SE crosswalk could increase pedestrian exposure to bus traffic;
- When yielding to a crossing pedestrian at the SE crosswalk, the rear of an articulated bus entering the bus terminus from Great Canadian Way could block sidewalk crossing, bike lane and a portion of the travel lane on Great Canadian Way;
- Pedestrians crossing from SE sidewalk to the island platform might not be able to see an approaching bus turning left from Great Canadian Way NB into the terminus driveway;
- When stopped at the passing lane beside Bay #13, the rear of an articulated bus could block NE crosswalk; and
- While Bay #12 is occupied, pedestrians crossing at NE crosswalk might not notice a right-turning bus entering the driveway beside Bay #13.



Given the above concerns, the following recommendations were suggested:

- Eliminate the NE crosswalk and provide only one crosswalk to facilitate pedestrian access to and from the western sidewalk of Great Canadian Way;
- Relocate/rearrange the orientation of the new crosswalk so that it's perpendicular to the bus travelling direction in front of Bay #13;
- Move Bay #13 slightly to the north and install a bulge in front of it so bus drivers can see pedestrians using the crosswalk;
- Install fencing and signage to regulate pedestrians to cross at the designated crossing location;
- Install appropriate signs to warn pedestrians of bus movement near crosswalk;
- Install appropriate signs to warn bus drivers of pedestrians crossing the sidewalk at the bus loop's entrance/exit;
- Install pedestrian guide signs along the Great Canadian Way sidewalk and inside the terminus to direct transit passengers to the nearest crosswalk when accessing the bus loop and Canada Line; and
- Discourage jaywalking inside the terminus with TransLink Patrol Team enforcement during the initial opening of the station and bus loop.

C.3 PARK & RIDE

Project #5

Maple Meadow West Coast Express Park & Ride

Overview

Review existing park-and-ride lot on the north side of the Maple Meadow West Coast Express station, and develop a new conceptual layout to accommodate more handicap parking stalls and improve circulation at current drop-off and pick-up bays.

Existing Park & Rides

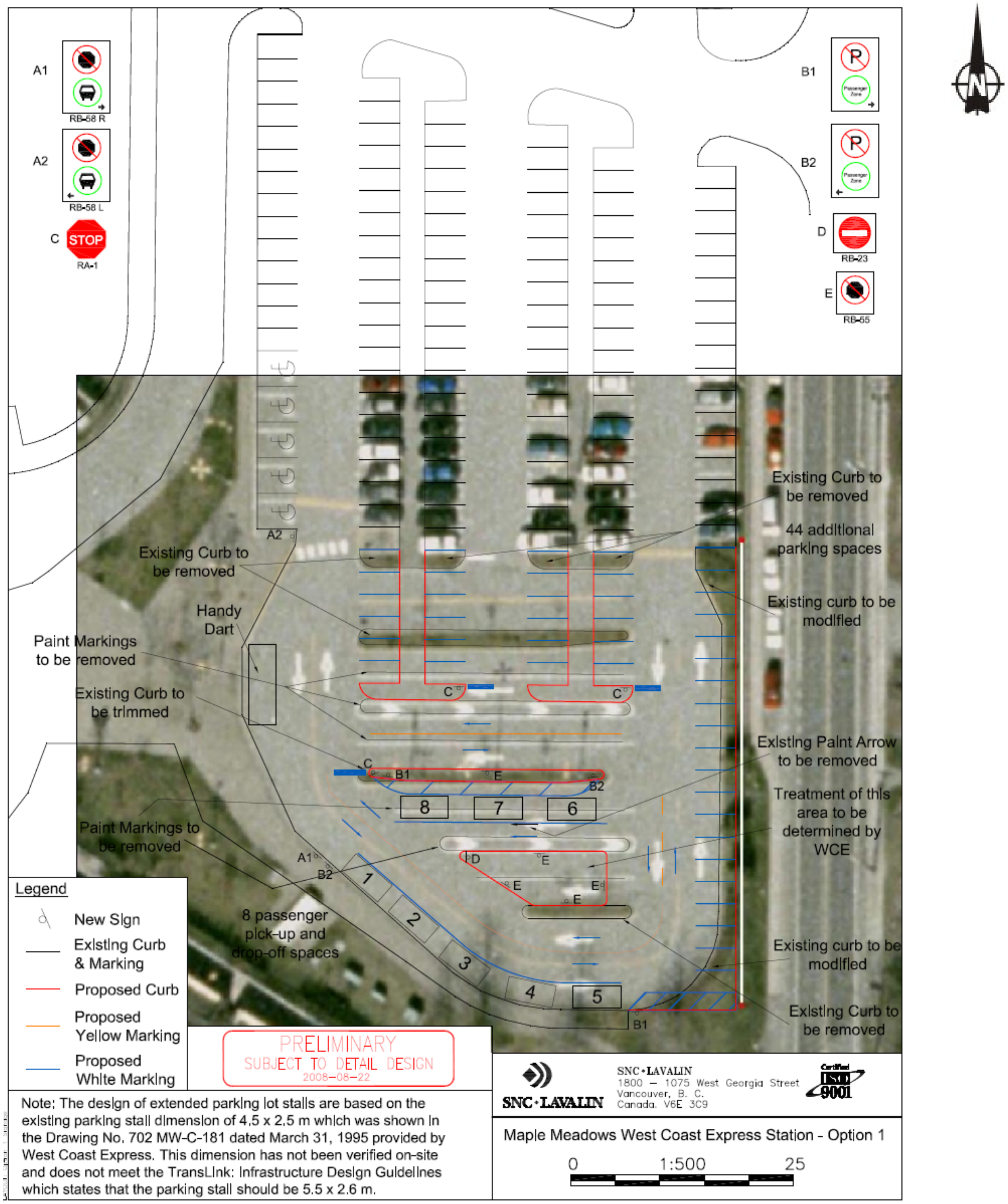
Key Design Elements

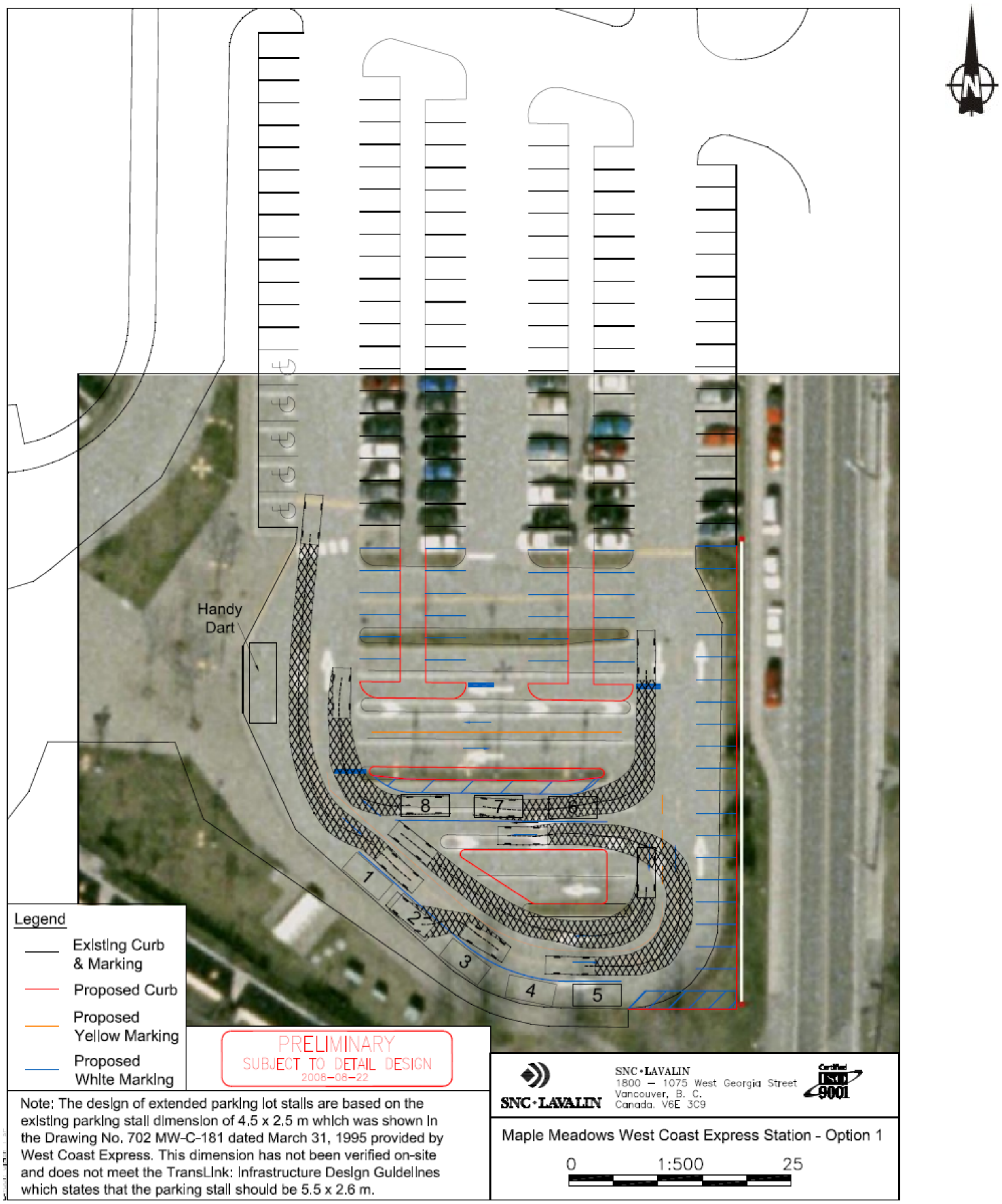
No design standard was available from either West Coast Express or District of Maple Meadow for the dimensions and spacing of parking lanes. On-side dimensions of the existing parking stalls were 4.5 m x 2.5 m, sub-standard compared to current standard of 5.5 m x 2.6 m.

There are five handicapped parking stalls, with a loading/unloading bay dedicated to the handyDART vehicle.

Surveys of pick-up and drop-off demand at the station were conducted in March and July 2008. Wait times were observed during the busiest time of the day (in the afternoon when the two longest trains arrive): about five cars waited for approximately 5-8 minutes each. Vehicle swept path analysis were conducted (see below), and a factor of 1.6 was further applied to forecast the station's future ridership demand.

As a result of this research, the proposed conceptual layout recommended an additional 44 parking stalls and 8 pick-up and drop-off bays, with signage and pavement markings.




Handy
Dart
8
7
6
1
2
3
4
5
Legend
Existing Curb & Marking
Proposed Curb
Proposed Yellow Marking
Proposed White Marking
PRELIMINARY
SUBJECT TO DETAIL DESIGN
2008-08-22
SNC·LAVALIN
SNC·LAVALIN
1800 – 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9
Certified ISO 9001
Note: The design of extended parking lot stalls are based on the existing parking stall dimension of 4.5 x 2.5 m which was shown in the Drawing No. 702 MW-C-181 dated March 31, 1995 provided by West Coast Express. This dimension has not been verified on-site and does not meet the TransLink: Infrastructure Design Guidelines which states that the parking stall should be 5.5 x 2.6 m.
Maple Meadows West Coast Express Station - Option 1
0
1:500
25

REFERENCES

Accessible Bus Stop Design Guidance

Transport for London, 2006

Design Guidelines for Accessible Bus Stops

BC Transit

Bus Pre-signal Assessment and Design Guidance

Transport for London, 2005

Bus Priority at Traffic Signals Keeps London's Buses Moving

Transport for London, 2006

Bus Stop Design Guidelines

Omnitrans, 2006

Chittenden County Metropolitan Planning Organization

http://www.ccmpo.us/library/glossary_list.php

Department of Transportation Services City and County of Honolulu Transit Glossary

http://www.honolulu.gov/dts/transit_glossary.htm#d

Design Guidelines and Standards for Sound Transit Capital Projects: Sounder & ST Express Passenger Facilities

Sound Transit, 2007

North American Public Transport Glossary Revision 3

Ian Fisher and Tom Parkinson, 2006

Public Transport Bus Stop Site Layout Policy

Public Transport Authority, Government of Western Australia, 2003

Public Transport Guidelines for Land Use Development

Department of Infrastructure, State of Victoria, 2006

Shoulder Bus Stop Guidelines

Department of Infrastructure, State of Victoria, 2007

Toolkit for the Assessment of Bus Stop Accessibility and Safety

Easter Seals Project ACTION

Traffic Calming Measures for Bus Routes
Transport for London, 2005

Transit and Land Use Planning
BC Transit

Transit Capacity and Quality of Service Manual, 2nd Edition
Transportation Research Board, 2004

Transit Design Manual
PalmTran, 2004

Transit Facilities
BC Ministry of Transportation and Infrastructure, 2009

Transit Facilities Design Manual
SunLine Transit Agency, 2006

Transit Friendly Design Guide
Calgary Transit, 2006

Transit Infrastructure Design Guidelines
TransLink, 2002

Transit Stop Installation Checklist
BC Transit

Transit Street Design Guide
National Association of City Transportation Officials, 2016

Universally Accessible Bus Stop Design Guidelines
TransLink, 2007

Urban Design Framework
Portland Mall Revitalization, 2005