Bus Infrastructure Design Guidelines

TRANSLINK

Revision 2018.01 (September 2018)

USING THIS GUIDE

The Bus Infrastructure Design Guidelines is offered as a guide to transit infrastructure design best practices, rather than as a set of strict design standards. Design matters requiring the approval of TransLink/CMBC will continue to be reviewed in previous manner. Municipal and provincial road design standards will continue to be applied.

The design parameters and criteria presented in this Guide are suitable for typical applications and will provide operational efficiency, safety and customer comfort. As every project is different with unique site context, Designers should consider site specific context and recommend appropriate design solutions on a case by case basis. For new projects that have specific considerations and/or constraints that may lead to designs deviating from the guidelines, Designers should provide rationale to support any deviations and consult with TransLink at the onset of a project to verify the assumptions and criteria to be followed.

This Guide is a living document. As technology, operational practice and customer expectation evolve, the document will be updated as needed. The information presented in the current version represents the best information available at the time of writing.

SOP: Bus Infrastructure Design Guidelines		
SOP #	INM-002 (Rev 01)	
Owner	TransLink Infrastructure Program Management Department – Transportation Engineering Group	
Purpose of the SOP	The purpose of this Standard Operating Procedure is to provide guidance on making updates and changes to TransLink's *Bus Infrastructure Design Guidelines* (*"BIDG")* following an update to the previous 2013 document. The *BIDG* provides guidance on design practices to accommodate buses and passengers, and promote safe and efficient bus operations. The *BIDG* provides the basis for any review of designs or other changes affecting bus-based transit. However, while the *BIDG* provides a useful foundation for design and review, a comprehensive design review should also include field testing, especially when *BIDG* guidelines are not met.	
SOP: Revisions to the *BIDG*	1	These SOP pages form part of the *Bus Infrastructure Design Guidelines* document, and are included at the beginning of the *BIDG* document. A copy of this SOP is also kept in the TransLink IPM Department SOP binder, which resides with the Confidential Assistant to the Director of IPM.
	2	***When to revise the BIDG:*** The *BIDG* will be revised when updated information is made available and when errors are corrected. *Please contact the Project Manager II in the IPM Department if you have updated or corrected information for inclusion in the BIDG.*
	3	***Who will revise the BIDG:*** The Transportation Engineering Group (IPM Department) is responsible for all updates and revisions to the *BIDG*.

<table>
<tr><td rowspan="2"></td><td>4</td><td colspan="3">Revision numbering and recording:
Revisions to the BIDG will be reflected in a new document Version number, 2018.XX, denoting the revision numbered sequentially from the 2013 base document, starting with 2013.00 for the base 2013 revision. A major update of the BIDG may result in a new base document designation, 20XX.00.
The “Revision History” page in the BIDG must be completed for each revision, and the Version number and date changed on the BIDG cover and page footers.</td></tr>
<tr><td>5</td><td colspan="3">Distribution list for revised BIDG: Following any revision, the revised BIDG will be posted on TransLink’s websites, and any previous version of the BIDG will be removed from TransLink’s websites.
A notification of the revised document will be sent to stakeholders via email, attaching a PDF copy of the revised BIDG (for external stakeholders) and advising where the updated document is on TransLink’s website (for internal and external stakeholders).
Notification should be sent to the following stakeholders:
a) TransLink IPM Department (Director and all Managers)
b) CMBC Transit Engineering (all Managers)
c) West Vancouver Blue Bus (Superintendent of Operations)
d) All members of RTAC Planning Subcommittee via their current representatives</td></tr>
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SOP No. INM-002: Revision History

Revision Number	Date of Revision	Brief description of revision(s)
2013.00	October 2013	--
2018.01	September 2018	- Change dates within SOP to new base document designation (i.e. 2018) - Graphics and figures updated - Bus dimensions match current fleet - Passenger amenities reflects current practice - Transit exchange information reflects current practice - Signage reflects current practice

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FOREWORD

TransLink regularly works with roadway authorities to ensure safe and efficient transit operations within Metro Vancouver; however, the operational requirements of transit vehicles are not fully reflected in existing roadway design manuals. It is our belief that guidelines that reflect the design, performance, and operational characteristics of buses will be valuable to road designers in their practice, resulting in better roadway design, public safety, and transit efficiency.

The Bus Infrastructure Design Guidelines (BIDG) is for engineers, planners, and other parties involved in designing and building urban infrastructure. The BIDG provides roadway design specifications for transit operations and supports the design rationale. It is a consolidation of geometric design practices and "rule of thumb" practice for bus transit facilities as currently applied in Metro Vancouver. Much of the information provided in the BIDG is not new; it has either been made available by TransLink or adopted from other sources including the Transportation Association of Canada's (TAC) *Geometric Design Guide for Canadian Roads,* the TAC's *Manual of Uniform Traffic Control Devices for Canada*, and the Canadian Urban Transit Association's *Canadian Transit Handbook*. Field measurements were obtained to supplement the areas not covered in the reference materials. The BIDG seeks to facilitate effective transit design and encourage consideration of such practices through consolidation of information from multiple sources into a single volume.

The material is offered as a guide to good transit design practice, rather than as a set of strict design standards. Design matters requiring the approval of TransLink/CMBC will continue to be reviewed in the previous manner, with application designs altered where appropriate. Municipal and provincial road design standards will continue to be applied. This document is intended to be used as part of an integrated design process with TransLink's *Transit Passenger Facility Design Guidelines*.

Wide circulation of the BIDG manual across Metro Vancouver will foster a better awareness of transit design considerations, leading to better integration of transit design on roads and at facilities where transit buses operate.

The BIDG will be updated and revised from time to time as needed. TransLink encourages all those who use the Guidelines to provide their comments and design experiences to the BIDG's Program Manager so as to enhance the use of this document.

TransLink
South Coast British Columbia Transportation Authority
September 2018

ACKNOWLEDGEMENTS

The BIDG was initially formulated in 2002 under the guidance and technical input from the members of a Project Steering Committee. Technical staff of member municipalities in Metro Vancouver also reviewed the drafts and provided the project team with constructive comments.

Updating the BIDG was necessary to ensure that planning and design parameters are up to date and appropriately reflected in the document. This allows TransLink and design consultants a point of reference when planning and designing new transit facilities. The update process involved data collection, internal consultation, technical content updates, as well as enhancement in the layout and readability of the document.

This is a living document that will be updated from time to time. The information presented in the current version represents the best information available at the time of writing. Contributions were made by the following people in the current update:

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INTRODUCTION

The purpose of the BIDG is to set in place comprehensive guidelines related to the design of transit infrastructure and to promote consistency and uniformity in the design of TransLink's transit infrastructure. Transit infrastructure is defined as all the fixed components in the environment in which transit operates, such as components that are occupied by transit customers waiting to get on and off of buses, as well as the roadway used by buses.

This document has incorporated existing practices that are available in various TransLink documents, as well as best practices by the BC Ministry of Transportation and Infrastructure, other North American transit service providers, and the TAC.

The guidelines contained in this document identify the general design and operational requirements by the existing TransLink bus fleet, and has taken into consideration the interaction and needs of transit customers and other road users.

This is a living document that may be updated from time to time to better tailor to practical applications. Future text revisions are anticipated to bring the document up-to-date.

This document contains six chapters. Each chapter is dedicated to a specific topic and is preceded by an introduction that describes the content of the chapter. To assist the design process, a design checklist was developed and is included in **Appendix A**. The checklist identifies key design elements and the relevant chapter(s) where guidance can be found.

The design dimensions and criteria presented in this document are intended for typical application. Nevertheless, some, if not all, projects are unique. Many may have specific considerations and/or constraints that lead to design criteria deviating from those used in typical design. Designers should provide rationale to support any deviations and consult with TransLink at the onset of a project to verify the assumptions and criteria to be followed.

CHAPTER 1. BUS OPERATION CHARACTERISTICS

1.1 INTRODUCTION

The dimensions of transit buses and their performance characteristics have significant implications in designing roadways intended for transit operations. At the beginning of the road design or transit facility design process, the designer should identify the types of transit vehicles that would use the roadway or transit facility, and the critical design values (e.g., minimum width and height clearances) based on the anticipated bus maneuvers.

An overview of the various types of buses currently operated by TransLink is provided in this chapter. The overview includes typical vehicle dimensions, turning requirements, considerations related to pavement widening, lateral sweep, visibility impairment, and vehicle performance, as well as provisions of bicycle racks and wheelchair lifts and ramps.

1.2 TYPES OF TRANSLINK BUSES

TransLink currently operates several types of buses in passenger service. Bus dimensions vary by manufacturer and production year, but generally fall within a consistent range to meet street operational requirements.

Seven transit design vehicles are currently developed for use in the design of transit-related facilities, which can be seen in Figure 1.2.1 to Figure 1.2.8. These transit design vehicles are:

- Trolley Bus;
- Standard Bus;
- Articulated Trolley Bus;
- Articulated Bus;
- Highway Coach;
- Mini Bus; and
- HandyDART

The standard buses run on diesel fuel, compressed natural gas (CNG), or a hybrid of diesel-electric power, while the articulated buses are powered by either diesel fuel or hybrid diesel-electric power. Trolley buses run off of electricity, as discussed further in Section 1.2.1, and all other buses in TransLink's fleet run on diesel fuel.

All TransLink buses are equipped with a bicycle rack at the front of the vehicle. See Section 1.6 for information on bicycle racks. All TransLink buses are equipped with a wheelchair lift or ramp to provide access to customers with disabilities. See Section 1.7 for information on wheelchair lifts and ramps.

Figure 1.2.1 Standard trolley bus

Figure 1.2.2 Standard bus (New Flyer)

Figure 1.2.3 Standard bus (Nova)

Figure 1.2.4 Articulated trolley bus

Figure 1.2.5 Articulated bus (New Flyer)

Figure 1.2.6 Highway coach

Figure 1.2.7 Mini bus

Figure 1.2.8 HandyDART bus

Note that the typical dimensions of the TransLink fleet are slightly different from the vehicle characteristics in the Transportation Association of Canada's (TAC) *Geometric Design Guide for Canadian Roads* (GDG), Section 2.4.3, specifically:

- The width of the Articulated Bus (without mirrors) is 2.6 m (instead of 2.4 m in the GDG);
- The rear wheelbase of the Articulated Bus is longer than that of the GDG;
- The minimum turning radius of the Standard Bus and Articulated Bus are slightly larger than that of the GDG; and
- The length of the Articulated Bus is 18.5 m instead of 18.3 m in the GDG.

The design of roadways or transit facilities should be based on the appropriate Transit Design Vehicle. In most cases, this is the largest or the most critical Transit Design Vehicle intended to operate on the road or at a transit facility.

Typical design dimensions of TransLink's existing bus fleet are summarized in Table 1.2.1, while the critical vehicle design dimensions are shown in Table 1.2.2.

Typical dimensions of the existing bus types are illustrated in Figure 1.2.9 to Figure 1.2.14.

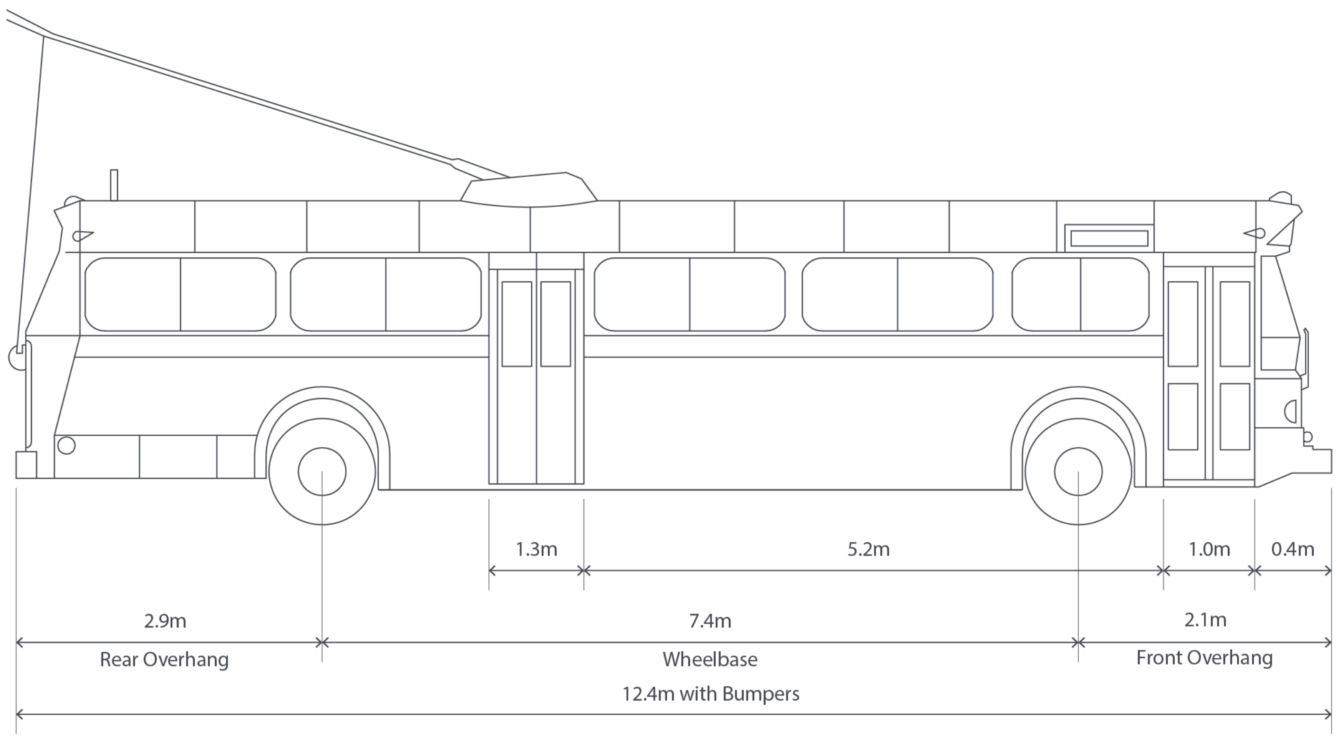
Table 1.2.1 Typical dimensions of the TransLink bus fleet

Bus Type	Length (1) (m)	Front Overhang (m)	Rear Overhang (m)	Wheelbase (m)	Width (2) (m)	Height (m)	Minimum Radius (Outer Curb) (3) (m)
Standard - Trolley	12.4	2.1	2.9	7.4	3.0 / 2.6	3.6	13.5
Standard - New Flyer	12.4	2.2	2.8	7.4	3.1 / 2.6	3.1	13.5
Standard - Nova	12.4	3.0	3.2	6.2	3.1 / 2.6	3.3	12.5
Standard CNG – New Flyer (4)	12.4	2.1	2.9	7.4	3.0 / 2.6	3.3	13.4
Standard Hybrid – Nova	12.4	3.0	3.2	6.2	3.1 / 2.6	3.3	12.5
Articulated - Trolley	18.5	2.1	2.9	5.8 / 7.7	3.0 / 2.6	3.6	12.9
Articulated - New Flyer	18.5	2.1	2.9	5.8 / 7.7	3.1 / 2.6	3.4	13.4
Articulated Hybrid – New Flyer	18.5	2.2	3.1	5.8 / 7.4	3.1 / 2.6	3.3	13.4
Highway Coach	12.4	2.3	3.0	7.1	3.1 / 2.6	3.2	12.4
Mini Bus	8.2	0.9	2.3	5.0	2.8 / 2.4	3.0	9.1
HandyDART	8.1	0.9	2.5	4.7	2.8 / 2.4	3.1	9.1

Notes:

1. Length with bumpers – refer to Section 1.6 for bike rack requirements
2. Bus width with / without side mirrors
3. Measured from the outer edge of the vehicle
4. Refer to Section 1.2.2 for more detail regarding CNG buses

Figure 1.2.9 Standard trolley bus typical dimensions



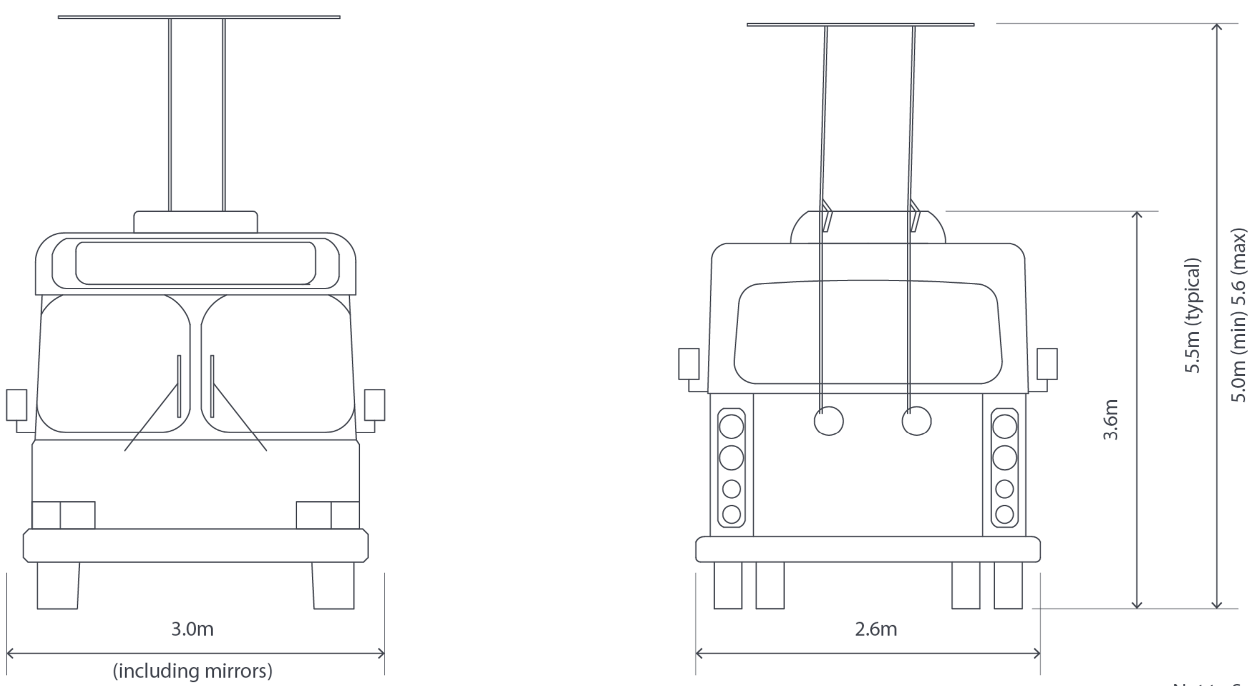


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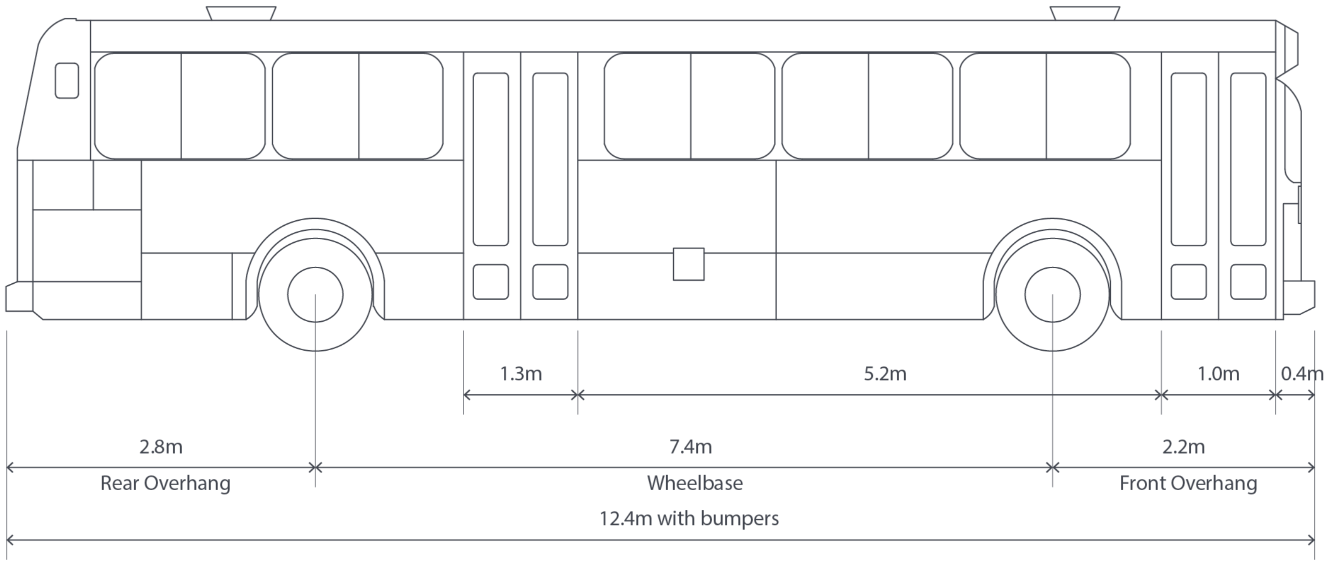
Figure 1.2.10 Standard bus (New Flyer) typical dimensions



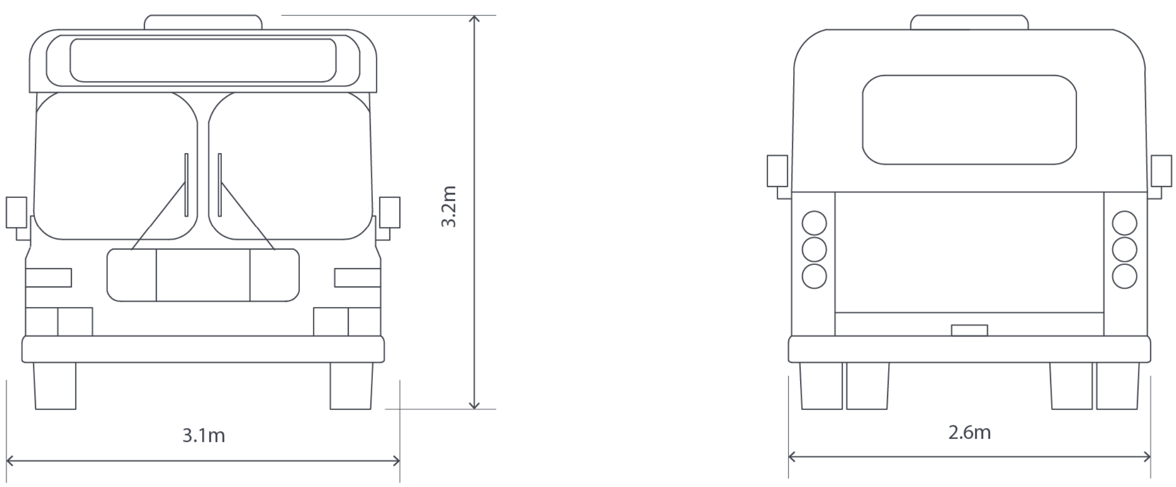


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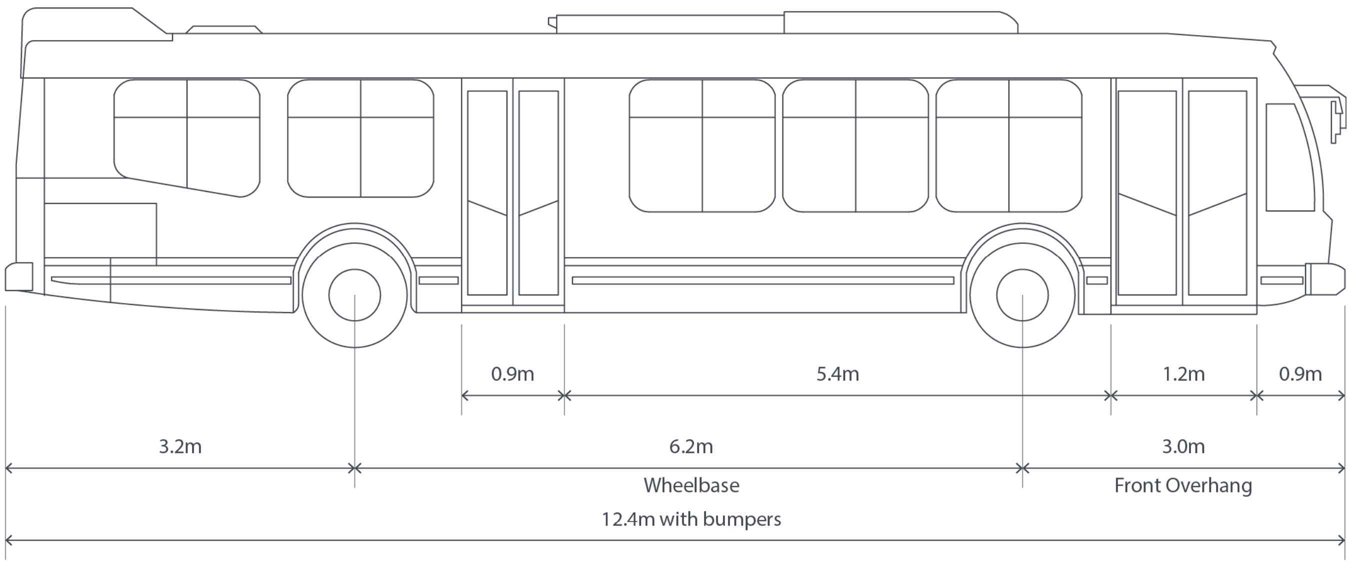
Figure 1.2.11 Standard bus (Nova) typical dimensions



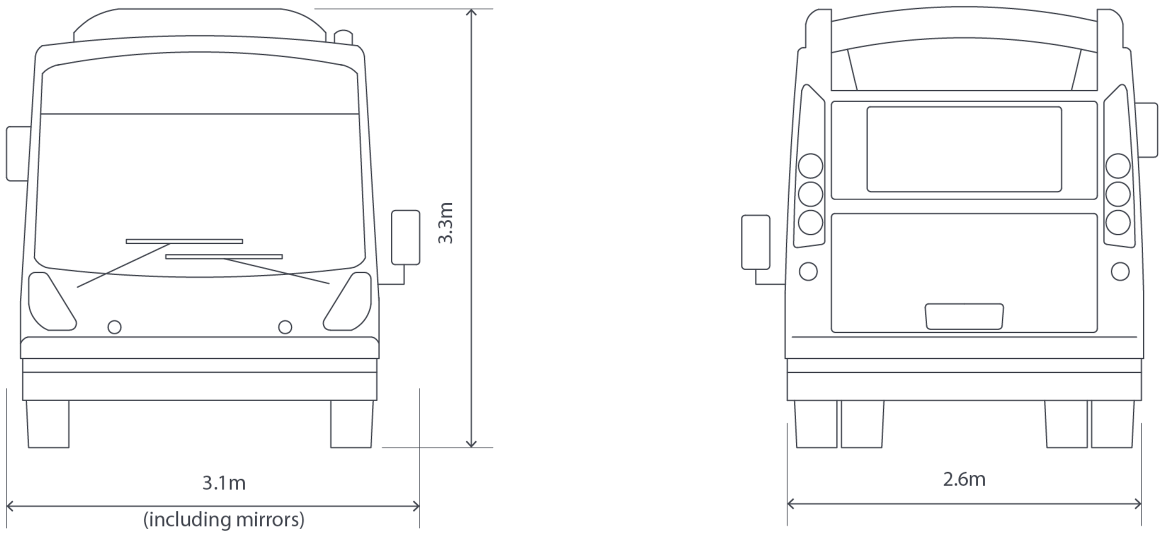


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Figure 1.2.12 Articulated bus (New Flyer) typical dimensions

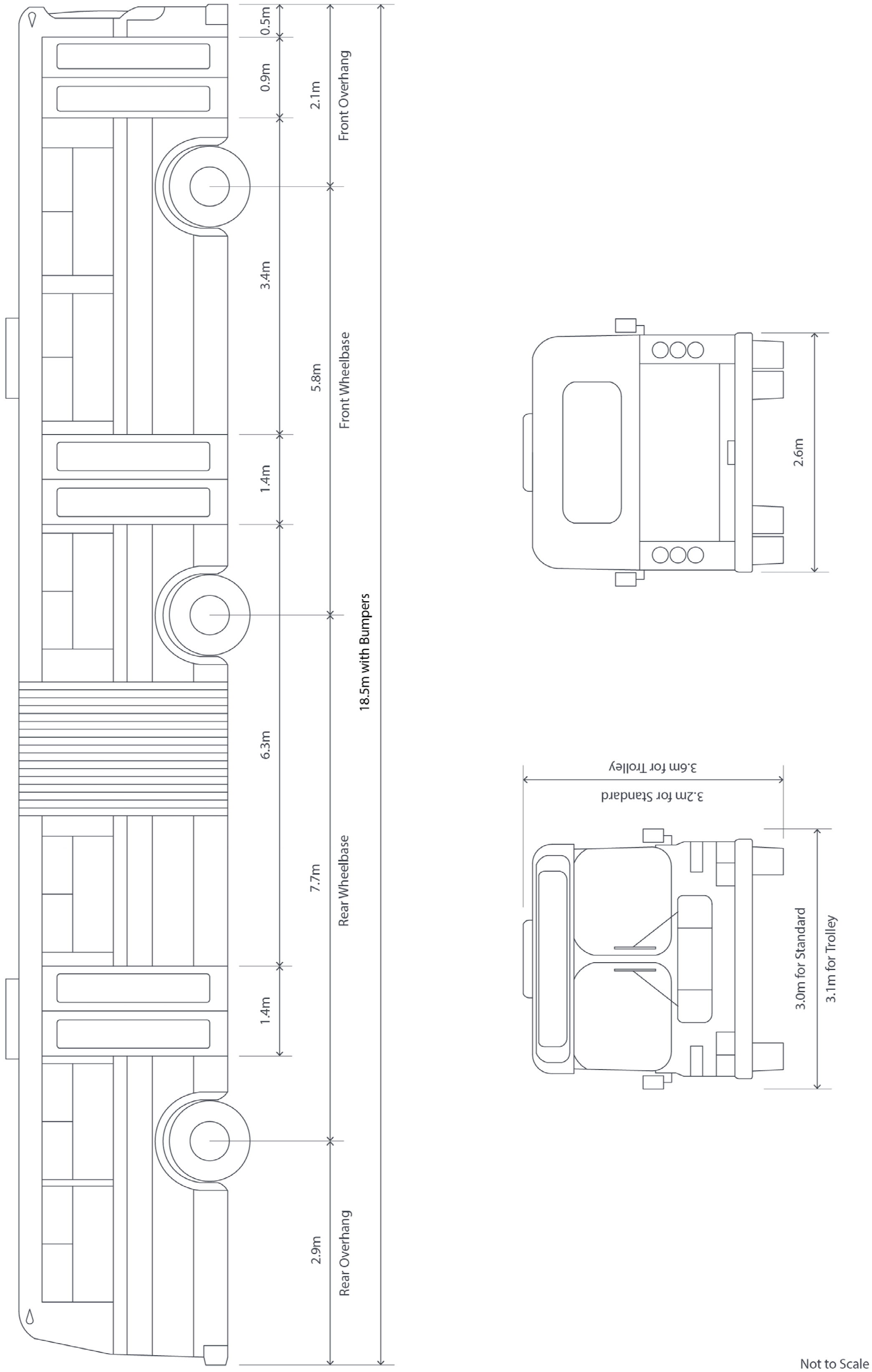
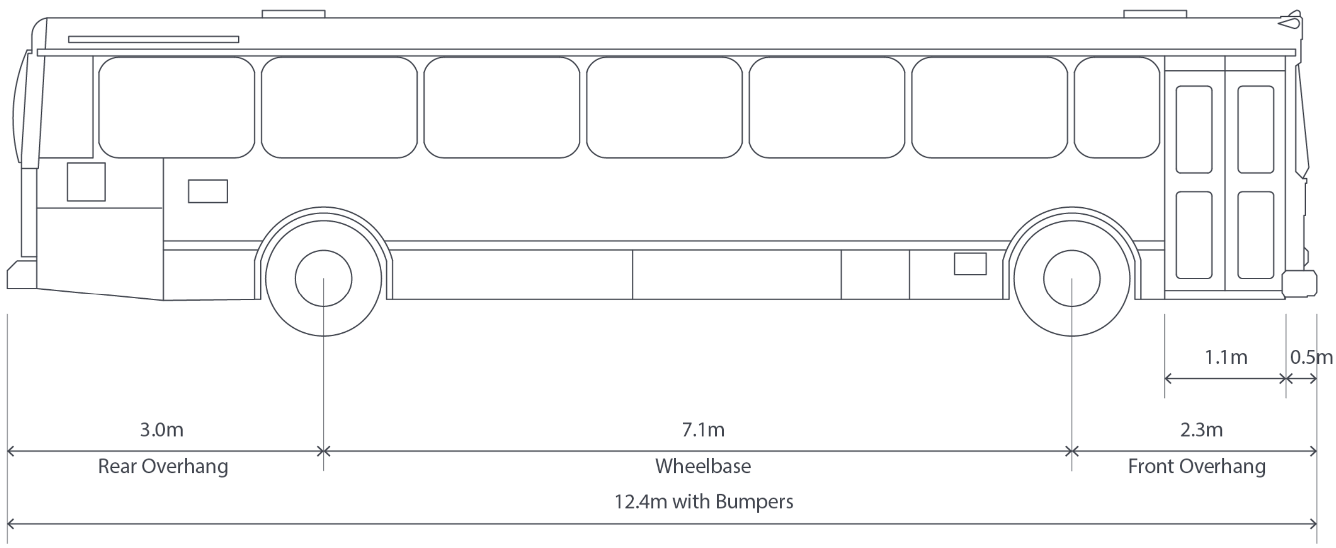


Figure 1.2.13 Highway coach typical dimensions



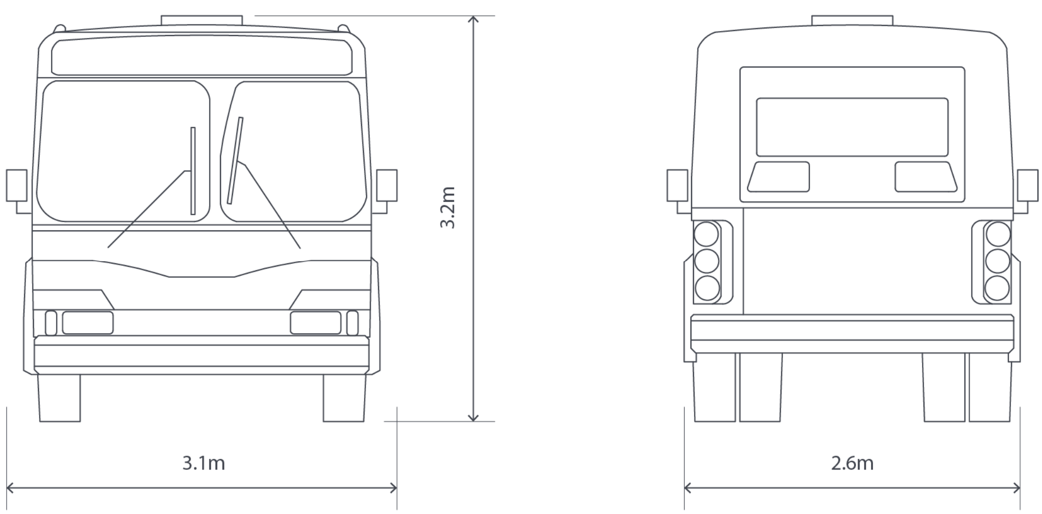


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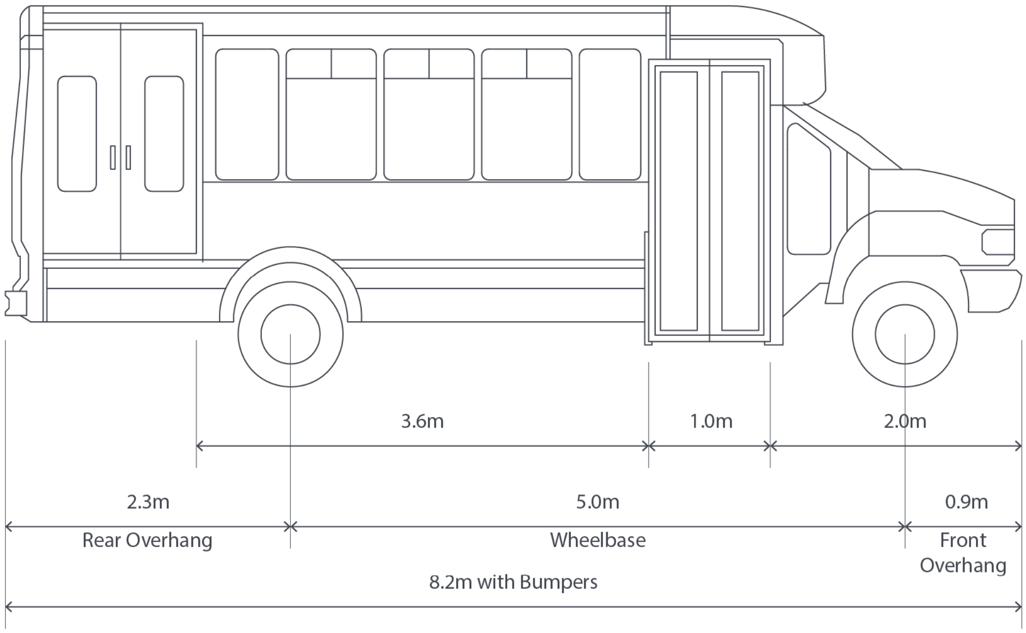
Figure 1.2.14 Mini bus typical dimensions



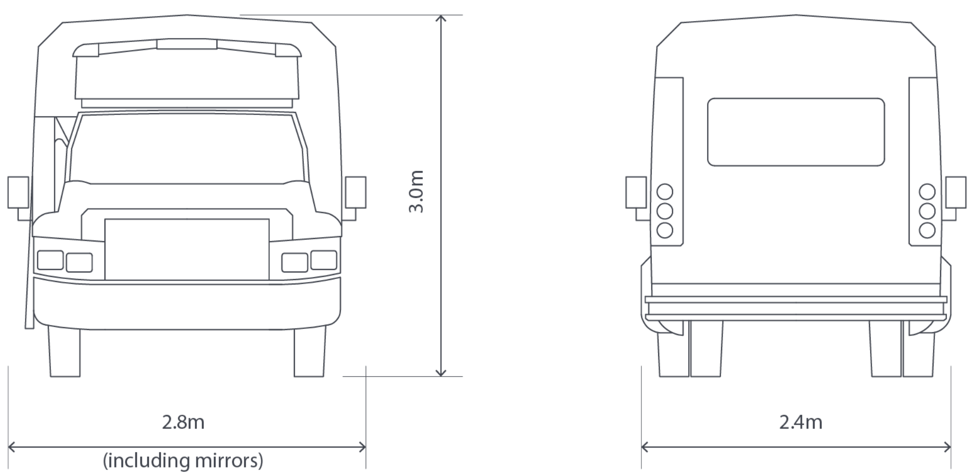


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Table 1.2.2 Critical vehicle dimensions

Design Parameter	Design Bus Type	Critical Design Value
Maximum Bus Length	Nova articulated bus	18.8 m in length, bumper to bumper.
Maximum Bus Width	Standard / articulated buses	3.1 m with mirrors 2.6 m without mirrors
Turning Radius	New Flyer low-floor Standard Bus	13.4 m turning radius 7.4m wheelbase.
Bus Rear Overhang Sweep	Nova standard bus	0.6 m rear curb-side overhang sweep
Extrusion from Front of Bus	Year 2006 or newer buses equipped with V2W bike racks	1.22 m with bikes on deployed bike rack
Extrusion from the Passenger Side of a Bus	Highway coach	1.6 m wheelchair lift

1.2.1 TROLLEY BUSES

TransLink's trolley buses are electricity-powered buses that run under overhead wire. The key components of an overhead trolley wire system include:

- Trolley poles – trolley poles are installed on the sides of the road and are used to support all trolley wire overhead components. The typical spacing of trolley poles along a straight section is 30 m (not more than 34 m - to avoid wire resonance that would break the wire). The spacing requirement for curves would be different and is subject to site-specific criteria;
- Span guy wire – wires that connect to the trolley poles and are used to support the trolley wires;
- Trolley wires – wires that the bus trolley poles are connected to for power;
- Switches – located where there is a split of the wire directions. There are 2 types of switches:
  - Power-on-power-off switch: activated by a toggle switch operated by the bus operator. Tear drops are painted on the pavement to indicate to the bus operator the location when the switch has to be activated;
  - Electric switch: activated by the turning position of the bus, i.e., the offset wire connection of the bus;
- Frogs – located where wires from two directions merge; and
- Cross-over – located where two wires cross over one another (i.e. when 2 trolley wires intersect).

In general, trolley buses have the same maneuvering requirement as regular buses, but since trolley buses only run under trolley wires, the following design considerations should be taken account when designing for trolley bus operation:

- A trolley bus can travel within 3.6 m laterally from the centre of the trolley wires;
- The maximum speed of a trolley bus under an overhead (i.e. with cross over) is 15 km/hr;
- The maximum speed of a turning trolley bus and a bus traveling under a switch or frog is 8 km/hr;
- A trolley bus cannot pass another trolley bus unless at a location where a by-pass overhead wire is provided;
- At bus stops, trolley buses typically would operate first-in-first-out, unless a bypass wire is provided to allow for independent departure from the second position of a bus bay; and
- The nominal vertical clearance is 5.5 m, and no more than 6.9 m for optimal contact pressure by the bus trolley poles. The typical vertical clearance required for special work (e.g., switches, frogs, or crossovers) above the trolley wires is 1 m.

1.2.2 COMPRESSED NATURAL GAS (CNG) BUSES

TransLink's current bus fleet includes vehicles powered by compressed natural gas (CNG). Special design considerations are required when designing a covered bus facility that utilizes CNG buses, including:

- Where CNG vehicles are stored below a pedestrian space, and openings exist in the floor assembly between spaces, noncombustible draft stops not less than 500 mm deep should be installed at the perimeter of the openings.
- Electrical installations at ceiling level should be investigated for ignition hazards.
- Mechanical ventilation within storage spaces should be investigated to ensure that air is not recirculated within the remainder of the building.

Possible covered bus facilities include transit exchanges, layover areas, and bus depots. Project teams should ensure that the bus facility design meets current building code, especially for CNG storage garages. The above design considerations do not apply to open air bus facilities.

1.2.3 DOUBLE DECKER BUSES

TransLink plans to expand its bus fleet to include double decker buses in the near future. Special design considerations are required when designing bus facility that utilizes double decker buses, including:

- Confirm that height clearance of covered facility can accommodate bus height clearance requirements.
- Confirm that height clearance of overhead obstruction (e.g. overpass, signage) along bus routes can accommodate bus height clearance requirements.

As double decker design vehicle specifications finalize, the information will be included in the appendices of the guidelines.

1.2.4 Electric Buses

TransLink is exploring to include electric buses in its bus fleet. Special design consideration is required when designing bus facility that utilizes electric buses, including:

- Electric charging station requirements at a bus exchange.

As electric buses design vehicle specifications finalize, the information will be included in the appendices of the guidelines.

1.3 Bus Turning Paths

1.3.1 Turning Templates

The Standard Bus (specifically the New Flyer low-floor Standard Bus) requires the largest turning radius. A turning template for the New Flyer low-floor Standard Bus, created by AutoTURN, a swept path analysis software, is presented in **Appendix B**. The turning speed is assumed to be 15 km/h or less as noted in the TAC's GDG, Section 2.4.4. The sweep path shown includes the side mirrors and assumes the bicycle rack at the front of the bus is in use. The TAC has a separate template to be used for scenarios where the bus is starting from zero speed.

The 180° turning path shown in **Appendix B** includes a transition section at the beginning of the turn corresponding to the bus operator's turning of the steering wheel to a 'full-lock' position on entry into the turn and a transition section at the end of the turn corresponding to the operator's straightening out the vehicle upon exit of the turn. When the full wheel lock is reached, the bus follows a circular path with the minimum turning radius during the middle portion of the maneuver. The transition sections of the turning path are determined by the duration and the rate at which the steering wheel is turned, the friction of the road surface, etc. The minimum swept paths for a bus turning either right or left in the circular section in the central part of the turn are the same.

The width of the vehicle path (or sweep) increases when the bus begins to turn and then gradually decreases as the bus completes the turn. The angle of the turn affects the maximum width of the sweep and its location. For a right-hand turn, the required vehicle path is the lateral distance between the path of the left front body overhang and the path of the right rear wheel. For safety reasons, physical objects should be a minimum lateral clearance distance of approximately 1 m away from the vehicle sweep. Where visibility is restricted or the bus is beside structures (e.g., columns, building edge, and walls), physical objects should have a lateral clearance distance greater than the minimum.

When a facility design is tested using AutoTURN, a smooth turning path is required as bus operators will not typically stop to adjust the path direction.

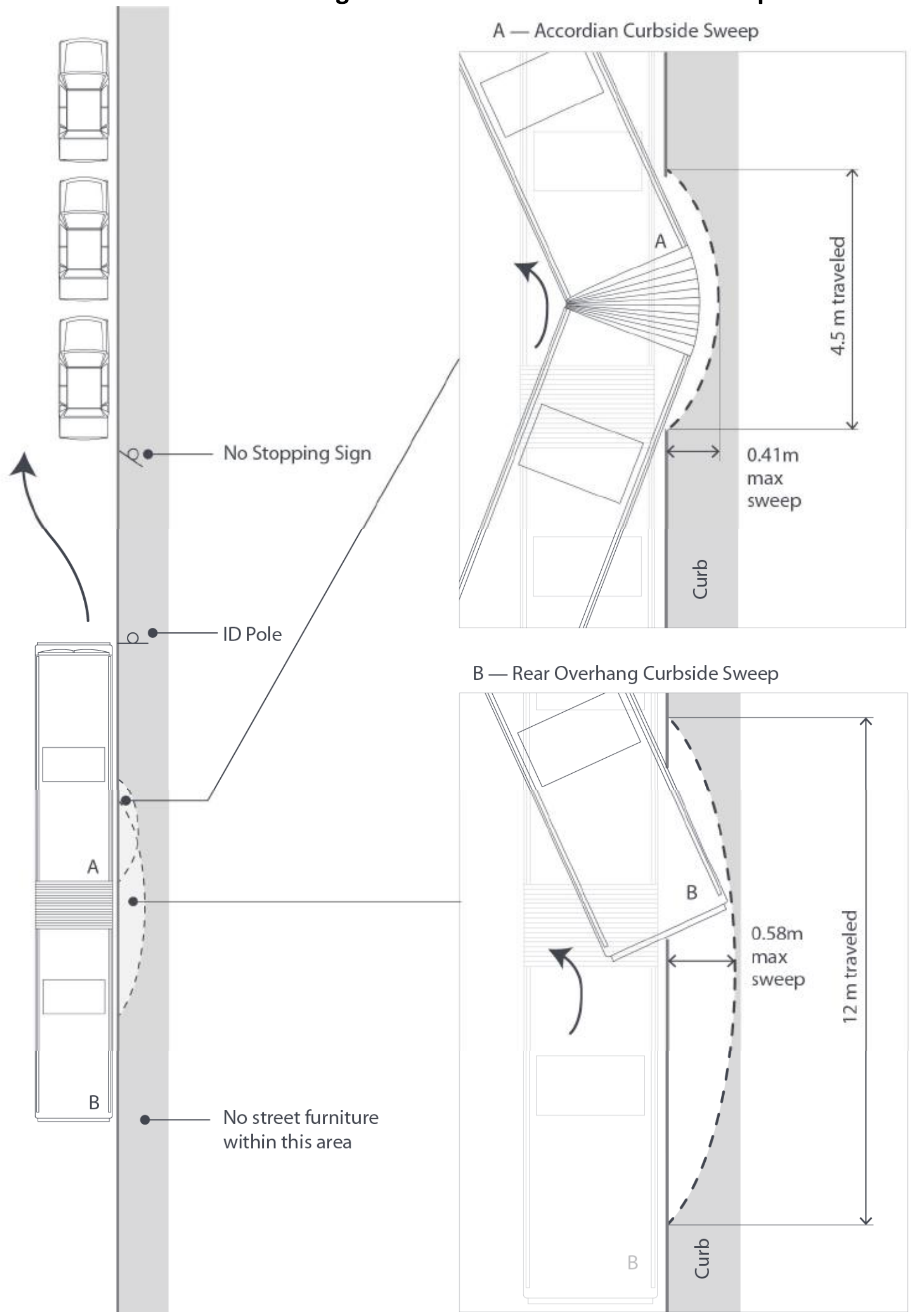
Pavement widening beyond standard widths should be considered when buses are the largest design vehicle for an undivided roadway. A safety hazard may result if the buses fail to slow down significantly to avoid contacting lateral obstacles or encroaches onto the adjacent travel lanes, etc. The general design principles proposed in the TAC's GDG, Chapter 1 should be followed.

1.3.2 Lateral Sweep of Standard and Articulated Bus

The movement of a Standard Bus produces a swept path drawn by the rear of the vehicle as it pulls out from a bus stop. Field tests will be required to confirm the maximum lateral sweep. Street furniture should be set back from the curb to provide adequate horizontal clearance from the lateral sweep of a Standard Bus.

The movement of an Articulated Bus produces a swept path drawn by the front and rear of the vehicle, but also by the accordion at the articulation point. These movements are unique to articulated vehicles and may not be anticipated by other motorists or pedestrians. Figure 1.3.1 shows the lateral curbside sweep of an Articulated Bus as it pulls away from a bus stop with minimum longitudinal clearance ahead. The maximum lateral sweep at the accordion of an Articulated Bus is approximately 0.41 m when it travels a distance of 2.5 m. The maximum lateral sweep at the rear overhang of a Standard Bus and an Articulated Bus is approximately 0.58 m and 0.51m respectively. Street furniture should be set back from the curb to provide horizontal clearance from turning buses.

Figure 1.3.1 Lateral curbside sweep of articulated bus



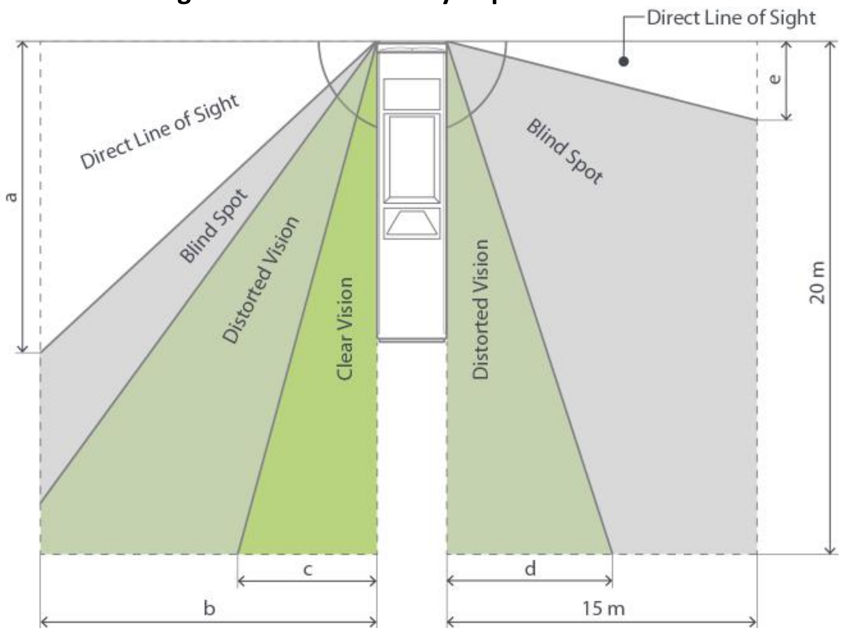
DISTANCE TRAVELED (m)	SWEEP (m)
0	0
0.5	0.13
1.0	0.23
1.5	0.27
2.0	0.32
2.5	0.41 (max)
3.0	0.26
3.5	0.20
4.0	0.10
4.5	0

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

1.4 VISIBILITY IMPAIRMENT ZONES

Bus operators have a limited line of sight to the sides and the rear of a transit vehicle, as shown in Figure 1.4.1. These limitations affect the placement of bus stops and the interactions between pedestrians and buses, and between buses and other vehicles. The following factors, summarized in Table 1.4.1, should be considered in assessing a bus operator's sight lines.

Figure 1.4.1 Visibility impairment zones



1.4.1 RIGHT SIDE OF OPERATOR

Customers in the bus typically block the bus operator's view through the windows behind his or her compartment. There is a limited direct line of sight to the right side of the bus operator though the windows of the front door as illustrated in Figure 1.4.1. The direct line of sight for Articulated Trolley Bus, Highway Coach, and Mini Bus will need to be confirmed in field tests.

Buses are equipped with a single convex mirror on the right side. This mirror allows the bus operator to check that customers have cleared the rear doors safely when alighting. As this mirror has some level of distortion, it does not allow the operator to clearly judge the real distance between the bus and a vehicle approaching from behind. Figure 1.4.1 illustrates the limited range of view through the right side mirror.

Also as shown in Figure 1.4.1, the bus operator has a large blind spot on the right side of the bus. This area 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. At intersections with dual left turn lanes (i.e. two left turn lanes), the standard practice is for buses to use the outside left turn lane.

1.4.2 LEFT SIDE OF OPERATOR

The bus operator obtains a direct line of sight to the left by "shoulder checking" through the window at the operator's seat. The direct line of sight for Articulated Trolley Bus, Highway Coach, and Mini Bus will need to be confirmed in field tests.

Table 1.4.1 Visibility impairment zones

Vision	Means	Purpose	Var.	Bus Type	Angle (°) 1	Angle (°) 2	Note
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
				CS	38	-	Door + first window
				HC	21	6.7	(Angle 1) Door to red line on window (Angle 2) Door only
				HD	52	27	(Angle 1) Door + first 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	-	-
				CS	64	-	-
				HC	22	-	-
				HD	22	-	-
Clear Vision (Right Side)	Flat mirror on right	To check real distance between approaching vehicles	d’	CS	7	-	-
				HD	11	-	-
Direct Line of Sight (Left Side)	“Shoulder checking” left window of operator seat on left	Direct line of sight	a	Std NF	Full	-	Full sight of surrounding with mirrors
				Std Nv	Full	-	Full sight of surrounding with mirrors
				CS	64	-	-
				HC	Full	-	Full sight of surrounding with mirrors
				HD	55	-	-
Clear Vision (Left Side)	Flat mirror on left	To check real distance between approaching vehicles	c	Std NF	15	-	-
				Std Nv	9	-	-
				CS	13	-	-
				HC	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	-	-
				CS	41	-	-
				HC	33	-	-
				HD	21	-	-

Buses are equipped with a flat mirror on the left side. This mirror allows the bus operator to judge the real distance between the bus and a vehicle approaching from behind, and thus recognize an adequate gap in traffic prior to re-entering the travel lane.

Buses are also equipped with a small convex mirror on the left side. This secondary mirror provides a distorted image of the area that cannot be viewed either through the flat mirror or by direct line of sight through the windows at the bus operator's seat area. While this image has some use, it cannot be relied on to estimate either distance or speed of an approaching vehicle from behind. However, it does, for example, permit the operator to determine if there is a vehicle travelling in the lane immediately beside the bus prior to starting a lane change.

The residual visibility impairment zones (or blind spots) on the left side of the operator, as illustrated in Figure 1.4.1, are outside areas behind the operator where visibility is limited to the range of view of the exterior convex mirror and the front door window.

Consideration should be given to the specific visibility impairment zones of buses when designing a transit facility. For example, locating a bus bay or a bus stop on a roadway immediately downstream of a convex horizontal curve should be avoided. A site visit or field test may be necessary in order to assess potential visibility problems.

1.5 Vehicle Performance

Buses have different vehicle performance characteristics compared to passenger cars. The maximum desirable rates of acceleration and deceleration, and the rate of change in acceleration and deceleration (or jerk rate), should be taken into consideration as they affect both the abilities of the transit vehicles and the tolerance of standees who may not be able to hold on to any hand grip.

The acceleration and deceleration rates for transit buses shown in Table 1.5.1 are suggested in the Canadian Urban Transit Association's *Canadian Transit Handbook*:

Table 1.5.1 Desirable acceleration and deceleration rates

Rate	Standard Bus (m/s^2)	Articulated Bus (m/s^2)
Desirable Service Acceleration Rate	0.9	0.7 – 0.9
Desirable Service Deceleration Rate	1.1	1.1
Maximum Emergency Deceleration Rate	2.7	2.7

The desirable service acceleration and deceleration rates allow for customer comfort and safety, and should be used in roadway design wherever possible as an upper limit. The maximum emergency deceleration rate should only be used in extreme conditions, such as to avoid a collision.

1.6 Bicycle Racks

All TransLink buses are equipped with bicycle racks mounted at the front of the vehicle to allow cyclists to access transit service.

Typically, cyclists require a 1.5 m clearance in front of the bus and a 0.5 m lateral clearance area to load/unload a bicycle to/from the side of a bike rack. A minimum 3 m clearance should be provided to load/unload a bicycle at tandem bus stops. Typical dimensions of existing bicycle racks are shown in Figure 1.6.1, and model types are shown in Figure 1.6.2 through Figure 1.6.4. No obstructions (i.e. fences and railings) should be placed beside a bus ID pole in order to allow sufficient access to the bicycle rack.

Figure 1.6.1 Bicycle rack dimensions

Var.	Dimension	VeloPorter 3 (cm)	VeloPorter 2 (cm)	DL2 (cm)
w	Width	234	150	163
d	Depth	18	18	15
c	Vertical Ground Clearance [1]	51	46.5 – 55.5	60
l_1	Folded Length	36	23 – 27	27 – 30
l_2	Unfolded Length	95	80 – 84	84 – 87

Note:

1. Measurement varies depending on the bus types and models

Figure 1.6.2 VeloPorter 3 bicycle rack

Figure 1.6.3 VeloPorter 2 bicycle rack

Figure 1.6.4 DL2 bicycle rack

1.7 WHEELCHAIR LIFTS AND RAMPS

All TransLink buses are equipped with either a wheelchair lift or ramp. All low-floor standard and articulated buses are equipped with wheelchair ramps, while the high-floor buses, Highway Coaches, Mini Buses, and HandyDART are equipped with wheelchair lifts. The typical dimensions of a wheelchair lift and ramp are summarized in Table 1.7.1. Figure 1.7.1 shows a typical wheelchair lift while Figure 1.7.2 shows a typical wheelchair ramp. See Section 3.5.2 for the design requirements for wheelchair pad at the passenger zone of a bus stop.

Table 1.7.1 Dimensions of wheelchair lifts and ramps

Type	Width (m)	Length (m) (extension for landing)
High-floor bus / Highway Coach Wheelchair Lift	0.79	1.60
Low-floor bus Wheelchair Ramp	0.77	1.17
Mini Bus Wheelchair Lift	0.90	1.90
HandyDART Wheelchair Lift	0.95	1.70

Figure 1.7.1 Typical wheelchair lift

Figure 1.7.2 Typical wheelchair ramp

CHAPTER 2. ROADWAY GEOMETRIC DESIGN

2.1 INTRODUCTION

Roadway geometric design should be prepared in accordance with the TAC's GDG and other relevant design standards as required by the approving agency. The design should be suitable for the appropriate road classification, such as Arterial, Collector, and Local Street. However, as specific roadway geometric requirements for transit operations are not included in most design manuals, they are included in this chapter to assist roadway designers, taking into consideration the vehicle dimensions noted in Chapter 1 of this document. Specific requirements presented in this chapter include intersection design, lane widths, road alignment, grades, grade changes, sight distances, traffic calming measures, and roundabout design. TransLink/CMBC should be given an opportunity to review and comment on roadway-related designs on all existing or planned bus routes.

It should be noted that the design objective is to provide bus operators with adequate opportunity to act and react safely in all traffic conditions, taking into account the design and performance characteristics of buses, particularly those critical in roadway design. If any minimum design standards are not met, one or a combination of the following scenarios may occur, which may compromise public safety, transit efficiency, and customer service:

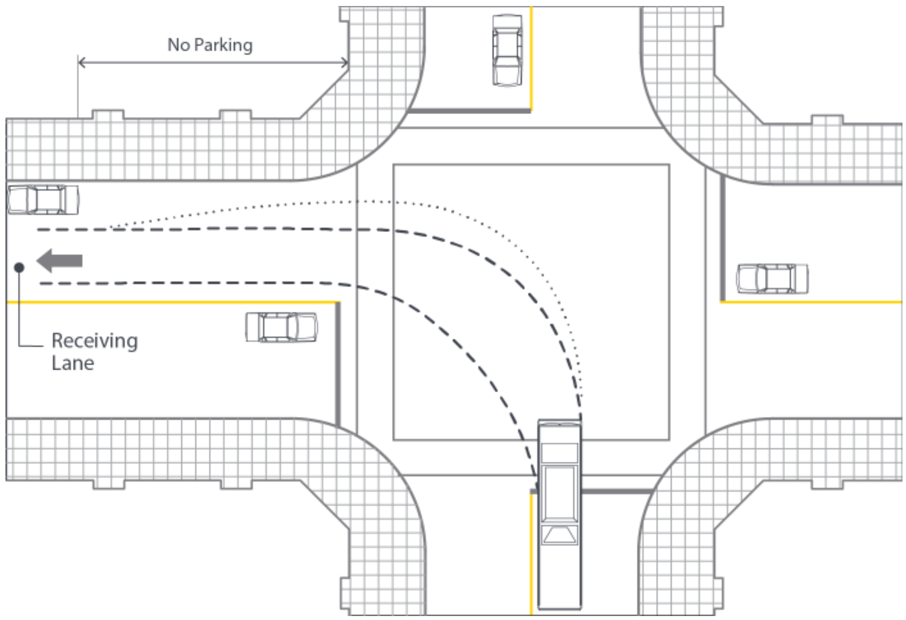
- A bus may not be able to physically complete a certain maneuver without conflicting other traffic movement(s);
- A bus operator may be forced to maneuver without adequate visibility of adjacent traffic;
- Bus adherence to schedule may be delayed due to design deficiency;
- The mechanical parts of the bus may be damaged, increasing maintenance needs and affecting operational safety;
- The safety and comfort of the customers may be adversely impacted; and
- The opportunity to provide bus customer facilities or bus stops may be limited.

2.2 INTERSECTION DESIGN

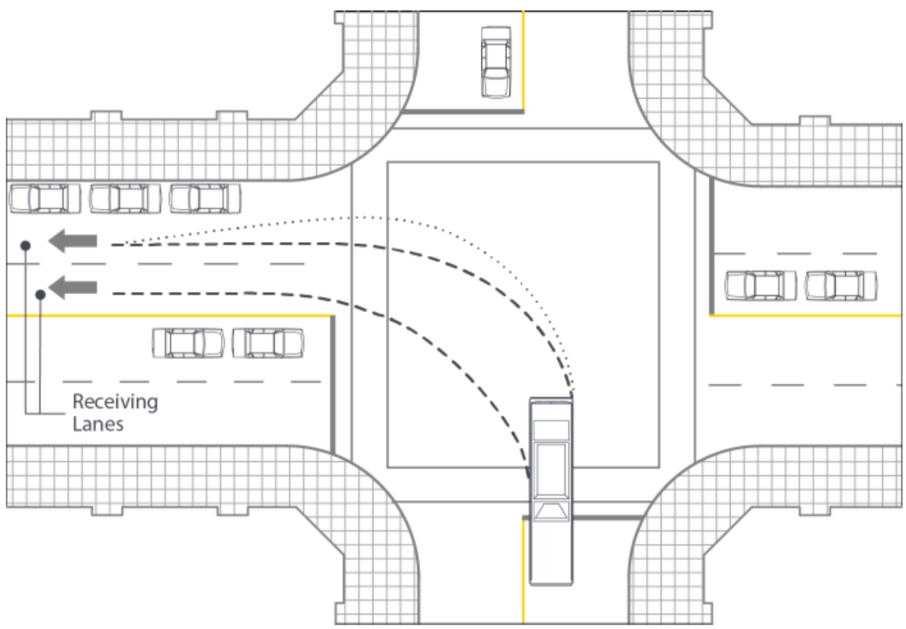
The geometric design of intersections should accommodate the required bus turning paths. The Design Vehicle selected should reflect the "worst case" condition for the types of vehicles, including buses, expected to operate on the specific route. It should be noted that the following design dimensions are provided as a guide only. Realities of urban design should be acknowledged, such as curb radius vs. pedestrian exposure and other trade-offs. Traffic conditions and frequency of bus movements may also affect intersection design.

Figure 2.2.1 illustrates the vehicle path of a Standard Bus making a typical left-turn movement at an intersection with either one or two receiving lanes. During the design of a new intersection or the evaluation of an existing one, the receiving lane should be wide enough to prevent a left-turning bus from encroaching on the directional lane line or from coming into contact with a parked vehicle. It is generally preferred that a buffer distance of 0.45 m is provided between the bus and these hazards.

Figure 2.2.1 Bus turning left at intersection



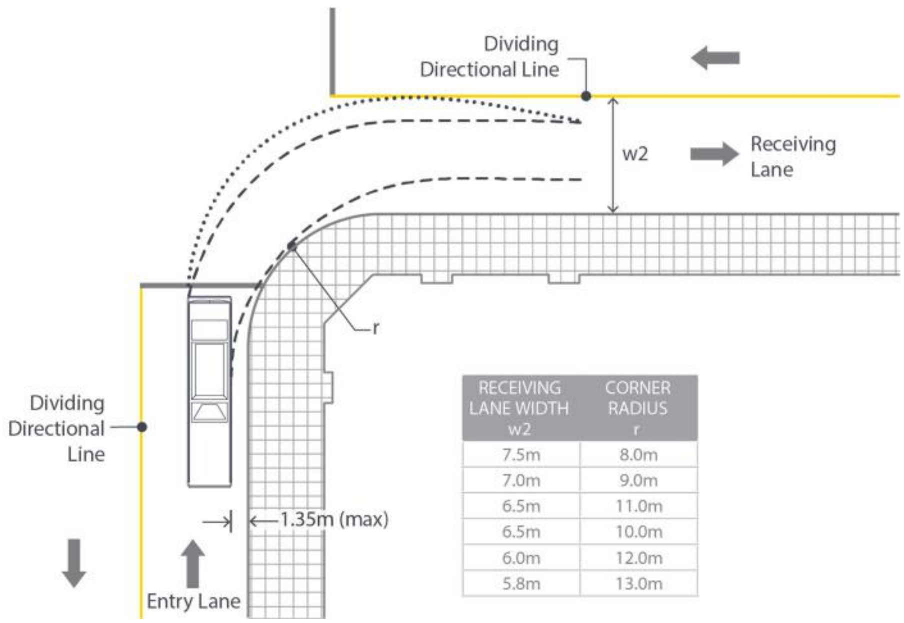
One receiving lane



Two receiving lanes

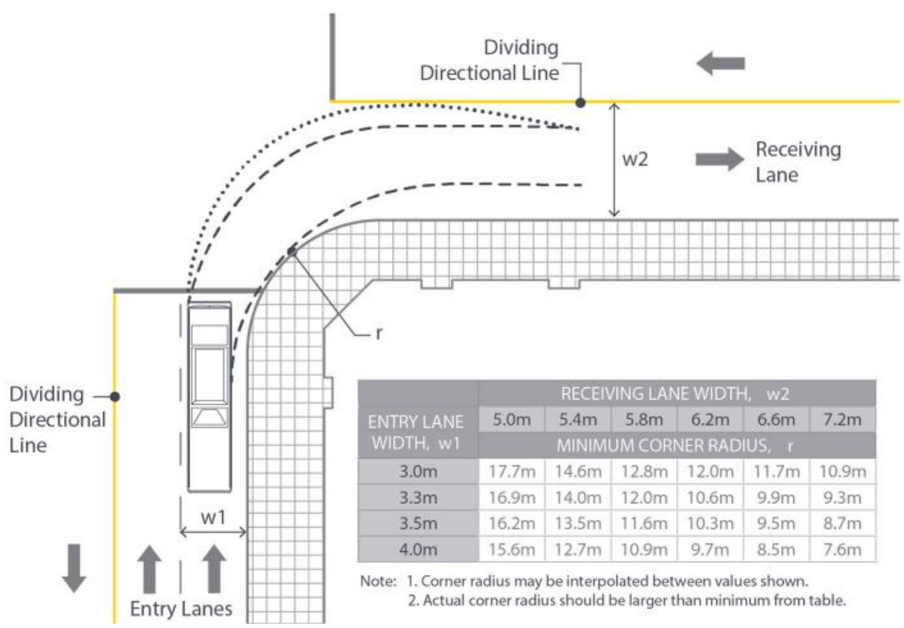
Figure 2.2.2 illustrates the vehicle path of a Standard Bus making a typical right-turn movement at an intersection, and the associated design considerations for corner radii and entry/receiving lane widths. During the design of a new intersection or the evaluation of an existing one, critical vehicle turning paths and other site-specific characteristics should be taken into account when determining corner radii and entry/receiving lane widths.

Figure 2.2.2 Bus turning right at intersection



RECEIVING LANE WIDTH w2	CORNER RADIUS r
7.5m	8.0m
7.0m	9.0m
6.5m	11.0m
6.5m	10.0m
6.0m	12.0m
5.8m	13.0m

One entry lane



ENTRY LANE WIDTH, w1	RECEIVING LANE WIDTH, w2: 5.0m	5.4m	5.8m	6.2m	6.6m	7.2m
	MINIMUM CORNER RADIUS, r					
3.0m	17.7m	14.6m	12.8m	12.0m	11.7m	10.9m
3.3m	16.9m	14.0m	12.0m	10.6m	9.9m	9.3m
3.5m	16.2m	13.5m	11.6m	10.3m	9.5m	8.7m
4.0m	15.6m	12.7m	10.9m	9.7m	8.5m	7.6m

Note: 1. Corner radius may be interpolated between values shown.
2. Actual corner radius should be larger than minimum from table.

Two entry lanes

In a single wide lane, the current practice for a right-turning bus is to leave no more than a 1.35 m gap from the curb prior to the turn to avoid safety hazards resulting from vehicles, bicycles, etc. trying to pass the bus on its right side. This is a 'defensive driving' behavior.

For safety and legal reasons, TransLink does not endorse the practice of crossing the directional dividing line while completing any turns. Figure 2.2.2 is intended to give guidelines to keep buses within their own lane while completing right turns.

Depending on the lane assignment at an intersection, specific design considerations at entry and receiving lanes, as summarized in Table 2.2.1, should be reviewed.

Table 2.2.1 Bus turning design considerations at intersections

Turn Type	Entry Lane	Receiving Lane
Left Turn	• The starting position of the turn. • The sight triangles for crossing traffic (see Section 2.5). • The potential conflict with the turning path of opposing traffic. • The sight line for opposing traffic.	• The stop position of the cross traffic on the left. • The width of the receiving lane(s). • The lateral clearance between any parked vehicles and the turning path of the bus.
Right Turn	• The starting position of the turn. • To prevent small vehicles such as bicycles, motorcycles, etc. from passing the bus on its right side, a right-turning bus should commence the turn at a distance no more than 1.35 m from the curb, where possible. • The sight triangles of traffic from the left (see Section 2.5).	• The corner radius. • The width of the receiving lane(s). • The lateral clearance between any parked vehicles and the turning path of the bus.

2.3 LANE WIDTHS

Section 4.2.1.3 of the TAC’s GDG provides design standards for lane widths that generally meet transit operation requirements. However, under some conditions, transit buses may require additional consideration. Pavement widening beyond standard widths should be considered when buses are the largest design vehicle for an undivided roadway. The general design principles proposed in the TAC’s GDG, Section 4.2.1 should be followed.

Figure 2.3.1 shows the desirable curb lane widths on road sections for bus operation, as well as the ideal pull-out distance between a stopped bus and parked vehicles.

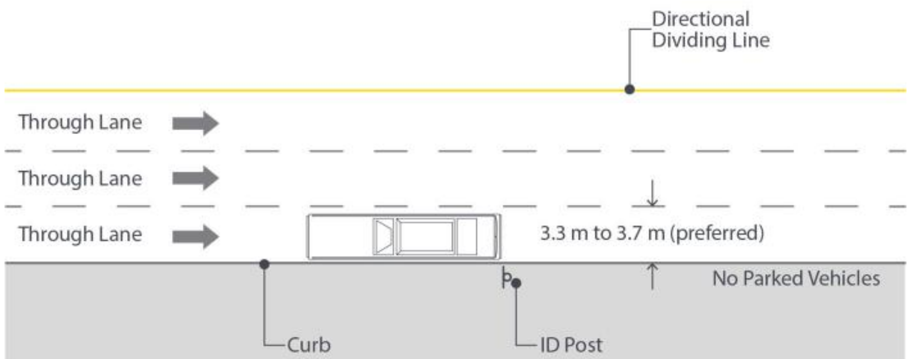
The required width of the curb lane depends on the number of through lanes available in the same direction of travel, any allowance for parking in the curb lane, and the presence of bike lanes. Table 5.3.7 of the TAC’s GDG provides lane specifications for application with bicycle lanes. The minimum width of a shared lane for transit and bicycle use is 4.3 m.

When two or more through lanes are available and parking is not allowed in the curb lane, the desirable width of the curb lane ranges from 3.3 to 3.7 m as per the TAC’s GDG. When more than one lane is available and parking is allowed in the curb lane, the minimum width of the shared curb lane is 5.8 m. When there is only one travel lane in the direction of travel and parking is allowed, the minimum lane width is increased to 6.0 m to provide clearance from opposing traffic.

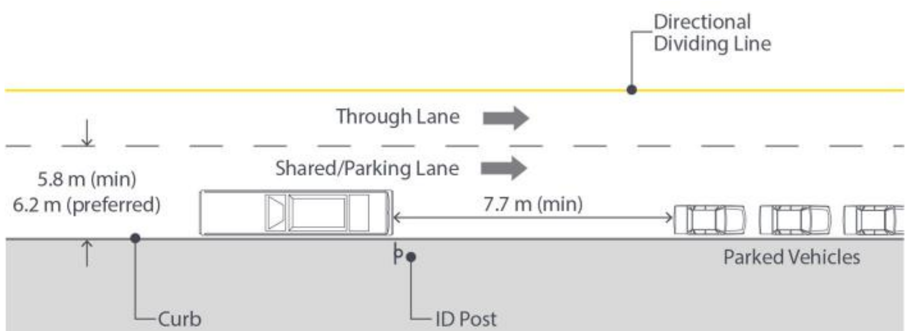
The width of the travel lane immediately upstream of a bus stop should not be more than 4.5 m such that approaching vehicles must change lanes to pass a stopped bus. The 4.5 m width can be achieved by having a curb bulge at a bus stop area close to an intersection.

The recommended minimum widths in the TAC's GDG for outside a bus stop area are 3.3 m for a travel lane and 1.8 m for a bike lane.

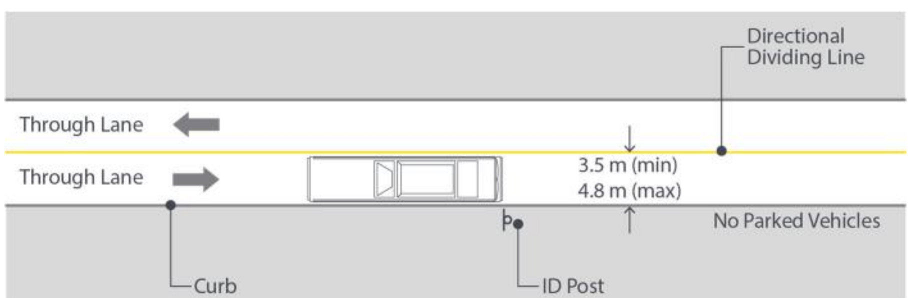
Figure 2.3.1 Lane widths



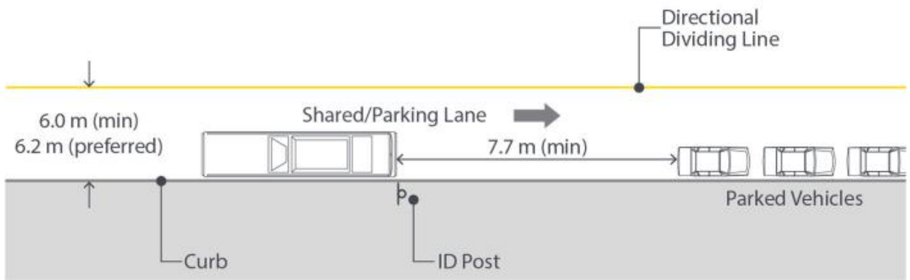
Three through lanes



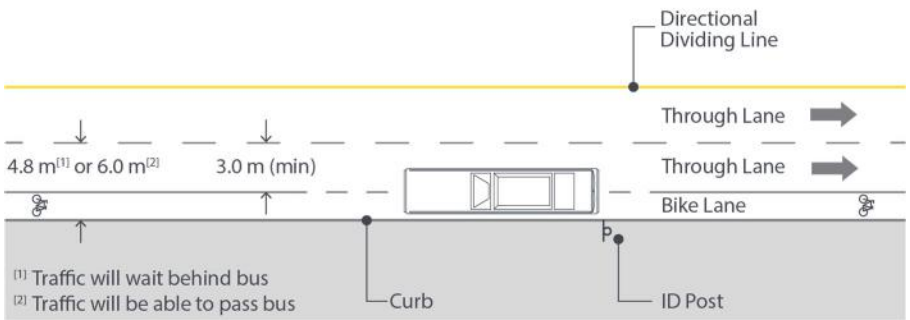
One through lane and one shared/parking lane



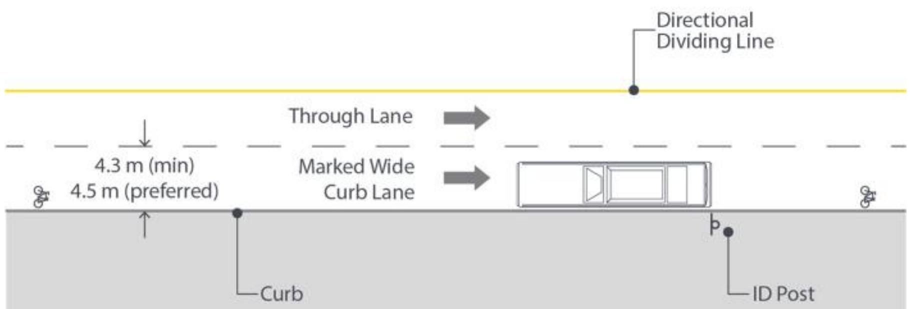
Two-way bus-only lane



Shared/parking lane



Bike lane – separated



Bike lane – shared

2.4 Alignment, Grades and Height

Road alignment elements, such as horizontal curvature and vertical profile, should be designed in accordance to the TAC's GDG and other relevant standards as required by the approving agency. Given the vehicle performance characteristics of buses, such as lower rates of acceleration and deceleration, using minimum geometric design standards should be avoided wherever possible to achieve a high level of bus performance and customer comfort.

2.4.1 Maximum Gradient

The maximum grade or slope that transit buses can negotiate safely and economically is somewhat less than that for general traffic. The maximum grade for roadways designed for transit buses is generally 12%. For sustained gradients longer than 800 m, the maximum grade is 8%. Note that 8% is also the maximum grade at a bus stop so that wheelchair users can maneuver manually. All roads proposed for bus services should preferably be designed with sustained grades of no more than the maximum value to allow safe and efficient bus operation.

Although buses can climb a grade greater than 12%, the speed and operating performance will be significantly reduced. Stopping sight distance and other safety aspects are also important design factors that must be considered on downhill road sections with grades greater than 12%.

The maximum grade at bus layover locations should not exceed 3%.

2.4.2 GRADE CHANGE POINTS WITHOUT VERTICAL CURVES

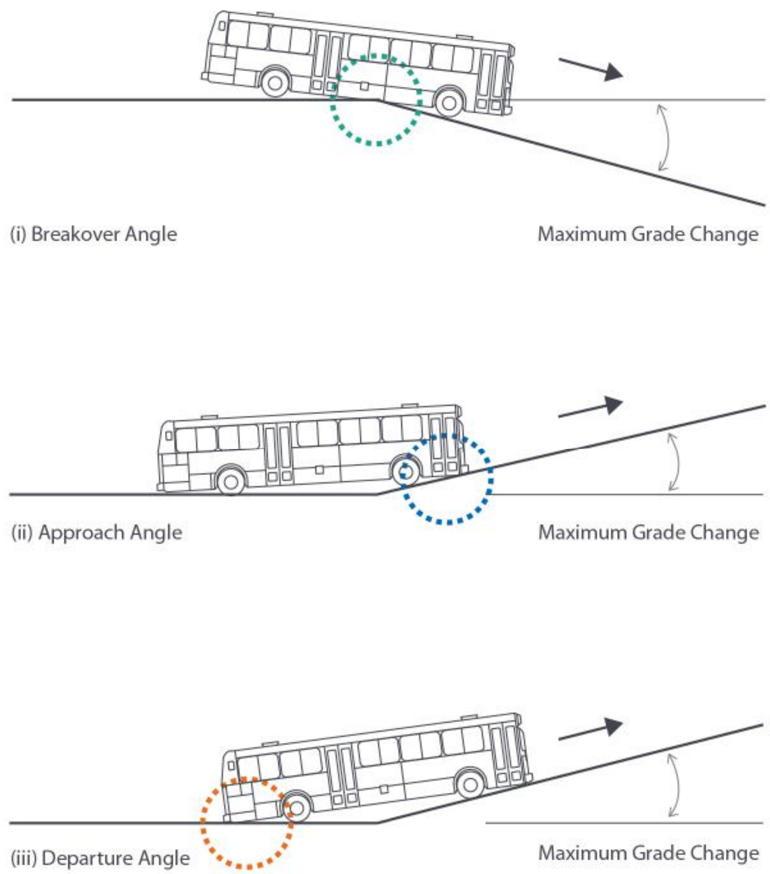
On roadway alignment with changes in road grades, the transition at the grade change point should be no more than the breakover, approach, and departure angles shown in Figure 2.4.1. The provision of appropriate grade change points will prevent the underside or the front/ rear bumpers of the bus from contacting the pavement. The values shown in Figure 2.4.1 are absolute maximum values that should not be exceeded on any road design.

When towed, the front of a bus is lifted, reducing the clearance between the rear bumper and the road, as seen in Figure 2.4.2. Highway coaches have the most critical departure angle (5.1%) when being towed. Since only the front compartment of an articulated bus is lifted when towed, towing does not change the departure angle of an articulated bus. The grade change design criteria for towing should be considered in all transit facilities designs.

2.4.3 MINIMUM VERTICAL CLEARANCE

When a bus is being towed under a roofed structure, the minimum vertical clearance is 4.5 m. This clearance accommodates access for repair activity on the roof of the bus and height needed for towing. Overhead structures including sprinkler and HVAC equipment should be mounted higher than 4.5 m from the ground.

Figure 2.4.1 Grade change points



Grade Change Point	Maximum Grade Change	Bus Type with Most Critical Requirement
Breakover	15.2%	New Flyer Low Floor Standard Bus
	14.0%	New Flyer Low Floor Articulated Bus
Approach	13.0%	New Flyer Low Floor Standard Bus (with V2 type bike rack)
Departure	14.3%	New Flyer Low Floor Standard Bus (normal operation)
	8.3%	New Flyer Low Floor Standard Bus (when towed)
	5.1%	Highway Coach (when towed)

Figure 2.4.2 Towing of a highway coach

2.5 SIGHT DISTANCES

The TAC's GDG provide sight distance requirements for automobiles and trucks. The acceleration and deceleration capability of transit buses is different from these vehicles, and there is a need to maintain a high level of customer comfort and safety. Sight distance requirements specifically for transit buses are provided in this section to assist in the design of roadways for bus operation.

2.5.1 STOPPING SIGHT DISTANCE

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

- 'Perception and Reaction Distance' (PRD) is the distance travelled at the operating speed (or posted speed limit) during the operator's perception of an incident and the subsequent brake reaction time. This corresponds to the time elapsed from the instant an object for which the bus operator decides to stop comes into view, to the instant the operator contacts the brake pedal. Perception and reaction time is typically taken to be 2.5 s for design purposes.

- 'Braking Distance' (BD) is the distance travelled from the time that braking begins to the time the transit bus comes to a stop. The minimum braking distance for transit buses may be calculated from the bus deceleration rates indicated in Section 1.5. 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 customer comfort and safety is maintained. In emergency conditions, such as collision avoidance, the maximum deceleration rate for transit buses is 2.7 m/s^2.

See Table 2.5.1 for the equations to calculate the “Perception and Reaction Distance” and the “Braking Distance”.

Table 2.5.1 Stopping sight distance formula

Stopping Sight Distance (m)	
$SSD = PRD + BD$	
Perception and Reaction Distance (m)	**Breaking Distance (m)**
$PRD = 0.278vj$	$BD = \frac{0.0386v^2}{d}$
Variable	**Meaning**
v	Initial Operating Speed (km/h)
j	Perception and Reaction Time (s)
d	Deceleration Rate (m/s^2)

Table 2.5.2 summarizes the minimum Stopping Sight Distance for transit buses in service and emergency stopping conditions.

Table 2.5.2 Transit bus stopping sight distance

Initial Operating Speed (km/hr)	Perception and Reaction Time (s)	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	25	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

To maintain reasonable customer comfort and safety during deceleration, the minimum Stopping Sight Distance for service conditions should be provided whenever possible. Higher deceleration rates (such as the emergency deceleration rate) are used if and when the operator is in an extreme situation, and should not be used for design purposes.

2.5.2 Decision Sight Distance

In the relatively complex situations that bus operators and other vehicle drivers often encounter, evasive maneuvers may be required. Situations can arise that require longer perception and reaction times and more complex action than an operator's straightforward decision to stop. In these circumstances, it is desirable to provide the 'Decision Sight Distance', which is a longer measure than the Stopping Sight Distance as shown in Table 2.5.3 and Table 2.5.4.

Table 2.5.3 Stopping sight distance on level roadways for automobiles

Design Speed (km/hr)	Stopping sight distance (m)
40	50
50	65
60	85
70	105
80	130
90	160

Table 2.5.4 Decision sight distance

Design Speed (km/hr)	Decision Sight Distance for Avoidance Maneuver (m)				
	A	B	C	D	E
50	75	160	145	160	200
60	95	205	175	205	235
70	125	250	200	240	275
80	155	300	230	275	315
90	185	360	275	320	360

Notes:

Avoidance Maneuver A: Stop on rural roadway
Avoidance Maneuver B: Stop on urban roadway
Avoidance Maneuver C: Speed / path / direction change on rural roadway
Avoidance Maneuver D: Speed / path / direction change on suburban roadway
Avoidance Maneuver E: Speed / path / direction change on urban roadway

As recommended in the TAC's GDG, Section 2.5.5, 'Decision Sight Distance' allows for a greater distance to react to unexpected circumstances and enhances safety in such complex situations. Table 2.5.6 of the TAC's GDG provides the recommended Decision Sight Distance for a range of design speeds. Further research may be required to determine the Decision Sight Distance applicable to transit buses, 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 the deceleration and acceleration rates of buses are significantly lower than those of a passenger car.

The provision of Decision Sight Distance is desirable wherever feasible. If it is not possible to provide the Decision Sight Distance, special attention should be given either to the use of traffic control devices for providing advance warning of the conditions to be encountered or for segregating transit movement from those of other traffic. Roadway geometric modifications may be considered to meet safety requirements.

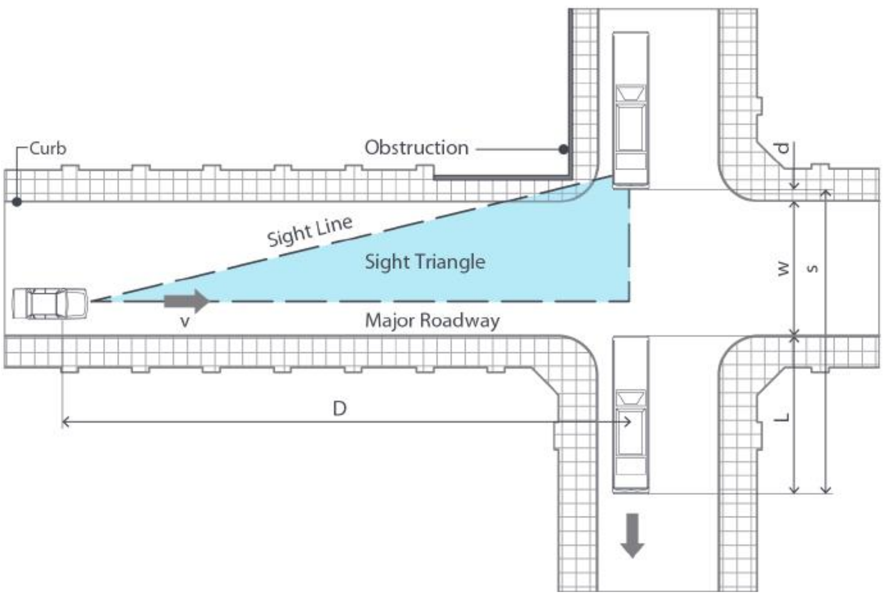
2.5.3 Crossing Sight Distance

The required sight distance for transit buses to make a crossing maneuver from a stop is a function of the time it takes for a stopped bus to clear the intersection and the distance that another vehicle would travel along the major roadway at the design speed during the same period of time. 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.

The minimum Crossing Sight Distance along the major roadway from an intersection can be calculated, as shown in Figure 2.5.1, based on (i) the design speed of the major roadway, V, (ii) the perception and reaction time of the crossing driver on the major roadway, j, and (iii) the acceleration time for the bus to cross the major roadway, t.

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

Figure 2.5.1 Minimum crossing distance along major roadway



Distance travelled during acceleration of the bus:

$$s = d + w + L$$

Where:
- s = distance travelled to cross the major roadway (m)
- d = distance from near edge of pavement to front of stopped bus (3.0 m)
- w = width of pavement (m)
- L = length of bus (m)

Minimum crossing sight distance along the major roadway:

$$D = \frac{v(j+t)}{3.6}$$

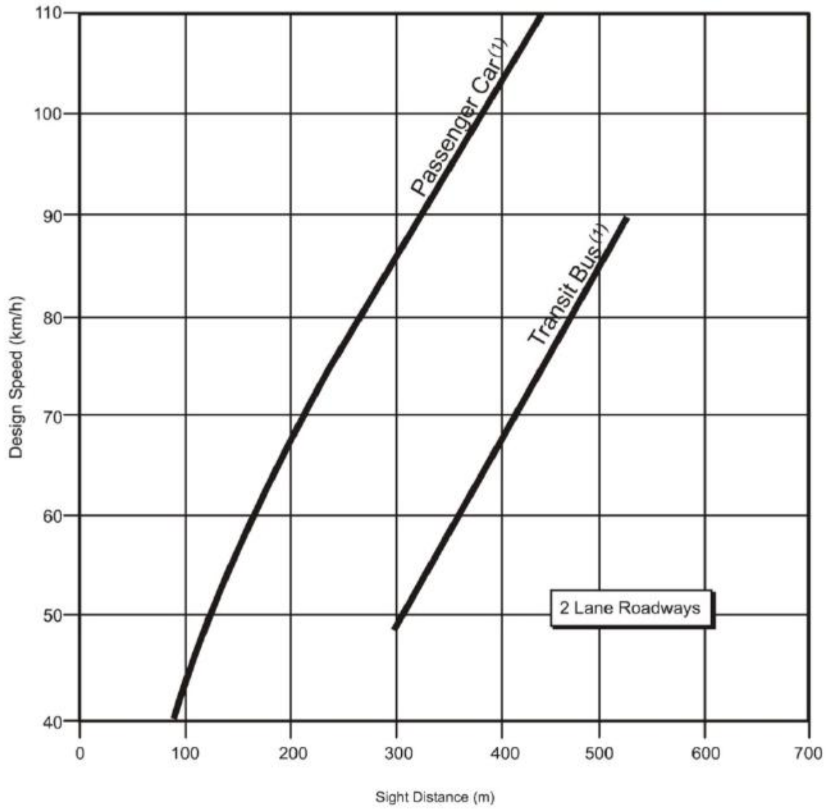
Where:
- D = minimum crossing sight distance along the major roadway from intersection (m)
- v = design speed of major road (km/h)
- j = perception and reaction time of crossing bus operator (2.5 sec)
- t = time (sec) to cross distance "s" (m) (see Figure 2.5.2). t should be corrected for cross road grade % (see Table 2.5.2)

2.5.4 TURNING SIGHT DISTANCE

The opposing vehicle of a left-turning bus, at the instant the turning maneuver begins, should be sufficiently far away so that the turning bus can accelerate to a speed which does not significantly interfere with the approaching vehicle. To determine the required 'Turning Sight Distance', it is assumed that (i) the approaching vehicle will slow to a speed of 85% of the design speed at the intersection, and (ii) there should be always a gap of at least 2 seconds between the turning bus and the approaching vehicle. Due to the acceleration characteristics of transit buses, the requirement for transit buses making right or left turns is generally greater than other vehicles.

Figure 2.5.2 shows the Turning Sight Distance requirements for transit buses from a stop control on a minor road. An average acceleration rate of 0.9 m/s^2 for transit buses (instead of 1.9 m/s^2 used for passenger cars) is assumed for both left and right turning movements. Buses typically turn at a speed of 15 km/hr, and trolley buses may turn slower at approximately 8 km/hr.

Figure 2.5.2 Turning sight distance for stopped buses



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.

2.5.5 Merging Sight Distance

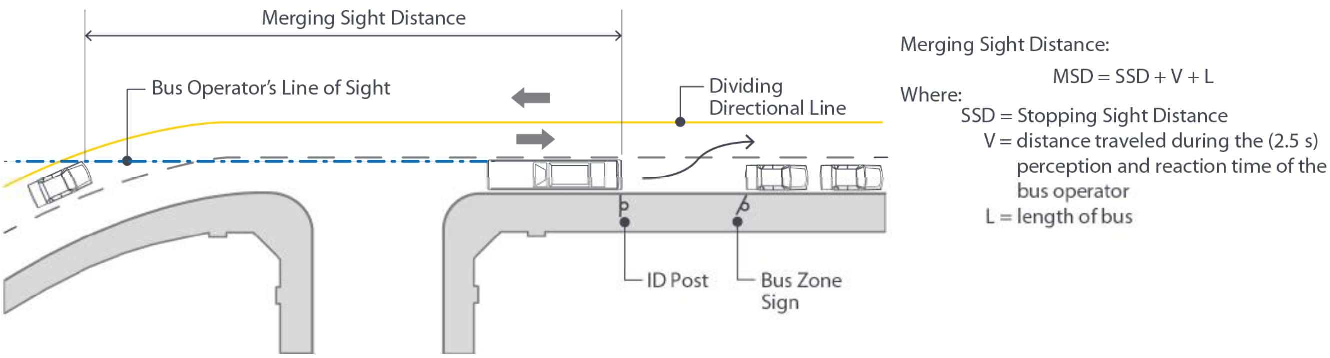
A bus merging into an adjacent travel lane from a bus stop should have the required Merging Sight Distance. It is assumed that the driver of a vehicle approaching from behind would brake to allow the bus to merge (see Section 5.2.3).

The minimum Merging Sight Distance for a transit bus to merge onto the adjacent travel lane is the sum of (i) the minimum Stopping Sight Distance of the approaching vehicle in the travel lane, (ii) the distance travelled by the same approaching vehicle at the design speed during the 2.5 s of perception and reaction time required by the bus operator, and (iii) the length of the bus.

The minimum Merging Sight Distance for transit buses may be used to 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 2.5.3 illustrates the minimum Merging Sight Distance for transit buses when leaving a bus stop for a range of vehicle speeds on a through traffic roadway.

Figure 2.5.3 Merging sight distance for stopped buses



Design Speed (km/h)	SSD (m)	V (m)	L (m) (1)	MSD (m)
40	45	30	12.5	87.5
50	65	35	12.5	112.5
60	85	40	12.5	137.5
70	110	50	12.5	137.5
80	140	55	12.5	207.5
90	170	60	12.5	242.5

Notes:

1. Assume standard bus

2.6 PEDESTRIAN SIGHT LINES

Pedestrians boarding or alighting transit buses or walking near bus facilities may not be aware of the restricted visibility of bus operators. Adequate sight lines should be provided for both pedestrians and transit operators wherever there is any potential conflict between buses and pedestrians. This is particularly critical for the right-turning bus movement.

As noted in Section 1.4, there are visibility impairment zones, or blind spots, on both sides of the bus where the operator may not be able to see pedestrians. For example, to allow the operator to turn right safely either at an intersection or within a transit exchange, he or she must be able to have direct line of sight to the pedestrians to the right before starting the turning maneuver. See Table 2.6.1 for the equation to calculate the "Pedestrian Sight Distance."

Typical pedestrian sight distance is 25 m based on these assumptions.

Table 2.6.1 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)

2.7 TRAFFIC CALMING MEASURES

Traffic calming measures are often installed on local or residential streets for the purposes of:

- Reducing vehicular speeds;
- Discouraging through traffic;
- Minimizing conflicts between street users; and
- Improving the neighborhood environment.

Traffic calming measures may be regulatory, such as posting reduced speed limits or four-way stop signs. However, many involve physical measures that deflect or alter vehicle paths. The latter type includes speed humps, traffic circles, curb extensions, etc. If traffic calming measures are to be installed on transit bus routes, their effects on bus operations must be considered, particularly for the physical traffic calming measures.

On bus route, the impacts of physical traffic calming measures should be very carefully considered in order to maintain safe and efficient bus transit operations.

2.7.1 SPEED HUMP

A speed hump slows down vehicles by transferring an upward force to a vehicle and its occupants as it crosses the speed hump. A level of discomfort results, depending on the profile of the hump, the speed of the vehicle, and the length of the vehicle's wheel base. As per the Institute of Transportation Engineer's (ITE) *Guidelines for the Design and Application of Speed Humps*, if feasible alternatives are available, speed humps are not recommended for use on streets with public transit. TransLink also does not support, in principle, the installation of speed humps on bus routes for reasons of customer safety and comfort, operational efficiency, and vehicle maintenance implications.

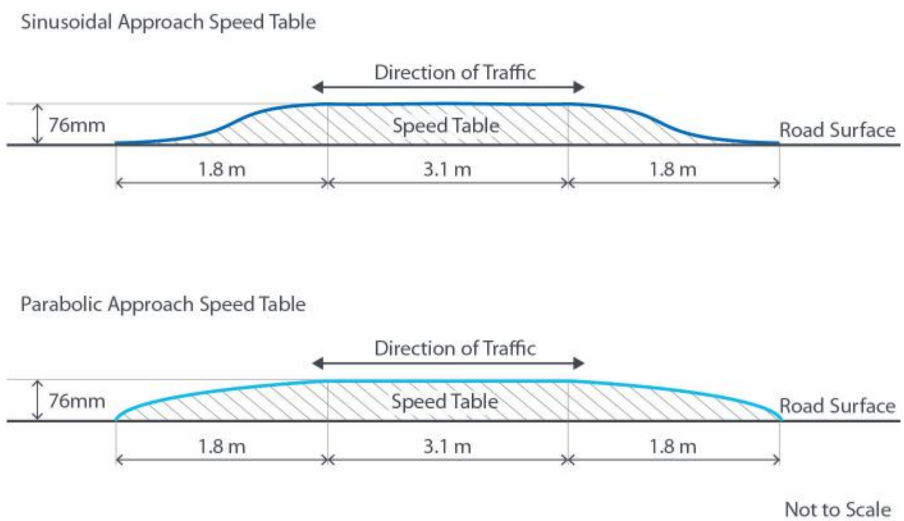
As per the ITE's *Guidelines for the Design and Application of Speed Humps*, if speed humps or speed tables are to be installed on transit routes, the design should consider the special operational characteristics and the needs of transit vehicles, including:

- A speed table (with flat top) is preferred to a speed hump for installation on transit routes. If speed tables are to be installed on transit routes, a 6.7 m (22 ft) speed table with a 3.1 m (10 ft) plateau, 1.8 m (6 ft) sinusoidal or parabolic approaches, and a vertical height of 76 mm (3 in) is recommended. Figure 2.7.1 shows the typical sinusoidal and parabolic approach speed tables.

- Speed humps should not be installed immediately before or after a bus stop as they may affect the stability of the customers who are walking to the doors for alighting, walking to their seats, or moving toward the back of the bus. It is recommended that the speed tables be located at least 25 m (80 ft) in advance or after a bus stop.

- Typically, buses cannot travel over a speed hump at the same speed as passenger vehicles. A special transit speed reduction warning sign may be required to advise the operators of the speed at which they should travel over the speed hump.

Figure 2.7.1 Typical speed table



Speed tables can serve as a raised marked crosswalk. As per the ITE's *Guidelines for the Design and Application of Speed Humps*, design considerations for a speed table that is used as a raised pedestrian crosswalk include:

- The crosswalk markings and the delineation elements on the speed table must be visible to motorists, especially at night;

- The speed table surface should not be slippery when wet;

- The speed table should not be installed on streets with vertical grade over 5%;

- The speed table should be less than 4 inches high; and

- The speed table should be far enough from an intersection that road users, including cyclists, do not have to negotiate a speed table while turning.

2.7.2 CURB EXTENSIONS, RADIUS REDUCTIONS, AND TRAFFIC CIRCLES

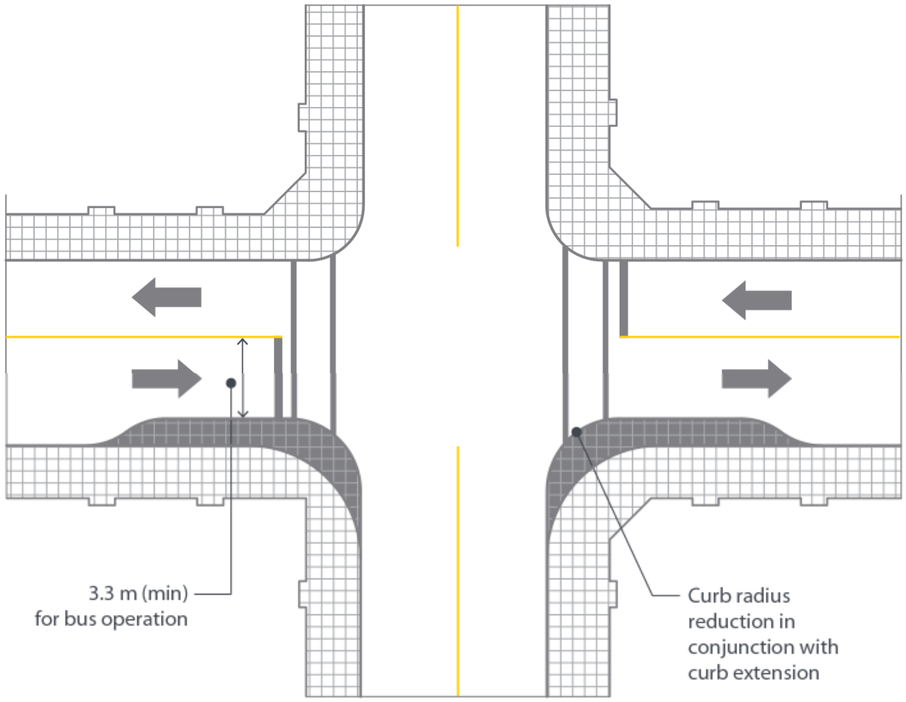
Curb extensions, radius reductions, and traffic circles are examples of traffic calming measures used to influence the path and speed of moving traffic by modifying the alignment, the width of the travel lane, and/or the corner radius. Figure 2.7.2 shows an example of a curb extension, while Figure 2.7.3 illustrates the conceptual layouts of the possible arrangements.

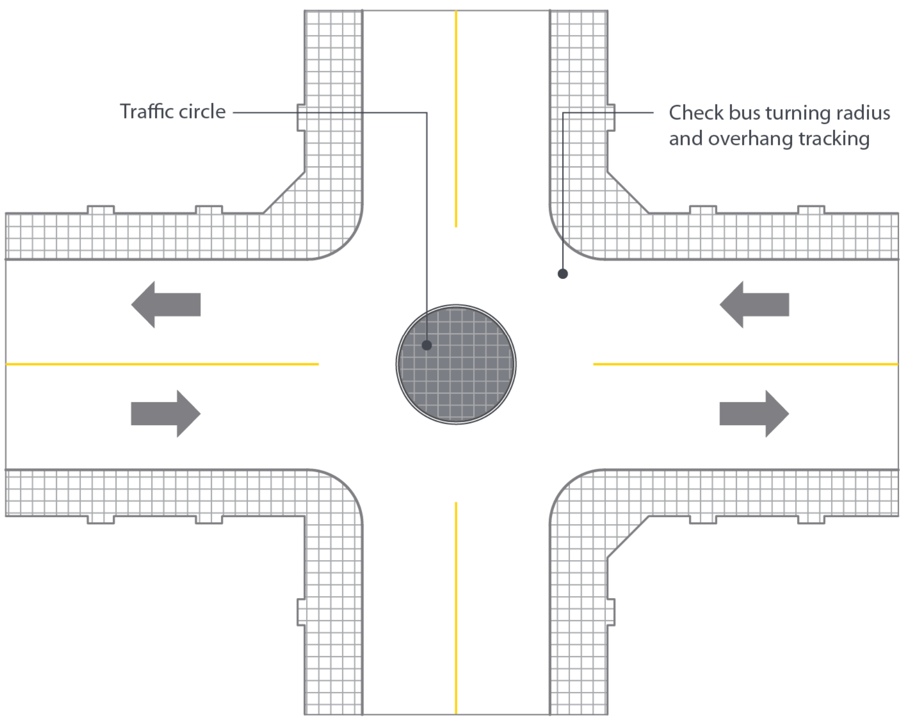
When designing these traffic calming measures on transit bus routes, the following transit operation requirements should be considered:

- Bus routing;
- Bus turning paths for a 12.4 m Standard Bus (since existing Mini Bus routes could eventually become standard size bus routes and 18.6 m articulated buses actually have a tighter turn radius than standard buses);
- Minimum lane width; and
- Corner radii.

Figure 2.7.2 Example of curb extension

Figure 2.7.3 Curb extension, radius reduction, and traffic circle





2.8 ROUNDABOUT REQUIREMENTS

2.8.1 TRANSIT BUSES IN ROUNDABOUTS

To minimize customer discomfort associated with driving over a mountable curb at a roundabout, buses should circulate the roadway without intruding on the truck apron. The minimum diameter of a roundabout is 32 m. Figure 2.8.1 shows an example of a bus navigating a roundabout.

2.8.2 SIGNALIZED ROUNDABOUTS

Roundabouts may provide opportunities for transit priority if signals hold approaching traffic while a transit vehicle enters in its own lane or in mixed traffic.

Figure 2.8.1 Example of roundabout

CHAPTER 3. BUS STOP LOCATION AND DESIGN

3.1 INTRODUCTION

Since bus stops provide the interface between customers and buses, they are one of the critical components in transit infrastructure design. There are three aspects to bus stop location and design. The first is the selection of the location based on spacing between bus stops, ridership, and safety. The second is placement of a bus stop (far-side, near-side, or mid-block). The third is the physical configuration of the stop, which will allow customers to board, alight, and make transfers in a safe and efficient manner, and will minimize bus conflicts with other traffic (for example, bicycle traffic and traffic at access driveways). This chapter discusses these three aspects of bus stop location and typical design requirements.

The bus stop design dimensions and criteria presented in this chapter are suitable for typical bus stop application, including transit exchange. Nevertheless, some projects may have specific considerations and/or constraints that lead to design criteria deviating from those used in typical design. Designers should provide rationale to support any deviations and consult with TransLink at the onset of a project to verify the assumptions and criteria to be followed.

Refer to TransLink's *Transit Passenger Facility Design Guidelines* for general design considerations and principles for transit facilities design, and to TransLink's *Universal Accessibility Guidelines for Transportation Facilities* for guidance on accessible design.

3.2 LOCATION OF BUS STOPS

The accessibility of a bus route, and hence its effectiveness, depends on the location and, to a certain extent, the physical design of the bus stops. An excessive number of bus stops en-route will slow down the bus service, reduce the bus route efficiency, and affect the level of customer riding comfort. A lack of sufficient bus stops, on the other hand, will increase customer walking distance and thus limit its accessibility. To maintain a balance between accessibility and efficiency, the locations of bus stops are generally governed by three factors: (i) network-based stop spacing guidelines; (ii) passenger demand; and (iii) other traffic considerations.

TransLink has adopted bus stop spacing guidelines for determining the broad pattern of bus stop locations within Metro Vancouver. TransLink tries to maximize coverage where possible and as resources allow. Shorter stop spacing, and thus reduced walking distances, would be encouraged in situations where steep grades or safety hazards create an unacceptable pedestrian access route.

Recommended bus stop spacing varies by service type provided. Refer to TransLink's *Transit Service Guidelines* for recommended bus stop spacing.

3.2.1 PASSENGER DEMAND AT ACTIVITY CENTRES

Bus stops are generally warranted where there are concentrated commercial, services, residential, office, or industrial development that generate high passenger demand. The consideration of this factor may override the stop spacing guidelines noted above.

3.2.2 OTHER TRAFFIC CONSIDERATIONS

Having decided that a bus stop is warranted on general spacing and demand requirements, the final location will be influenced by the following traffic safety factors:

- Merging sight distance requirements for bus operators, especially on vertical and/or horizontal curves, should be considered (see Section 2.5.5).
- Pedestrian routes to/from the stop should be considered, with attention to safety risks such as crossings of high-speed or high-volume roadways. As much as possible, bus stop should be located where proper pedestrian access is available.
- After leaving a bus stop, if a bus has to turn left at the next intersection downstream, the location of the stop will be determined by the distance required by the bus to complete the lane change prior to the beginning of the left-turn bay or the leftmost lane. This distance is governed by the tracking of the bus, typical queuing related to the traffic volume, and the prevailing speed of the traffic.
- A bus should be able to access the stop efficiently without being significantly delayed by traffic queues.
- Bus stops should be installed at locations where at least a minimum passenger landing pad and wheelchair pad can be provided.
- Wheelchair accessible bus stops should not be located on road sections with grades greater than 8%.
- For security reasons, bus stops should be installed at locations with adequate lighting, whenever possible.
- Conflicts with other curb-side activities such as commercial loading zones, banking machines and other passenger drop-off/pickup areas should be avoided, wherever possible.
- A bus at a bus stop should not create any sight line problems for an adjacent cross-walk or driveway.
- Bus stops should be located away from the vehicle entrance of adjacent properties, wherever possible, particularly near commercial and multi-family residential development. This would avoid potential conflicts between customers waiting at the bus stop and the pedestrian traffic generated by the properties.
- Street furniture such as utility poles, trees, and fire hydrants should not obstruct the doorways of the bus.

Provision of new bus stops and modifications to existing bus stops, are either identified directly by TransLink/CMBC or may be requested by the municipality. Once approved, the functional requirements of the bus stop are summarized in the Bus Stop Request Form attached in **Appendix C**.

3.3 Bus Stop Placement

3.3.1 General Considerations

Bus stop placement falls into one of three standard locations: (i) far-side or (ii) near-side with respect to an intersection, or (iii) midblock between two intersections. When designing new facilities, the preferred minimum dimensions that should be used for all three types of bus stop placement are shown in Figure 3.3.1.

Other considerations:

- 6 m clearance to a crosswalk; and
- Door location not obstructed by street furniture.

Far-side stops are preferred. If physical conditions do not suit a far-side stop, a near-side stop at the same intersection is the next preferred choice. If the near-side position is impractical, then consideration should be given to a mid-block position on either side of the intersection.

3.3.2 Far-Side Bus Stops

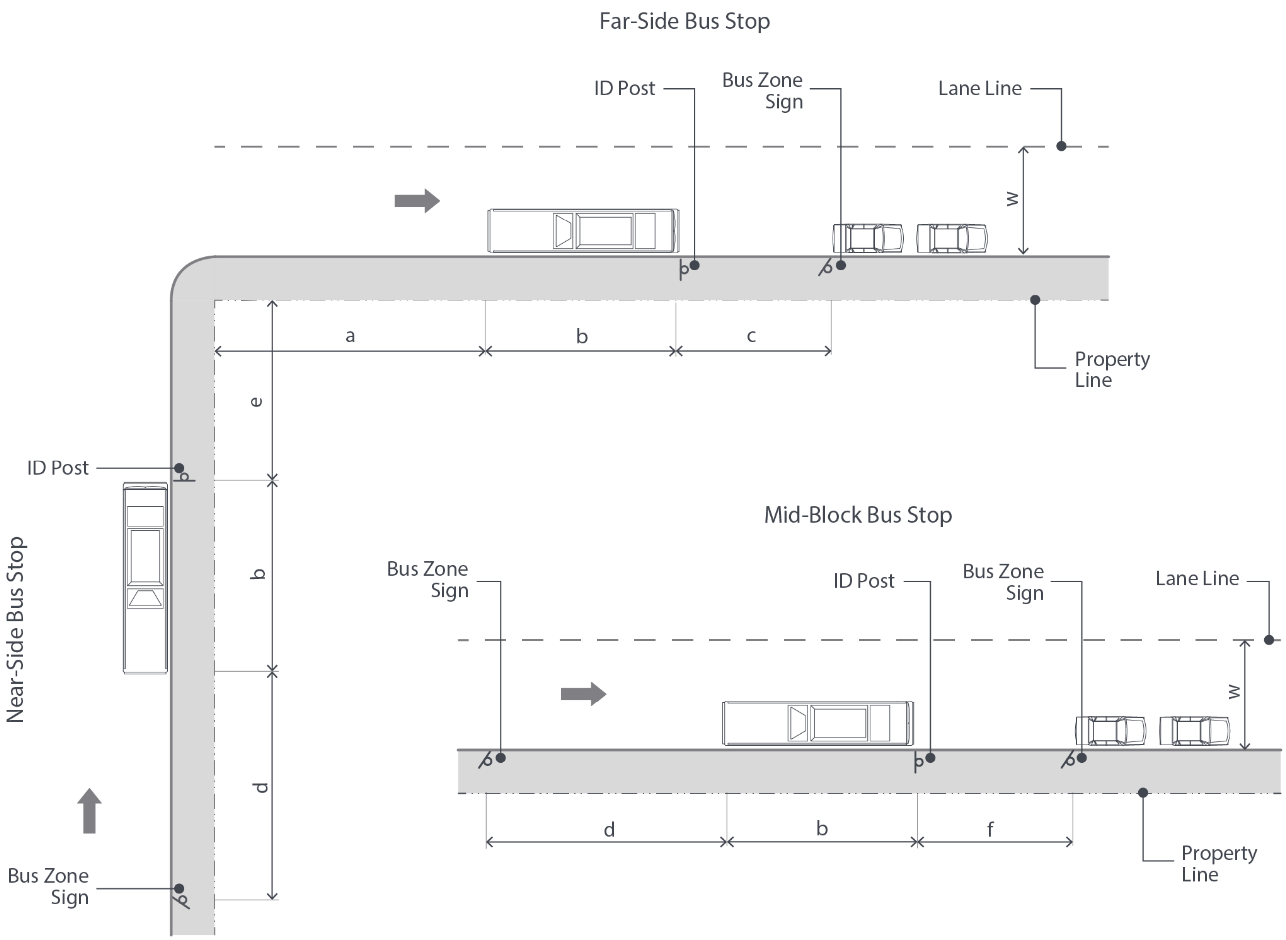
Far-side stops are generally preferred so as to minimize sight distance or intersection capacity problems that frequently occur with near-side stops, particularly where right-turn traffic at the intersection is heavy.

When placing a far-side stop at a channelized intersection or in an acceleration lane, special consideration should be given to eliminating the potential weaving conflicts between buses approaching the stop area and right-turn traffic from the cross street. By placing the stop at the channelization island, buses do not need to weave against right-turn traffic from the cross street. However, the presence of buses at the channelization island may potentially reduce the available merging sight distance for right-turn traffic from the cross street.

Advantages of far-side stops include:

- Reduced bus queuing behind curb lane traffic;
- Stopped buses do not obstruct sightlines for pedestrians;
- Stopped buses do not interfere with right-turn vehicles;
- Buses re-entering traffic flow do not experience as much delay;
- Risk of bus customers stepping in front of an accelerating bus to cross the street is reduced;
- Waiting customers accumulate at less crowded sections of sidewalk rather than close to the intersection;
- Stops can also be used by buses approaching from the cross street after they turn; and
- On-street parking loss is reduced.

Figure 3.3.1 Bus stop dimensions



Type of Bus	Bus Length (b)	Far-Side Stop		Near-Side Stop		Mid-Block Stop		Width (w)
		Corner Clearance (a) [1][2]	Pull Out (c)	Pull In (d) [3]	Corner Clearance (e) [1]	Pull In (d) [3]	Pull Out (f)	
Standard Bus/ Highway Coach	12.4 m	6.0 m or 14.0 m	7.7 m	18.0 m	Minimum 6.0 m	18.0 m	7.7 m	Minimum 6.0 m Preferred 7.0 m
Articulated Bus	18.5 m			21.0 m		21.0 m		
Mini Bus	8.2 m			12.0 m		12.0 m	5.0 m	

Notes:

1. Municipalities typically require a minimum clearance distance of 6.0 m between the stopped bus and either side of a crosswalk; the approach of a flashing beacon, stop sign, or traffic control signal located at the side of a roadway; or the property line of an intersecting street. Please refer to municipality bylaws for more information
2. The clearance distance between the crosswalk edge and the rear of the bus is to be 6.0 m for a bus making the through movement and 14.0 m for a bus making the left-turn or right-turn movement
3. For bus bays, an extra 3.0 m should be included at the stop for a standard/articulated bus to straighten out

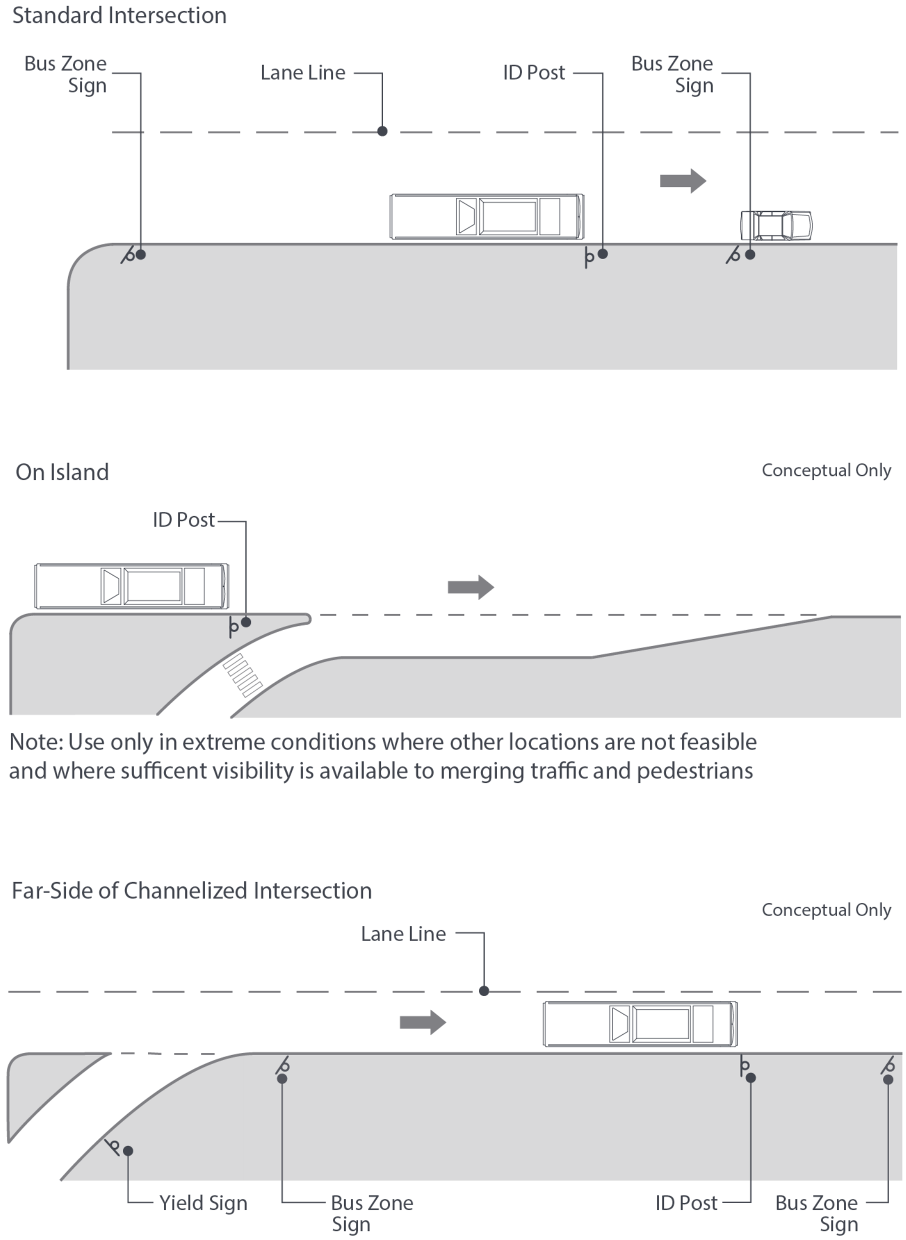
Disadvantages of far-side stops include:

- Walking distance to crosswalk is increased;
- Bus operators have restricted view of customers approaching from the intersection;
- Far-side stops may require further consideration of street lighting; and
- Conflicts with vehicles turning right from the cross street may occur.

An example of a far-side bus stop is shown in Figure 3.3.2, while different arrangements of far-side bus stops for a Standard Bus are shown in Figure 3.3.3. Typical dimensions of a far-side stop are shown in Figure 3.3.1.

Figure 3.3.2 Example of far-side bus stop

Figure 3.3.3 Far-side bus stop arrangements



3.3.3 NEAR-SIDE STOP

Near-side stops may be acceptable at an intersection if the far-side position is physically infeasible or if efficient customer transfer with a cross-street route is required; however, the following conditions should generally be met:

- The buses will not be blocked by a traffic queue at the intersection;
- The curb lane continues on the far-side of the intersection; and
- The right-turn traffic volume at the intersection is low.

To ensure safe and efficient operation, the length of the bus pull-out section should be reviewed for potential conflicts between bus operation and the right-turning traffic, considering: (i) the volume and visibility of vehicles making right turns in front of the stopped bus, and (ii) the type of traffic control at the intersection. If required, the near-side stop may have to be located closer to the midblock to separate the right-turn conflicts spatially.

Advantages of near-side stops include:

- Bus operators have a better view of approaching customers;
- Street lighting is generally better near the crosswalk; and
- Customer transfers between a near-side stop and a far-side stop on the cross street may be facilitated.

Disadvantages of near-side stops include:

- Vehicles making right turns may conflict with an accelerating bus;
- A stopped bus may obscure a Stop sign and/or pedestrians crossing in front of the bus;
- Intersection operational efficiency may be reduced, especially at congested signalized intersections;
- When there is no receiving lane on the far side of the intersection, buses moving to the travel lane may be delayed or may have to change lanes in the intersection; and
- A near-side bus stop usually occupies longer curb space than a far-side bus stop (since the pull-in distance is along the curb rather than as part of the intersection), resulting in possible loss of on-street parking spaces.

Typical near-side bus stop placement for a Standard Bus is shown in Figure 3.3.4. Typical dimensions of a near-side bus stop are shown in Figure 3.3.1. An example of a near-side bus stop is shown in Figure 3.3.5.

Figure 3.3.4 Near-side bus stop

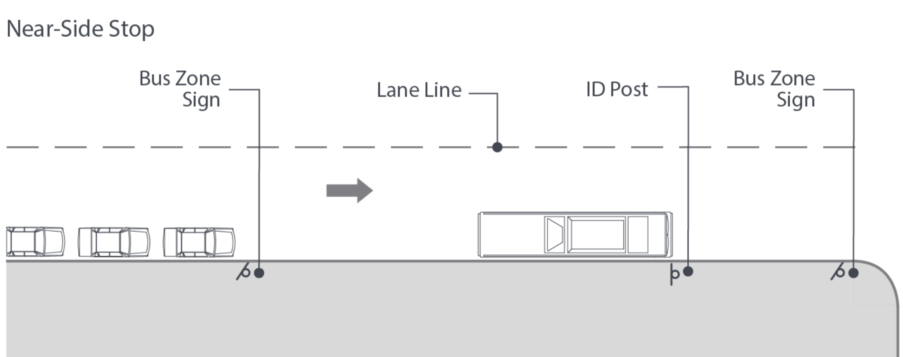


Figure 3.3.5 Example of near-side bus stop

3.3.4 MID-BLOCK STOP

In downtown areas where multiple routes require long bus loading areas, a far-side stop may be extended to a mid-block position to meet capacity requirements. Mid-block stops may also be used when the physical or environmental conditions prohibit near-side or far-side stops, or when the block length is exceedingly long.

Advantages of mid-block stops include:

- Stop may be located near a large customer generator; and
- Waiting customers use a less crowded section of sidewalk than at an intersection.

Disadvantages of mid-block stops include:

- A higher risk of unsafe mid-block crossings;
- Sightline obstructions to/from vehicles exiting adjacent driveways;
- Increased walking distance for pedestrians to/from the cross street;
- Possible need to remove a greater number of curb parking spaces compared to far-side stop configuration; and
- Poor transfer efficiency with cross street routes.

The typical placement for a mid-block stop is shown in Figure 3.3.6. Typical dimensions of a mid-block stop are shown in Figure 3.3.1. An example of a mid-block bus stop is shown in Figure 3.3.7.

Figure 3.3.6 Mid-block bus stop

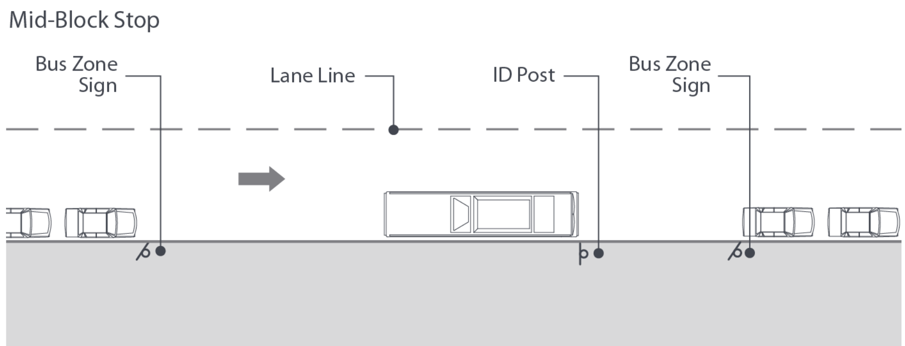
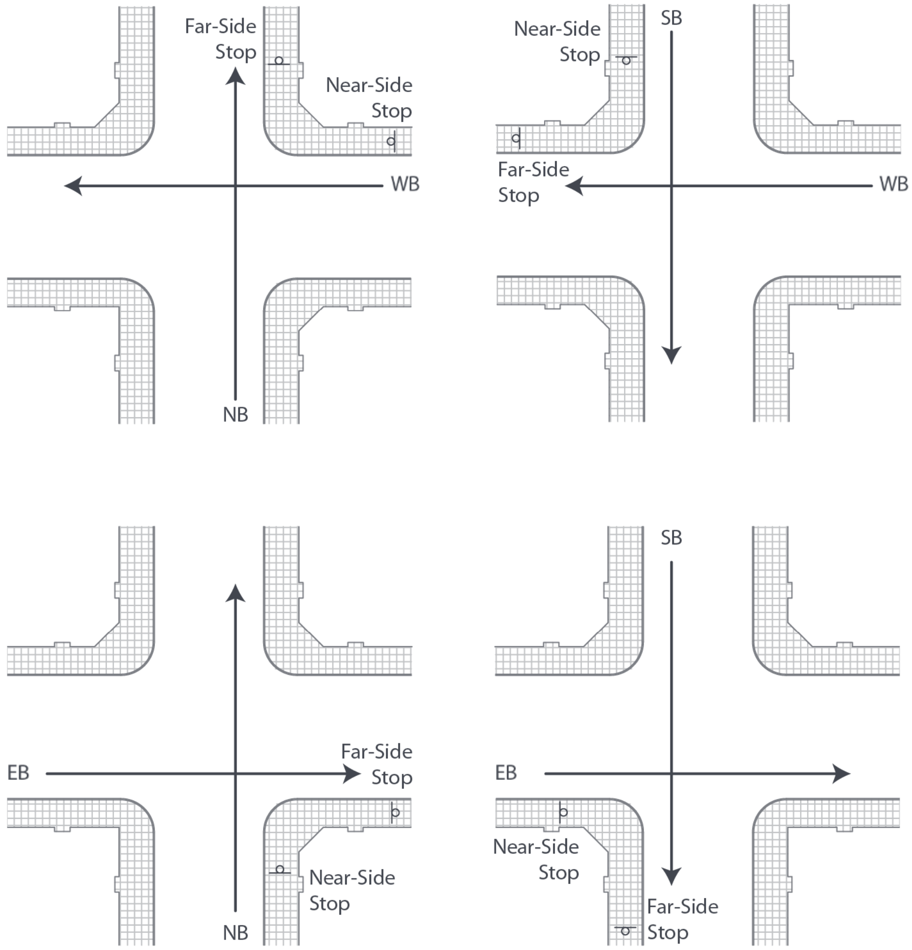


Figure 3.3.7 Example of mid-block bus stop

3.3.5 Bus Route Transfer Co-ordination

At bus route transfer points with heavy customer transfer volumes, special consideration should be given to coordinating bus stop placement with customer transfer movements. Figure 3.3.8 illustrates the special arrangements for transfer co-ordination at an intersection. If a near-side stop does not meet the service requirements, a complementary far-side stop may also be considered at the same intersection.

Figure 3.3.8 Bus stop placement for transfer co-ordination



3.3.6 Bus Stop Between Access Driveways

To minimize conflicts between buses and vehicles entering/exiting the driveways of adjacent properties, bus stops should be located away from such critical areas wherever possible. Where this cannot be avoided, Figure 3.3.9 illustrates the minimum requirements for placement of a bus stop located between two front access driveways. The placement of bus stop between access driveways is to be examined on a case-by-case basis. The key parameters in the consideration should include:

- The type and spacing of access driveways near the bus stop;
- The peak volume of traffic entering/exiting the access driveways;
- The expected service level and customer boarding/alighting volumes at the bus stop;
- The peak time of bus stop usage vs. the peak time of driveway traffic;
- Adequacy of passenger waiting area at the bus stop;

- Sight line requirements between customers walking to/from bus stop and drivers at the access;
- Possibility that traffic queued at the driveway will affect the efficient operation of the bus stop; and
- Availability of alternative bus stop locations.

The pull-in and pull-out distance requirements shown in Figure 3.3.9 generally follow the pull-in and pull-out requirements for a mid-block stop as shown in Figure 3.3.1. An example of a bus stop adjacent to an access driveway is shown in Figure 3.3.10.

Figure 3.3.9 Bus stop between access driveways

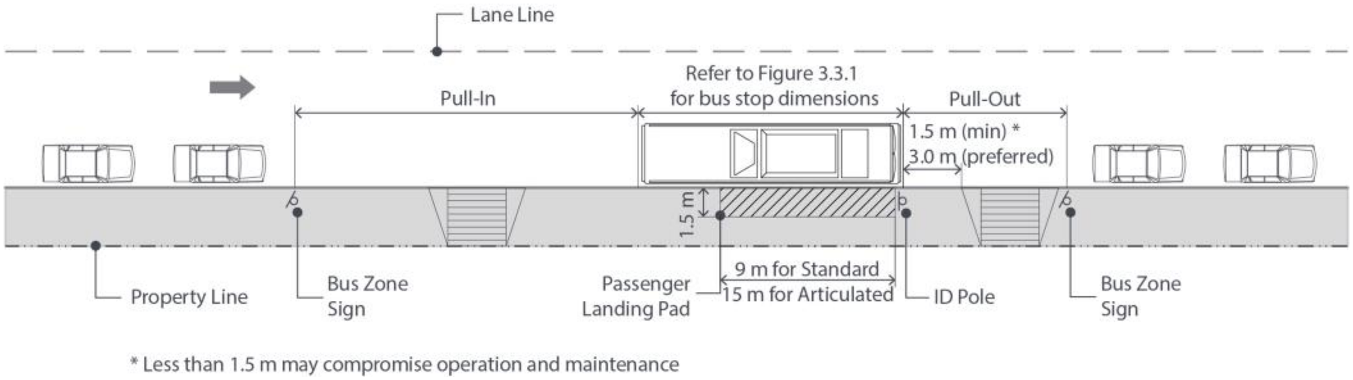


Figure 3.3.10 Example of a bus stop adjacent to an access driveway

3.3.7 Bus Stop Locations Near Roundabouts

When a bus stop is in the vicinity of a roundabout, locating it on the nearside provides the advantage of being in a potentially slower speed environment where vehicles are slowing to enter the roundabout, compared to a far-side location where vehicles may be accelerating as they exit the roundabout. A bus stopped at a nearside stop should not obstruct sightlines to and from pedestrians crossing in a crosswalk. At the approaches to multilane roundabouts, a nearside bus stop can be included in the travel lane (a bus bulb-out design) as long as it is set back at least 15 m (50 ft) from the crosswalk. Nearside stops should be far enough away from the splitter island so that a vehicle overtaking a stationary bus does not strike the splitter island, especially as the bus starts to pull away from the stop.

Far-side stops should be located beyond the crosswalk so they do not obstruct the view of crossing pedestrians. Bus pullouts can reduce the risk of vehicles queuing into the crosswalk or roundabout behind a stopped bus, but may limit sightlines for bus drivers attempting to merge into traffic. At multilane roundabouts in slow-speed urban environments, a bus stop without a bus pullout may be located immediately beyond the crosswalk, as exiting traffic can pass the waiting bus. In a traffic-calmed environment or close to a school, it may be appropriate to locate the bus stop so that other vehicles cannot pass the bus while it is stopped.

3.4 Bus Stop Layouts

3.4.1 Multi-Position Stops

The typical bus stop dimensions shown in Figure 3.3.1 are for one-position stops, i.e. only one bus stopping at a time. For stops serviced by high frequency routes or more than one bus route, two or more buses may arrive at the same time, requiring a multi-position stop layout.

For tandem bus stop operations with a "first-in, first-out" arrangement, the required length for a multi-position stop should be based on the recommended bus stop dimensions as shown in Figure 3.4.1 plus extra length to accommodate the second bus (or as many as required) with suitable spacing between two consecutive stop positions. A minimum of 3 m spacing is typically the required clearance for a deployed bicycle rack on the front of the second bus. For tandem bus stop operations with a "first-in, independent-departure" arrangement, longer spacing would be required for independent departure of the buses, as shown in Figure 3.4.2. If independent operations (i.e. "independent arrival, independent departure") are required, Figure 3.4.3 illustrates the recommended bus stop dimensions between two consecutive stop positions.

Figure 3.4.1 First-in, first-out bus stop layout

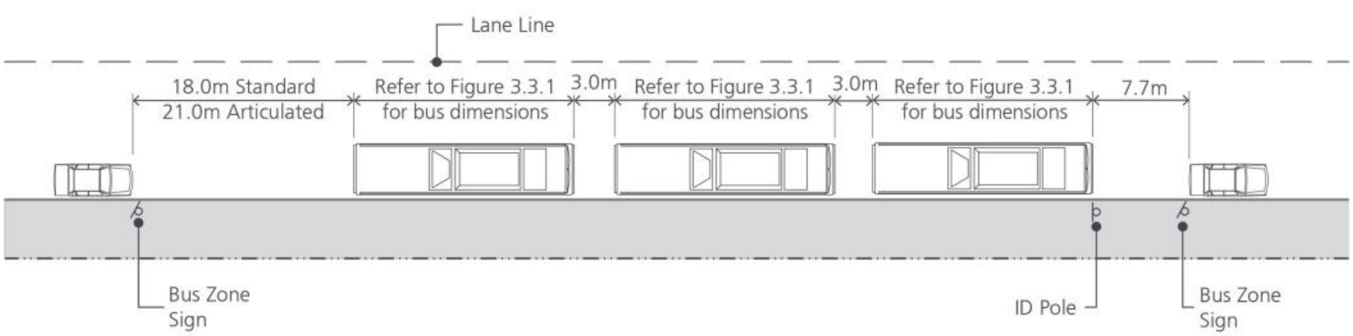


Figure 3.4.2 First-in, independent-departure bus stop layout

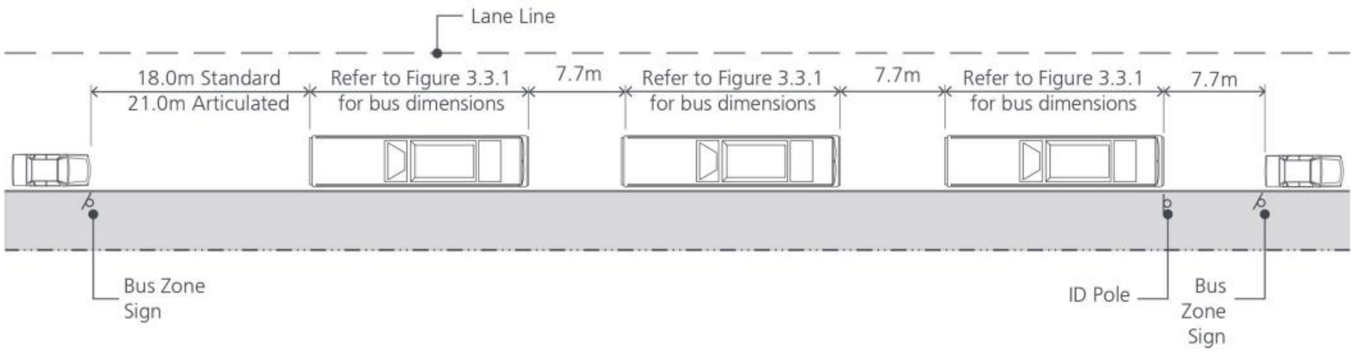
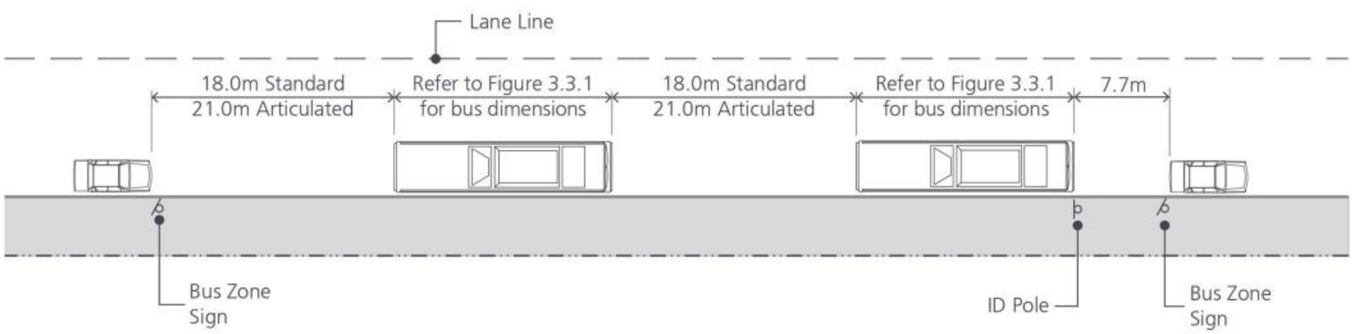


Figure 3.4.3 Independent-arrival, independent-departure bus stop layout

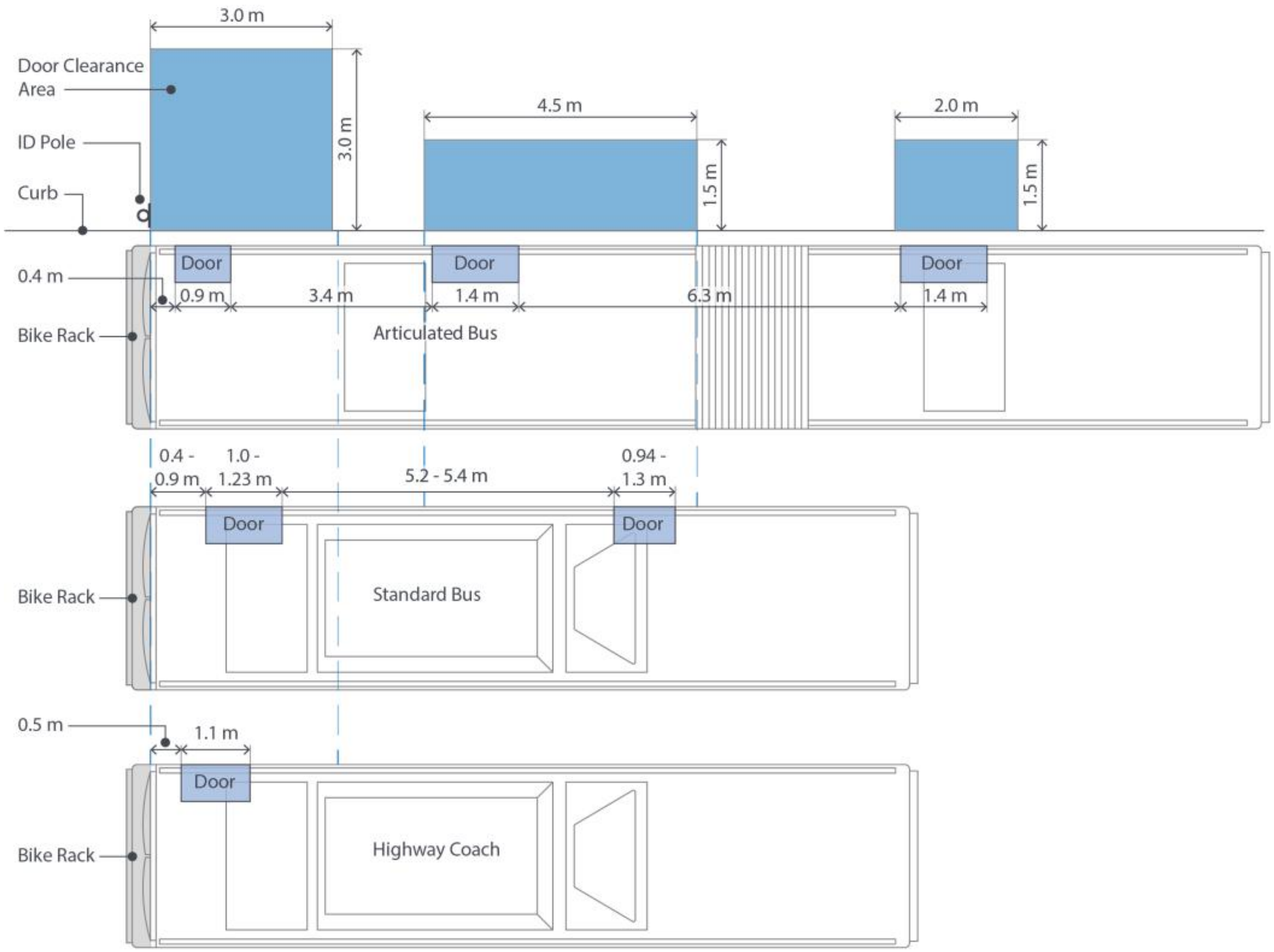


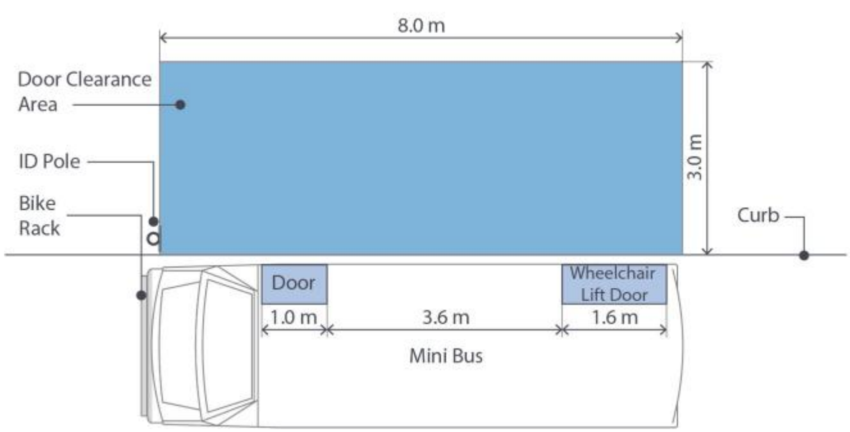
3.4.2 DOOR CLEARANCE ZONES

As a general bus operation guideline, bus operators are trained to load and unload customers in the first two positions at bus stops with room to accommodate three or more buses. The operator in the third bus may load or unload customers in the third position, but would be required to move up to the first position to load, as customers (particularly visually impaired customers) may be waiting at the bus stop ID post. Figure 3.4.4 illustrates the required doorway clearance areas at a bus stop to accommodate a Standard Bus, an Articulated Bus, and a Highway Coach, as well as the required doorway clearance areas for a Mini Bus. The distances for the doorway clearance areas are measured from the bus stop ID post. The depth of the door clearance areas would be accommodated within the passenger landing pad or wheelchair pad. Requirements associated with passenger landing pads and wheelchair pads are further discussed in Sections 3.5.1 and 3.5.2 respectively.

The door clearance areas should be free of street furniture that would interfere with customer loading or unloading activities at the bus doors.

Figure 3.4.4 Door clearance areas





3.4.3 BUS BAYS

A bus bay is a recessed bus stop separated from the adjacent travel lanes. Bus bays are not desirable from an efficiency standpoint as buses are required to pull off the roadway and re-enter the adjacent travel lane, causing customer discomfort and possible delay. However, bus bays may be required for safety reasons in the following cases:

- On highways or arterial roadways with a 60 km/h or higher posted speed limit;
- On roadways with single lane operation in each direction where passing sight distance for other traffic is not available at the bus stop;
- On roadways with high traffic volumes where a stopped bus might negatively impact the operation of the roadway; and
- At a bus route schedule timing point where a bus may stop for an extended period of time.

There are five types of bus bays:

Type I: Corner - Located immediately adjacent to an intersection in a near-side or far-side location. A near-side Corner Type may be combined with a right-turn bay function. However, before this type of bus bay is selected, conflicts with right-turn traffic and conflicts with through traffic on the far-side of the intersection should be satisfactorily addressed.

Type II: Mid-Block - Located between two adjacent intersections.

Type III: Island - Located at a major intersection, utilizing the right-turning roadway or large triangular island. The island is offset to provide sufficient space for a stopped bus without interfering with the through or turning traffic.

Type IV: Sawtooth - Used at both on-street and off-street locations where there is no sightline concern.

Type V: V-Type - Used at locations where sightlines to the rear are restricted by the roadway curvature upstream of the bus bay.

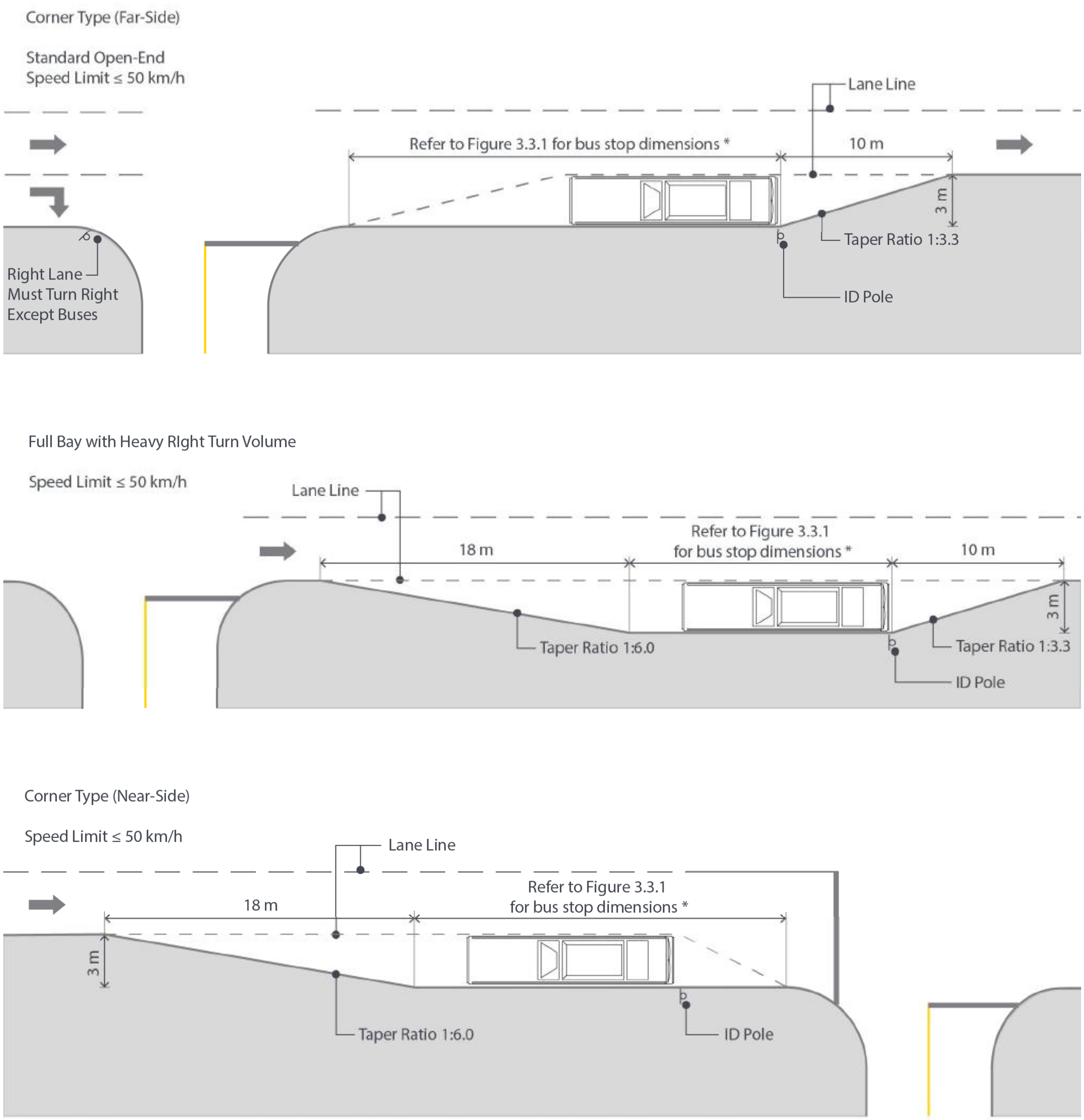
The typical dimensions for all bus bay types are illustrated in Figure 3.4.5, Figure 3.4.6, and Figure 3.4.7. The desirable minimum width of a Type I, II, or III bus bay is 3.0 m. Taper length requirements depend on the design speed of the roadway. Table 3.4.1 shows the taper requirements for various roadway posted speeds. Figure 3.4.8 shows an example of bus bay Type IV, which is used at several TransLink transit exchanges.

Surface-water drainage will require special attention in a bus bay. To reduce the risk of customers at a stop being splashed in wet weather, it is preferable that (1) the crossfall of a bus bay be outward from the curb towards the travel lanes, or (2) the catch basins, if any, be installed away from the bus stop.

Table 3.4.1 Bus stop taper requirements

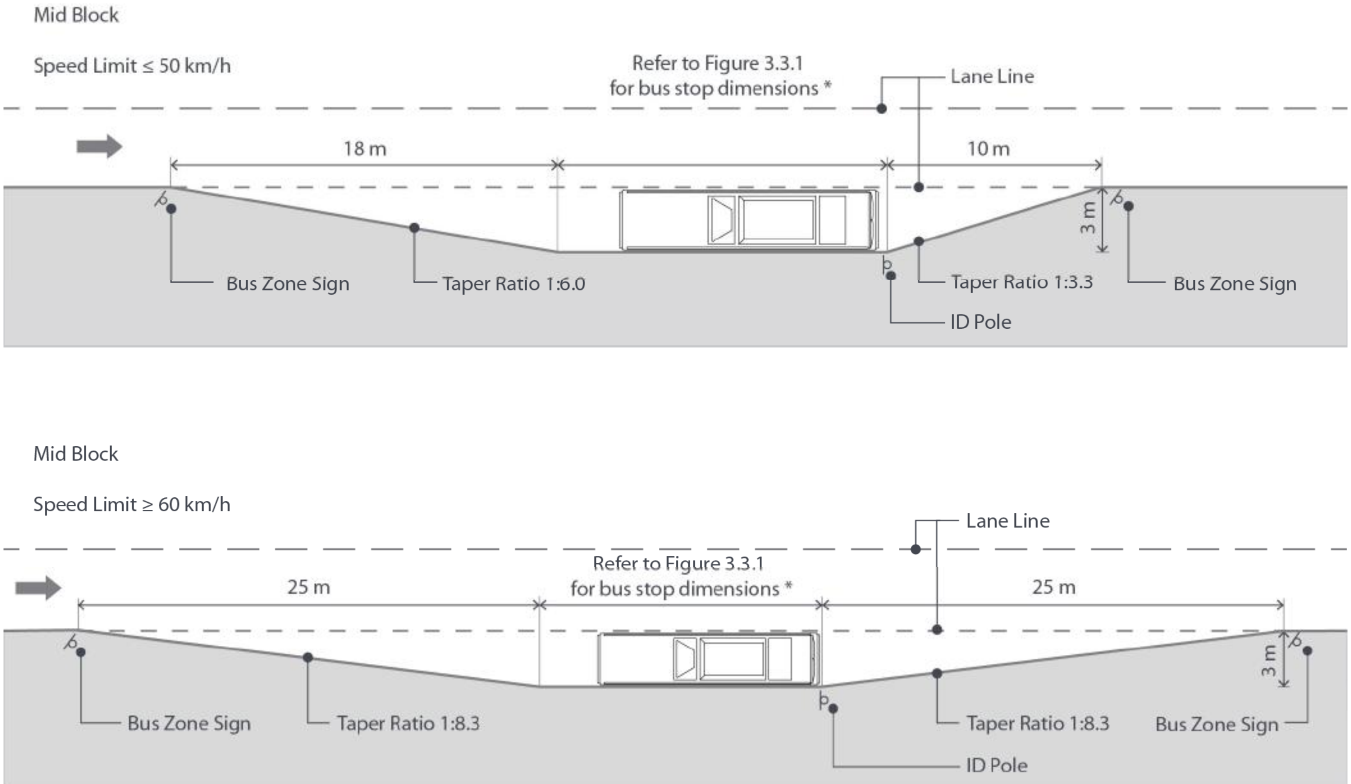
Roadway Posted Speed	Pull-in Taper	Pull-out Taper
<=50 km/hr	1:6	1:3.3
>=60 km/hr	1:8.3	1:8.3

Figure 3.4.5 Bus bay layouts (Type I)



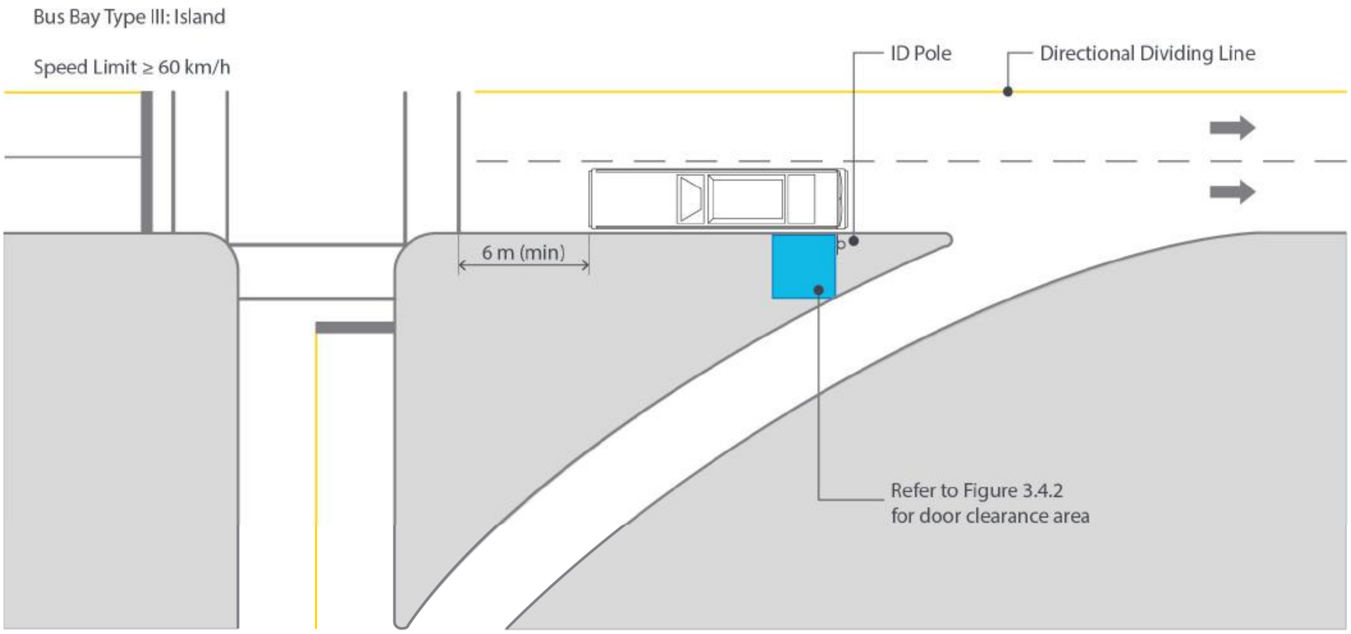
* For bus bays, an extra 3.0 m should be included at the stop for a standard/ articulated bus to straighten out

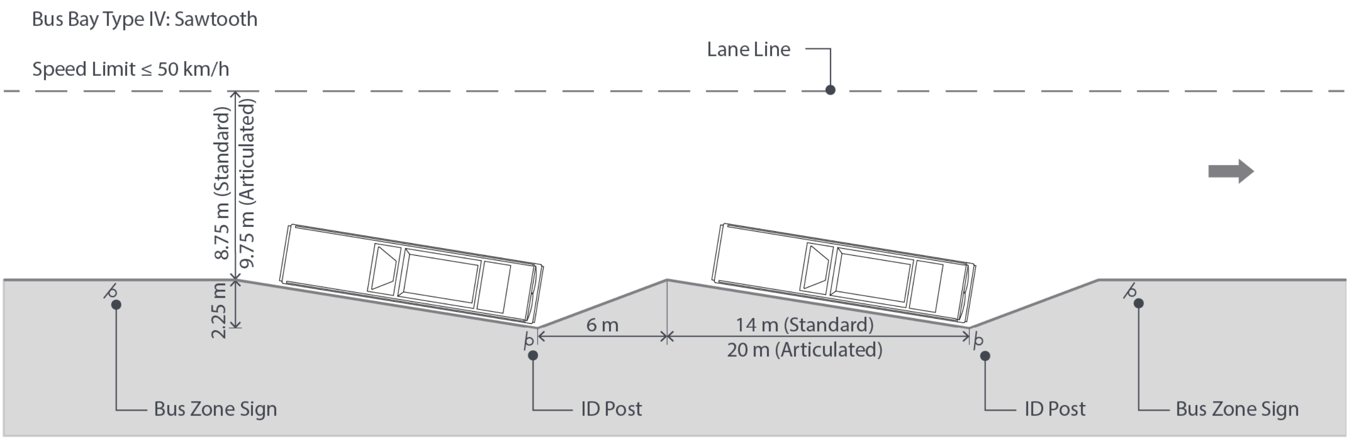
Figure 3.4.6 Bus bay layouts (Type II)



* For bus bays, an extra 3.0 m should be included at the stop for a standard/ articulated bus to straighten out

Figure 3.4.7 Bus bay layouts (Types III, IV, and V)





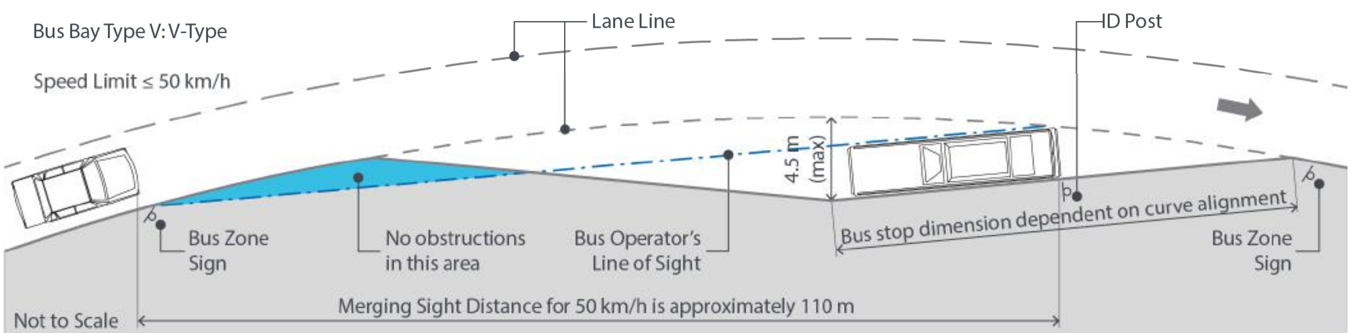


Figure 3.4.8 Example of sawtooth bus bays

3.4.4 Bus Bulges

A bus bulge is a protrusion of the curb into the right lane, typically the width of a parked car or less. The bus bulge allows a bus to stop and load/unload customers on the travel lane. There are several advantages of bus bulges for transit operations:

- Delay can be reduced since the bus does not have to pull back into the travel lane.
- If the bus pull-out area is frequently blocked by vehicles stopped illegally in the bus zone, a bus bulge will eliminate this problem as the bus pull-out zone is no longer required.
- The passenger landing area is larger to better serve transit customers and provide space to install a larger bus shelter, more benches, and other customer amenities.
- The lane change associated with entering and exiting a curbside bus stop is eliminated, improving safety and customer comfort.

General design considerations are:

- A bus bulge should be located in a far-side position to encourage pedestrians to cross the street at the intersection where traffic control, such as a traffic signal, is available.
- The rear of the second (or last) bus should be far enough from the intersection to allow other vehicles to complete a right or left turn from the cross street without being blocked by the stopped bus.

Street furniture within the passenger zone should not block the safe and efficient loading/unloading of customers. Refer to Section 3.4.2 for door clearance requirements.

Figure 3.4.9 shows an example of bus bulge, while, Figure 3.4.10 shows a typical layout for a bus bulge design. A narrow depth (D) may require a longer distance (L) between the bus stop ID post and parked cars downstream in order for the bus pulling away from the curb to safely pass parked cars. Field tests should be conducted to verify the dimensions and the relationship between the depth of the bulge and the distance between the bus stop ID post and parked cars downstream.

Figure 3.4.9 Example of a bus bulge

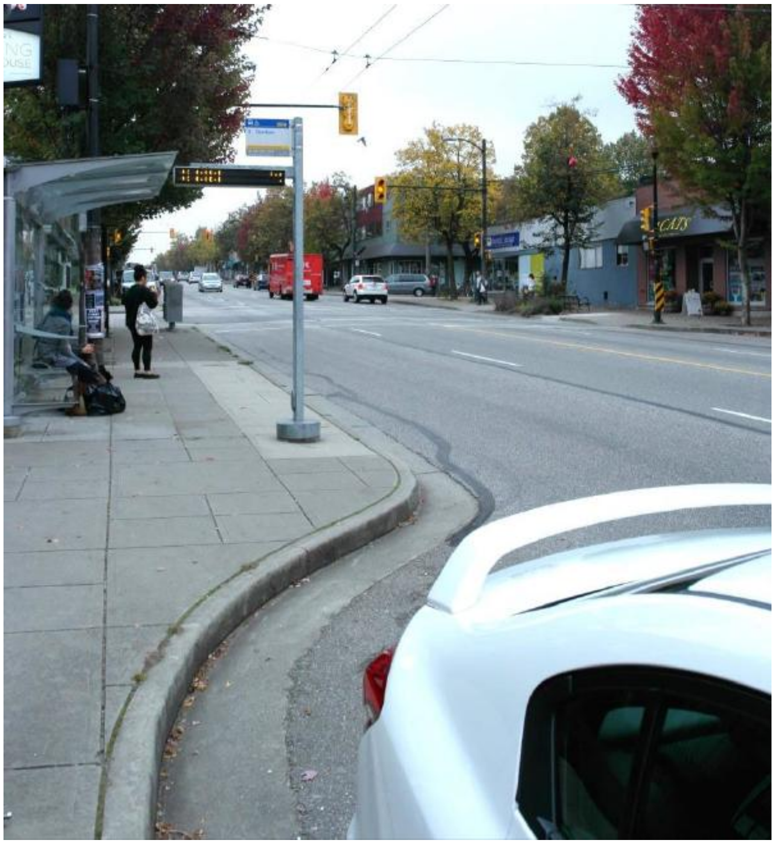
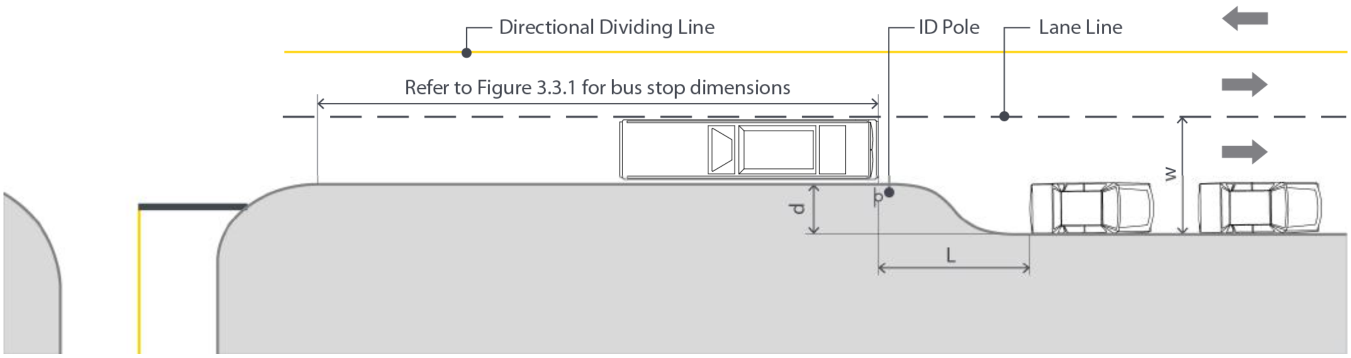


Figure 3.4.10 Typical bus bulge layout



Width of Curb Lane w (m)	Depth of Bus Bulge d (m)	Distance between ID Pole and End of Parked Car L (m)
5.6	1.9	5.0
	2.3	7.0
5.7	1.0	5.0
	1.9	7.0

3.4.5 Bus Concrete Pads

A bus concrete pad is a reinforced concrete slab installed in the pavement of the travel lane at the bus stop, loading/unloading bays at bus exchanges, and bus layover locations to improve resistance to rutting and petroleum deterioration, thus reducing pavement maintenance costs. Bus concrete pads should be provided at all bus bays to reduce long-term maintenance costs. The width of the pad should be a minimum of 3.0 m, and the length should be long enough to cover the rear wheel of the last bus stopping at the stop. The required length would depend on the number and types of buses stopping at the stop, as well as the operating scenario (e.g. "first-in, first-out", "first-in, independent-departure", "independent-arrival, independent-departure").

Typical bus pad lengths, as determined by the distance from the front bumper to the rear wheel of a bus, are as follows:

- Standard Bus = 10 m
- Articulated Bus = 16 m
- Mini Bus = 6 m
- HandyDART = 10 m

In general, bus pads are not required at a stop that serves only Mini Buses or HandyDARTs, as these lighter weight vehicles are less likely to cause damage to the pavement.

Full concrete pad coverage should be considered in exchanges with high bus volumes and/or tight turnaround spaces in order to minimize service disruption during the repaving and rehabilitation activities typically required for facilities featuring conventional asphalt pavement. Refer to **Appendix D** for typical concrete and asphalt pavement sections.

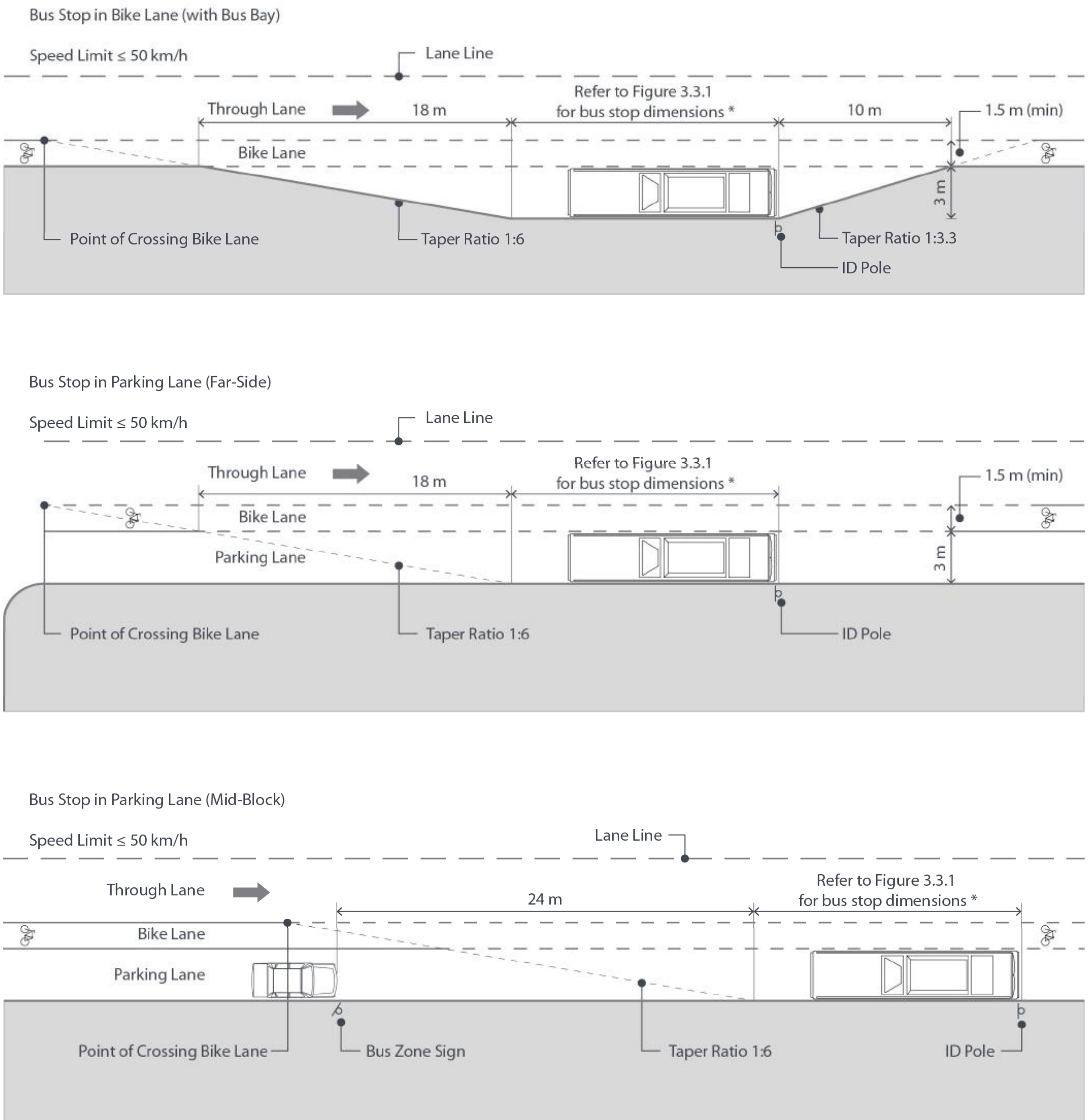
3.4.6 Bus Stop Adjacent to Bike Lane

Typically, bike lanes are provided on the right-hand side of the pavement adjacent to the curb or separated from the curb by a parking lane, a bus bay, or a turning lane. Key considerations of this arrangement are:

- A minimum 3 m wide bus stop next to a bike lane is desirable so that a stopped bus does not impact the bike lane.
- A bus stop in a bus bay adjacent to a bike lane requires longer pull-in and pull-out distances than a bus bay adjacent to a vehicle travel lane due to the additional bike-lane width that a bus needs to cross to enter or exit the bus stop. The taper ratio requirements should conform to those shown in Table 3.4.1.

Typical designs of this lane arrangement for various bus stop configurations are shown in Figure 3.4.11 and an example of a bus stop adjacent to a bike lane is shown in Figure 3.4.12.

Figure 3.4.11 Bus stop adjacent to bike lane layout



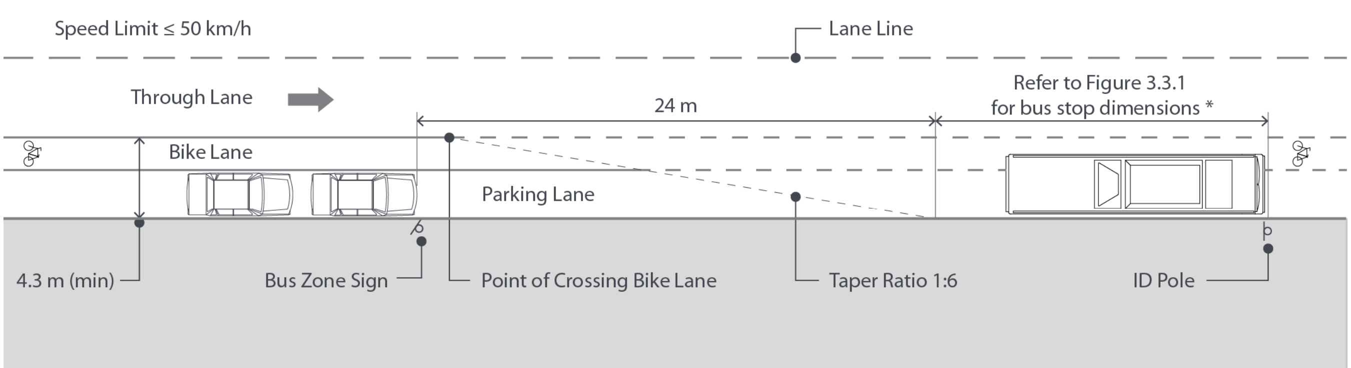
* Note: For bus bays, an extra 3.0 m should be included at the stop for a standard/ articulated bus to straighten out

Figure 3.4.12 Example of bus stop adjacent to bike lane

Subject to site-specific and right-of-way availability conditions, the following bus stop arrangements next to a bike lane might also be considered:

- At a location where the available right-of-way is not sufficient to provide a 3 m wide bus stop next to a bike lane, the stopped bus may partially encroach on the bike lane at the stop. In this situation, the cyclist must either be able to pass the stopped bus safely, or be able to make other decisions such as stopping behind the bus or making a deliberate lane change safely. Preferably, a minimum combined width of 4.3 m should be provided for the bus stop and bike lane to provide sufficient clearance for a cyclist to pass a stopped bus safely without the need to enter the adjacent travel lane. Figure 3.4.13 illustrates this bus stop arrangement, while Figure 3.4.14 shows an example of a bus stop crossing the bike lane. If a 4.3 m combined width for the bus stop and bike lane cannot be achieved, a sign advising cyclists to look before passing the bus should be considered.

Figure 3.4.13 Bus stop on narrow parking lane layout



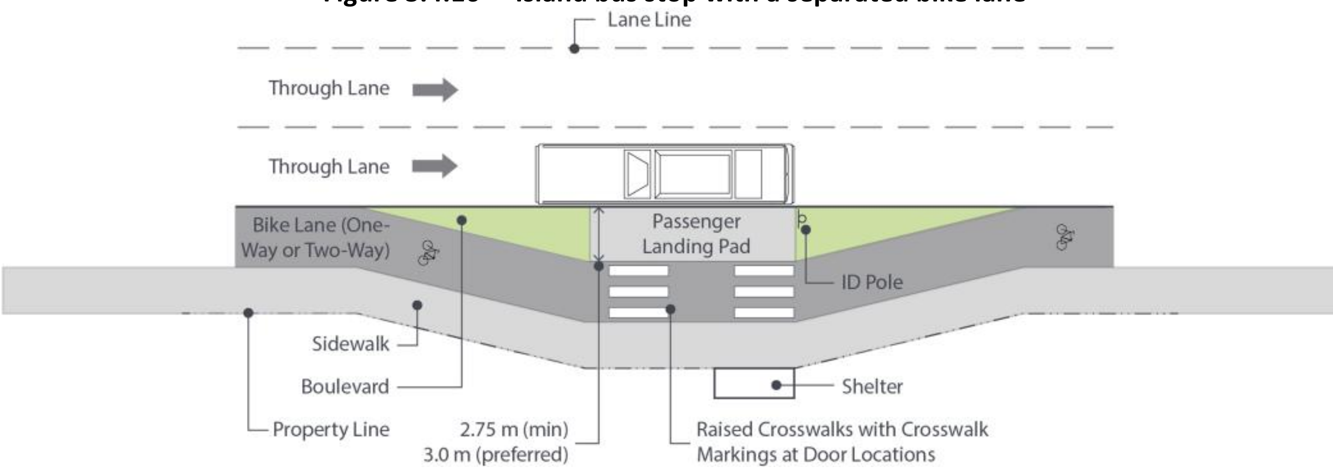
* Note: For bus bays, an extra 3.0 m should be included at the stop for a standard/ articulated bus to straighten out

Figure 3.4.14 Example of bus stop crossing bike lane

- At a location where separated bike path (one-way or two-way) is provided between the travel lane and the sidewalk, and where sufficient right of way is available, an "island bus stop" with the separated bike lane between the sidewalk and the bus stop could be considered. An example of an island bus stop is shown in Figure 3.4.15, while Figure 3.4.16 shows a schematic layout of this type of bus stop. Note the following:
  - To follow customer desire lines, a raised crosswalk could be placed across the bike path covering the front and rear bus door locations, with crosswalk markings at door locations.
  - A crosswalk sign supplemented by a sign directing cyclists to yield to pedestrians would be required facing approaching bikes.
  - If a bus bay is required, the taper lengths should accommodate the pull-in/pull-out tapers required by a bus (refer to Table 3.4.1).
  - If a minimum 4 m wide island is provided, it is desirable to place a bus shelter within the island, provided that the shelter does not interfere with sightlines between pedestrians and cyclists.

Figure 3.4.15 Example of island bus stop

Figure 3.4.16 Island bus stop with a separated bike lane



3.5 PASSENGER AMENITIES

The passenger zone at a typical on-street bus stop is defined as the area customers use to wait for, board, and alight the buses. It is bounded by the curb face and the adjacent property line or boulevard before the property line. The passenger zone extends laterally approximately 9.0 m downstream of the ID post, although it may extend upstream instead if there are physical constraints downstream.

The space required at a passenger zone depends largely on the expected maximum number of waiting customers at the bus stop. This may be estimated by the number of people boarding and alighting the bus, the volume of transfer customers, and the scheduled bus frequencies at the stop. The design capacity of a passenger zone is normally expressed in Level of Service (LOS), ranging from A (indicates good conditions) to F (indicates poor conditions). The LOS is related to the average space available for each waiting customer and the degree of mobility allowed (including mobility for non-transit pedestrians walking past the bus stop). A LOS B should normally be maintained as a Design Condition, in which the average pedestrian area occupancy is approximately 1 square metre per person, as seen in Table 3.5.1.

It is desired that the following features are incorporated into the passenger zone to provide a minimum level of universal accessibility:

- Passenger landing pad;
- Wheelchair pad;
- Tactile Walking Surface Indicators; and
- Benches.

Universal accessibility for bus stops consider the collective needs of the entire community, including persons with disability for mobility, visual, hearing, and cognitive.

There are a number of additional features that are desirable amenities to enhance accessibility, comfort, and safety, and that should be considered in the design and layout of the passenger zone of a bus stop; however, they are not considered to be essential components for universal accessibility. Wherever possible, these features should be considered, recognizing physical constrains. They include:

- Bus shelter; and
- Benches of various seating heights.

Accessibility outside of the defined passenger zone generally falls within the jurisdiction of municipalities, but must be considered as part of the overall system to ensure an accessible transit services within our communities. As such, clear and accessible approaches from the adjacent municipal sidewalk network are recognized as an important component of an accessible transit system as a fully accessible bus stop will be of limited use without accessible approaches.

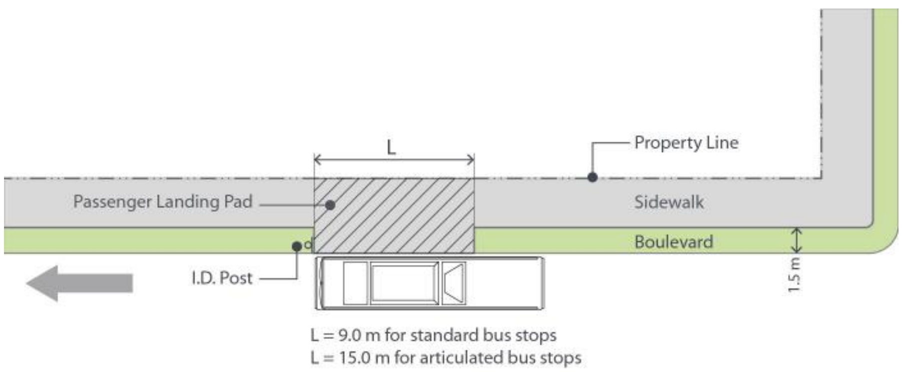
Table 3.5.1 Level of service for customer queuing and waiting areas

Level of service (LOS)	Average pedestrian area (m^2 / person)
A	≥ 1.2
B	0.9 – 1.2
C	0.7 – 0.9
D	0.3 – 0.7
E	0.2 – 0.3
F	< 0.2

3.5.1 PASSENGER LANDING PADS

A passenger landing pad is a solid surface provided at a bus stop for customer waiting and loading/unloading activity. Passenger landing pads should cover at least all potential bus door locations at the bus stop. For stops that serve one Standard Bus, the passenger landing pads are typically 1.5 m wide and minimum 9 m long (L), as illustrated in Figure 3.5.1. For stops that serve one Articulated Bus, a length of 15 m (L) is preferred. For a Mini Bus or HandyDART bus stop, a landing pad length of 8 m (L) and width of 3 m is required to accommodate the wheelchair lift access on the passenger side near the rear of the Mini Bus and on the rear of the HandyDART. A wheelchair landing pad is required at wheelchair-accessible bus stops and the typical requirements can be found in Section 3.5.2. Passenger landing pads should also be connected to sidewalks that lead to the adjacent intersections, wherever feasible.

Figure 3.5.1 Passenger landing pad minimum requirements



3.5.2 WHEELCHAIR PADS

A wheelchair pad should be present at a bus stop for wheelchair accessibility. All TransLink buses are equipped with a mechanical ramp at the front door or a lift at the side-rear of the bus to allow wheelchair customers to board or alight the bus.

To ensure that the wheelchair ramp or lift is deployed safely and efficiently, and to facilitate the maneuverability of wheelchair users, a clearance zone should be provided at the ID post as illustrated in Figure 3.5.2 and Figure 3.5.3 for Standard/Articulated Buses and Mini Buses, respectively. To improve operation efficiency and to accommodate wheelchair users with less agility, a wheelchair clearance area of 3 m long by 3 m wide is preferred. The minimum width of the clearance area should be 2 m.

Overhead clearance above the wheelchair pad (to a shelter roof or temporary hoarding, for example) must be at least 2.7 m at bus bays used by highway coach buses to accommodate the wheelchair lift. In some highly constrained locations, it is acceptable to locate the wheelchair pad partly within the shelter. Where the wheelchair pad is inside the shelter, the overhead clearance of 2.7 m is of particular importance.

The required cross section for a wheelchair pad and the protective measures at the back of the wheelchair pad are shown in Figure 3.5.4.

Figure 3.5.2 Wheelchair pad location and dimensions (standard or articulated buses)

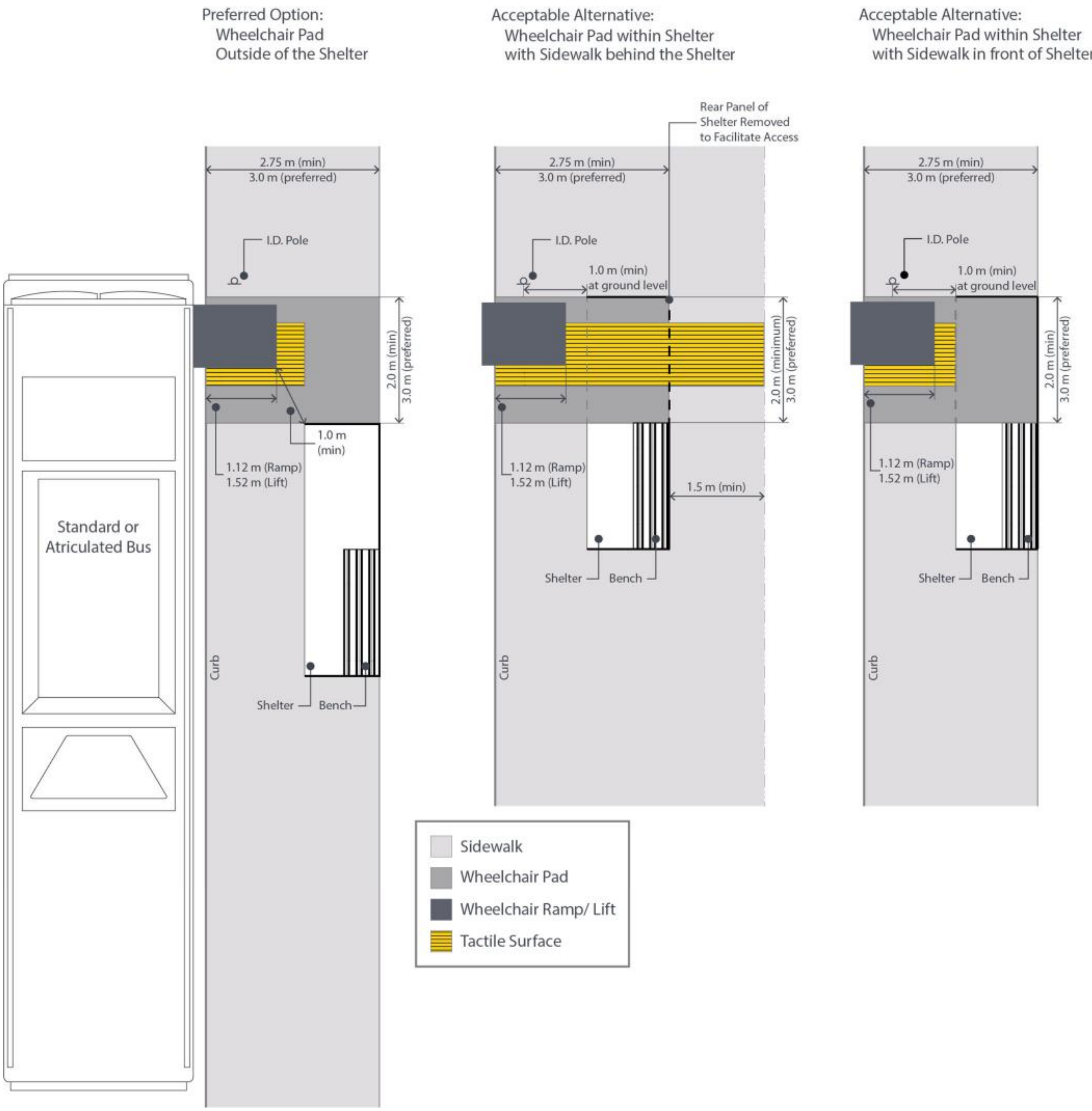


Figure 3.5.3 Wheelchair pad location and dimensions (mini bus)

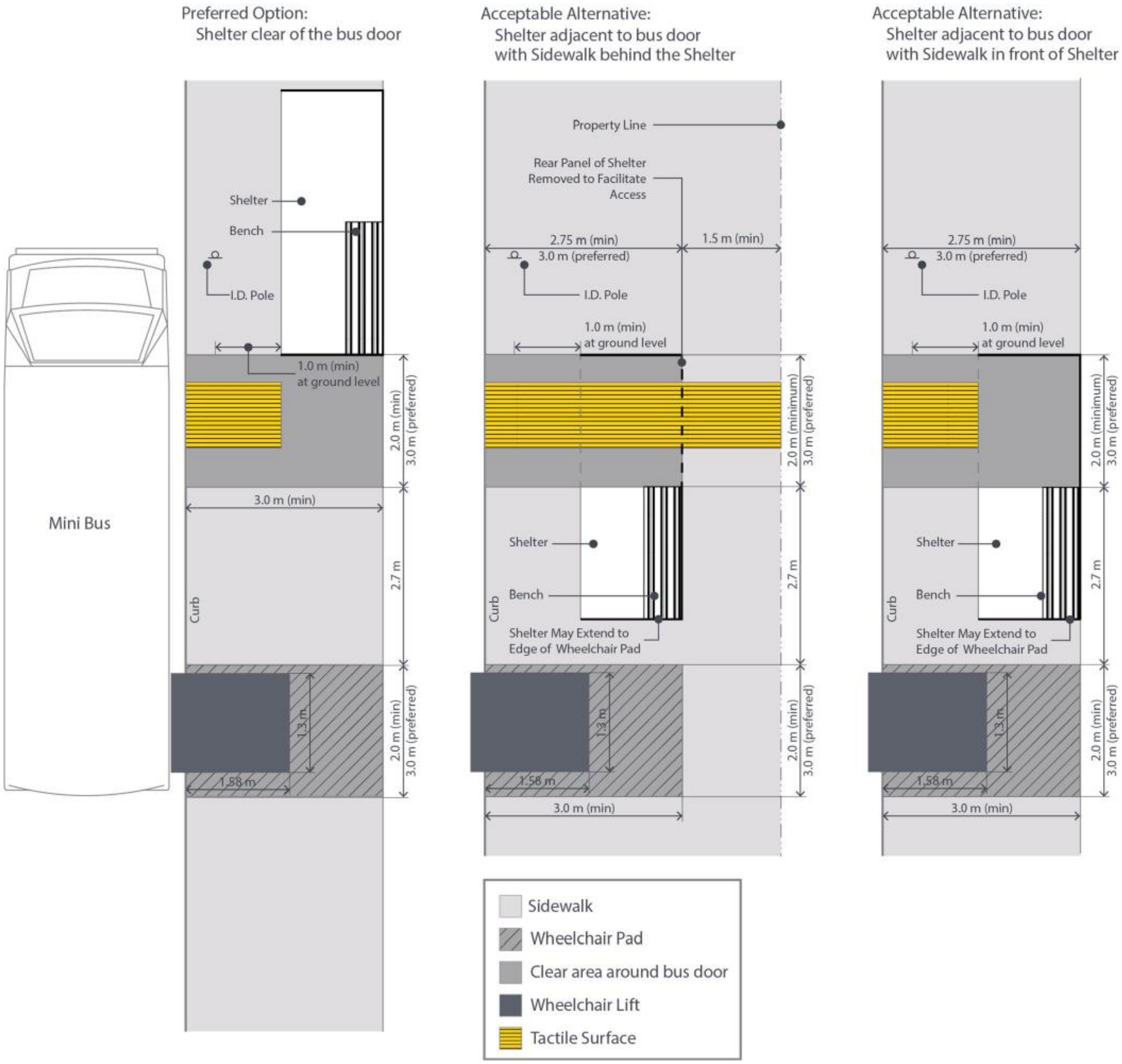
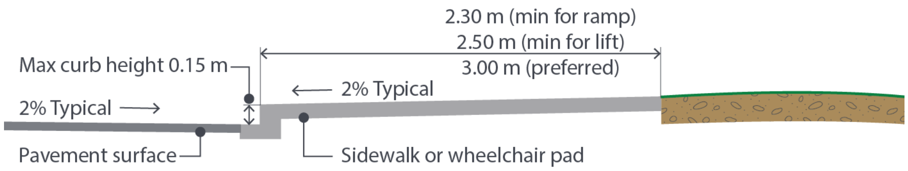
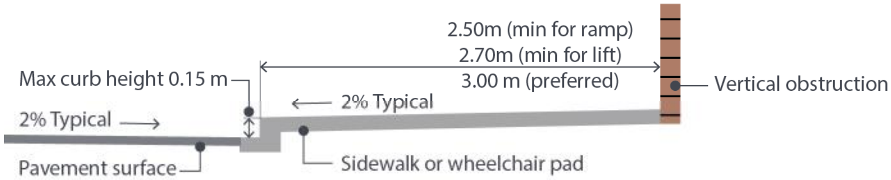


Figure 3.5.4 Cross-section design guidelines

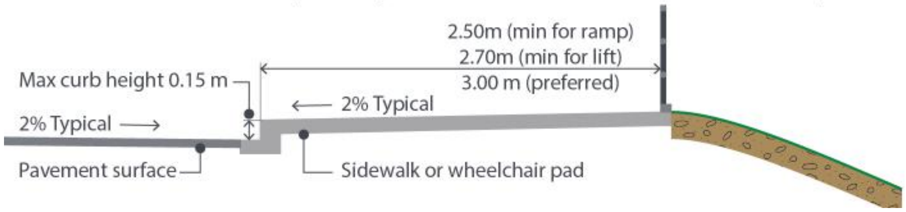
Scenario 1: Surrounding ground behind sidewalk is level and extends for at least 0.2 m



Scenario 2: Vertical obstruction at the back of the sidewalk (i.e. wall, fence, etc.)

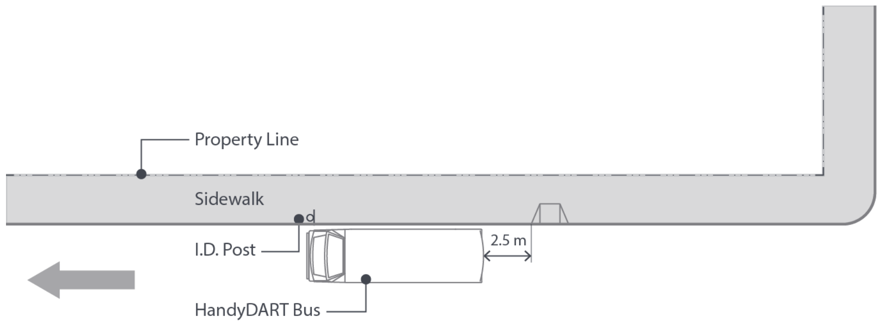


Scenario 3: Surrounding ground behind sidewalk slopes or drops down
The installation of a protecting curb or handrail at the back of the sidewalk is required



HandyDART buses are equipped with a wheelchair lift at the back-rear of the bus. This lift moves users between the road and the bus; therefore, designated HandyDART bus stops at transit facilities are required to have a curb ramp behind the bus to accommodate wheelchair users moving between the sidewalk and the pavement level. To ensure that the wheelchair lift is deployed safely and efficiently, and to facilitate the maneuverability of wheelchair users, a clearance zone of 2.5 m should be provided between the HandyDART bus and the curb ramp, as illustrated in Figure 3.5.5.

Figure 3.5.5 HandyDART wheelchair lift clearance zone



3.5.3 Tactile Walking Surface Indicators

Tactile Walking Surface Indicators (TWSIs), when incorporated into the sidewalk and passenger area, enable customers with visual impairments to locate bus stops within the pedestrian environment. The application guidance set out below resulted from extensive literature research and consultation with TransLink's Access Transit Users' Advisory Committee and CNIB.

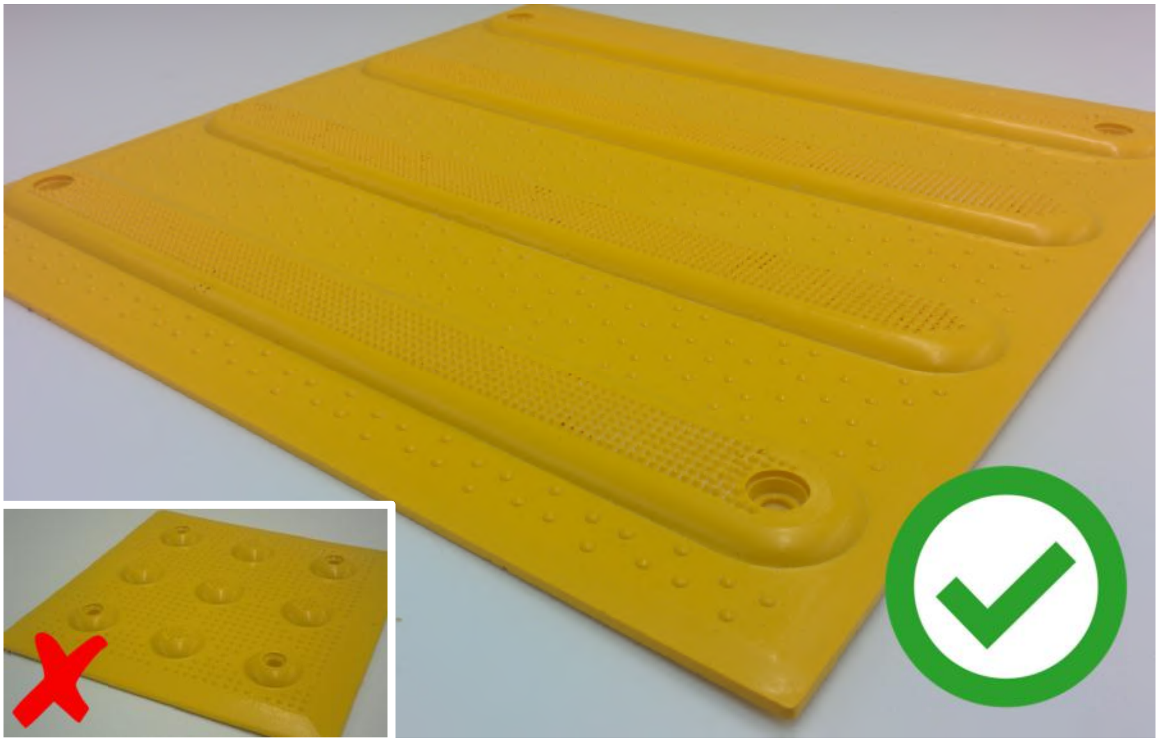
Examples of bus stops with TWSIs can be found at:

- Joyce-Collingwood Exchange;
- Carvolth Exchange;
- Newton Exchange;
- Scott Road Exchange;
- Burquitlam Station;
- Lafarge Lake-Douglas Station;
- Lincoln Station;
- Moody Centre Station;
- 29th Avenue Station; and
- 96 B-Line bus stops.

The primary purpose of TWSIs is to alert customers with vision loss of the bus stop location. The tactile pattern used at bus stops should be a raised flat-topped elongated bars style (pattern for direction purpose as per CSA Standards), as opposed to the truncated domes pattern currently used on the edge of SkyTrain platforms to indicate hazards. Refer to CSA Standards for additional guidance on the selection of TWSIs. Figure 3.5.6 shows examples of the flat-topped elongated bars style (for bus stop use) and the truncated domes style (not for bus stop use).

Generally, TWSIs for individual stops should extend a sufficient distance from the curb to intersect the general flow of pedestrian traffic along the passenger waiting area. Refer to **Appendix E** for detailed dimensions of the TWSIs for bus stop application, and example of bus stop configuration.

Figure 3.5.6 Example TWSIs – flat-topped elongated bars pattern



It is important to note that TWSIs can only be installed at bus stops with a hard-surfaced passenger zone and wheelchair pad. The TWSIs should have its base surface levels with the surrounding surface, or not more than 3 mm above or below it. Figure 3.5.7 illustrates an example bus stop with TWSIs.

Figure 3.5.7 Example bus stop with TWSIs

3.5.4 BENCHES

Benches are placed at bus stops for the comfort and convenience of waiting customers, particularly in locations where wait times are long. It is also necessary to provide seating to accommodate customers who cannot stand for long periods. In the design and placement of bus benches, the following factors should be considered:

- Benches should be large enough to seat three or more persons.
- Benches should be constructed to be comfortable and safe for customer use.
- Materials should have high resistance to vandalism and weathering.
- The seat must be 430-490 mm above ground.
- The seat must be 500-600 mm deep from front to back.
- Armrests must be located at both ends of the bench and be 200 mm above the seat.
- Benches without middle armrests are preferred, unless sleeping on benches is an issue.
- Backrests are preferred along the length of the seat. The backrest should have a typical height of 440-455 mm and be positioned at an angle between 95° and 100° to the (horizontal) seat surface. If the bench is located right in front of a bus shelter with wayfinding map case on the back panel, the backrests should not block the visibility of the wayfinding map.
- Benches should be located to minimize obstruction to the public right-of-way and access to/from the bus for all users, including those in wheelchairs.
- The minimum setback for a bus bench from the curb face should be 1.5 m.

The clearance requirements between a bench and the ID pole for different bus stop layouts can be found in **Appendix F**. Figure 3.5.8 shows an example of a bench at a bus stop.

Figure 3.5.8 Example of a bench at a bus stop

3.5.5 Bus Shelters

Bus shelters protect waiting customers from poor weather and may provide additional integrated amenities such as benches, route maps, lighting, etc. There are several forms of bus shelters, which meet various space restrictions and weather protection requirements. Bus shelters may be installed and maintained by TransLink, the municipality, or by a third-party advertising company.

The shelter size should be determined with reference to maximum number of expected customers waiting at the stop with an appropriate level of service (typically Level of Service B). Table 3.5.1 shows the LOS for customer queuing and waiting areas.

General considerations for shelters include:

- Shelters should be located close to bus boarding locations, typically at the bus stop ID post, but not farther than 9 m from the ID post, for customer convenience and to ensure timely boarding.
- Shelters should be designed to maximize visual transparency in order to improve visibility of buses to passengers and reduce CPTED issues.
- Shelters should be designed so as to not impede passenger queuing and pedestrian circulation. This can often be achieved by reducing the shelter's number of touch-down points. Site-specific analysis of passenger queuing and pedestrian circulation can inform the shelter design.
- In locations where pedestrian circulation would not be impeded, shelters may provide side or back panels. Advertising and wayfinding may be incorporated into bus shelters if they can be placed in such a way that allows for adequate sightlines.

- The shelter interior should be illuminated by its own light source or by adjacent street lighting. Shelter lighting should be considered in conjunction with Section 4.2.7.

- The closest portion of the shelter should maintain a minimum lateral clearance of 0.6 m from the curb face to avoid contact with a bus (to account for the maximum rear sweep of a bus).

- In narrow areas where adequate space is not available to site a bus shelter, it may be prudent to put the shelter immediately downstream. Customers waiting in the shelter should be able to clearly see approaching buses.

Shelters should be provided wherever possible. As a minimum, shelters are recommended at the following locations:

- Bus stops at transit exchanges or major transfer points.

- Bus stops with high loading/unloading volumes.

- In the vicinity of a HandyDART bus stop.

- Bus stops located near schools, seniors' housing developments, community and recreation centres, and other major generators such as shopping malls.

Figure 3.5.9 shows an example of a bus shelter. Specific considerations with respect to wheelchair accessibility include:

- A bus shelter should incorporate seating for at least three people and a clear area at least 1.0 m wide for one wheelchair.

- If wheelchair accessibility is provided within the shelter, the back of the shelter should preferably be set back at least 3.0 m from the curb face.

- Where the wheelchair pad is located within the shelter or under an existing building feature, overhead clearance of 2.7 m must be maintained (to accommodate buses with a wheelchair lift, such as the highway coach bus).

Figure 3.5.9 Example of a bus shelter

3.5.6 Supplementary Bus Stop Information Signage

TransLink is exploring options to improve accessibility of bus stop information signage to consider the collective needs of the entire community, including persons with disability. The intent of the supplementary bus stop information signage is to help passengers with vision loss to identify bus stops and receive bus stop information. The signage will be developed in consultation with stakeholders and further information will be updated in the appendices of the guidelines as the signage design finalizes.

3.5.7 Other Street Furniture

Other street furniture at on-street bus stops may include the ID post, bus schedules, route maps, wayfinding and customer information displays, newspaper vending boxes, waste and recycling receptacles, advertising displays, trees and planters, telephones, etc. Bus stops at transit exchanges may include the amenities discussed above, as well as several transit exchange specific amenities, which are discussed further in Section 4.2.10.

Bus stops should provide a positive customer experience in order to make transit a more appealing travel choice. High quality, attractive, and co-ordinated furniture should be chosen, with fittings and finishing of comparable quality. Street furniture should not interfere with safe bus/passenger operations at the bus stop. To provide adequate lateral clearance, street furniture at bus stops, including the bus stop ID post, shelter, lamp standards, etc., should be set back at least 0.6 m from the curb face.

3.6 Drainage Grates and Utility Covers

Drainage grates and utility covers are potential safety hazards for boarding and alighting customers at bus stops. They are often slippery when wet and a prime location for the formation of potholes.

To avoid these potential problems, the location of existing drainage grates and utility covers, if any, should be identified from field observation when siting a bus stop. The exact location of a bus stop may be adjusted so that the door openings of the bus are away from drainage grates and utility covers. For new road design, drainage grates and utility covers should be positioned with consideration of potential bus stop locations.

CHAPTER 4. TRANSIT FACILITIES

4.1 INTRODUCTION

At transit facilities, customers transfer between other modes of transportation and transit, or between transit services. This chapter discusses the design considerations related to three types of transit facilities:

- Transit Exchanges;
- Park and Ride Facilities; and
- Passenger Pick-Up/Drop-Off Facilities.

4.2 TRANSIT EXCHANGES

As per TransLink's *Transit Passenger Facilities Design Guidelines*, transit exchanges are broadly defined as customer facilities that serve multiple bus routes, provide layover space for buses, and may or may not be associated with a rapid transit station. Although stations and exchanges are identified here as separate facility types, most stations are associated with exchanges and both elements should be conceived and designed as a single facility to ensure a seamless travel experience. Transit exchanges are generally located at activity centers along the route and at the end of certain bus routes.

It is important that operating plans are developed in conjunction with geometric designs as the operating plan will affect how many bus bays are required and how they can be configured in relation to each other. Operating plans are discussed further in **Appendix G**.

In general, a transit exchange has the following basic functions:

- Customer access from non-transit modes, including walking, cycling, park and ride, and passenger pick-up/drop-off (kiss and ride);
- Customer transfers between buses and other modes of public transportation, such as SkyTrain, West Coast Express, and Sea Bus;
- Transit information and wayfinding for customers;
- Layover spots for bus routes;
- Interlining among bus routes;
- Minor bus maintenance, including space for tow truck operations;
- Operations supervisors and/or service vehicle parking; and
- Operators' crew room and washrooms (refer to Section G4.85(1)-2 of WorkSafeBC's *Occupational Health and Safety Guidelines* regarding maximum allowable distance to readily available washrooms).

4.2.1 Transit Exchange Design and Considerations

4.2.1.1 Approach to Transit Exchange Design

The design of transit exchanges requires a context sensitive, iterative design process. Therefore, the design process should consider physical and operational contexts, including available land size, transit operational requirements, transit network, customer access, and adjacent land uses.

A comprehensive and holistic design would involve participation and input from multidisciplinary professionals and stakeholders. This requires participation from design and operations professionals from TransLink and its subsidiaries, with input from stakeholders such as municipalities and adjacent land owners.

Please refer to TransLink's *Transit Passenger Facility Design Guidelines* for further information on the design principles and design processes for transit exchanges.

4.2.1.2 Transit Exchange Design Considerations

Transit exchange design teams need to consider the requirements of transit operation and customers, and the exchange's impacts to the adjacent road network and adjacent developments. The ultimate design of the transit exchange should optimize the needs of all users.

Transit exchanges should be built to meet the design horizon year, as those that are over or under built will be expensive to retrofit. The following are some design considerations for transit exchanges:

Transit operation

- Vehicle types (e.g., Standard Bus, Articulated Bus, Trolley Bus, CNG bus, Mini Bus, and HandyDART);
- Number of bus bays and layover requirements;
- Nature of bus routes (e.g., terminating routes or flow through routes);
- Bus bay function (e.g., first-in/first-out, independent departure, and independent arrival and departure);
- Bus operating plan (e.g., location and operating procedure for drop-off/layover/pick-up);
- Bus circulation (e.g., access to and from adjacent road network, and internal circulation within transit exchange);
- Height and ventilation requirements for covered facilities;
- Lighting requirements for exchange access, drive aisles, bus bays, pedestrian crossings, and layover area;
- Telecommunications requirements (radio and cellular);
- Trolley infrastructure requirements (if applicable);
- Concrete bus pads for bus bays and layover;

- Safe and efficient transit operation (e.g., location of pedestrian crossings within transit exchange, and travel distance between drop-off/layover/pick-up);
- Location of bus operator washroom and crew room (refer to Section G4.85(1)-2 of WorkSafeBC's *Occupational Health and Safety Guidelines* regarding maximum allowable distance to readily available washrooms);
- Transit supervisor and service vehicles parking;
- Integration with other modes, such as SkyTrain Station, WCE Station, park and ride lot, and passenger pick-up/drop-off zones;
- Resiliency (e.g., towed bus scenario, broken vehicles, bus bridges, and special services); and
- Environmental requirements (i.e. oil-water separator).

Passenger space

- Area for customer queuing, boarding and alighting, and transferring (e.g., passenger circulation);
- Covered customer waiting area (e.g., shelter) for weather protection at queuing areas;
- Space for customer amenities (e.g., benches, bike parking, lighting, garbage bins, wayfinding maps, and public art); and
- Accessibility requirements (e.g., wheelchair landing pad, accessible routes, and grades).

Passenger access

- Number and location of pedestrians and cyclists crossings within, and to and from, the transit exchange;
- Vertical circulation within, and to and from, the transit exchange (i.e. stairs, escalators, elevators);
- Safe pedestrians and cyclists crossings within, and to and from, transit exchange (e.g., sightline, lighting, pavement marking, and signage);
- Customer desire lines from origin to destination, potentially crossing into/out of a Fare Paid Zone (e.g., SkyTrain Station, WCE Station, park and ride lot, passenger pick-up/drop-off zones, and major employment/institutional/residential nodes); and
- Provision for bike storage (e.g., bike racks, lockers, and secure bike parking).

Site characteristics

- Land availability;
- Adjacent road network (e.g., bus access options);

- Adjacent or integrated developments;
- Integration with SkyTrain Station, WCE Station, park and ride lot, passenger pick-up/drop-off zones, and surrounding land uses;
- Street characteristics (e.g. block length, traffic speed, driveways, pedestrian crossings, sidewalks, and bike network and facilities); and
- Landscaping opportunities.

4.2.2 Types of Transit Exchange

The selection of a transit exchange type would generally depend on land availability, operating plan, bus bay requirements, and its location in relation to the adjacent road network and adjacent land uses. The following subsections provide a summary and general description of typical transit exchange types.

4.2.2.1 Centre Loading Platform Exchange

A centre loading platform exchange consists of a single customer platform surrounded by a bus drive aisle for clockwise circulation. Generally, the exchange is located off-street and is not accessible to general purpose traffic. Layover, like pick-up and drop-off, may be located in bays adjacent to the customer platform. It may also be accommodated around the perimeter of the bus circulation area or off-site. Figure 4.2.1 shows the general layout, while Figure 4.2.2 shows an example of a centre loading platform exchange.

Figure 4.2.1 Centre loading platform exchange layout

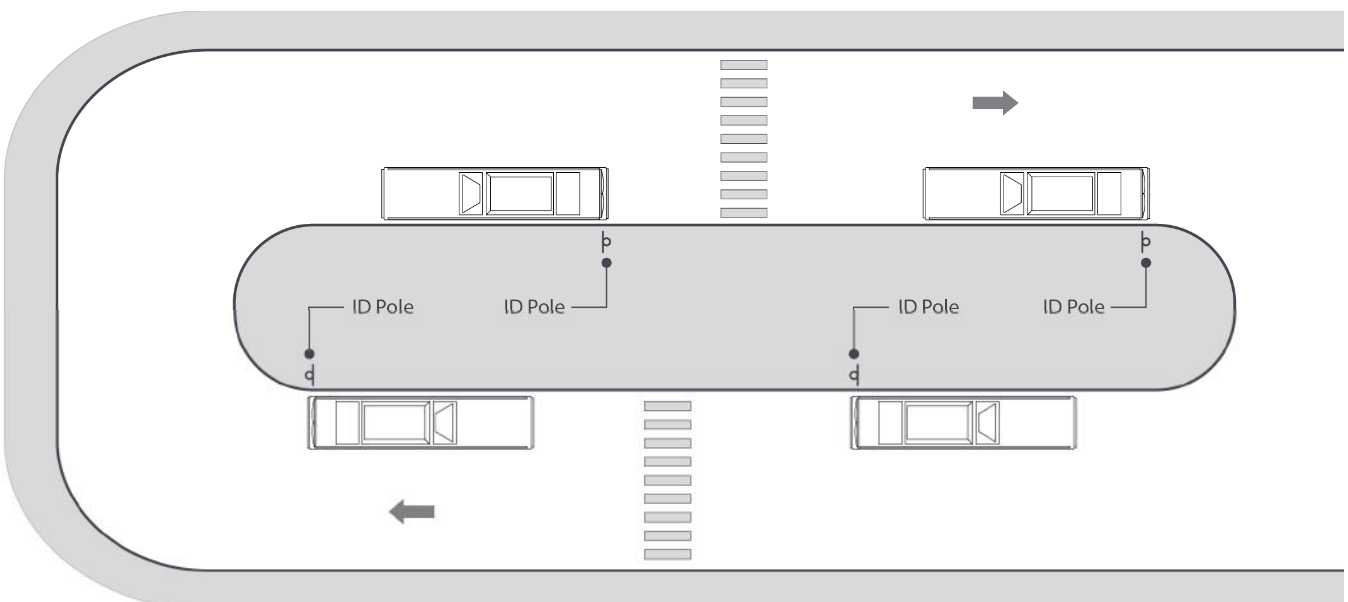


Figure 4.2.2 Sperling–Burnaby Lake Station Exchange (central loading platform)

Site characteristics:

- When majority of customers are transferring between buses, customers are not required to cross the drive aisle, therefore reducing bus-pedestrian conflicts;
- When associated with an elevated rail station, vertical circulation from the station can land on the platform, facilitating bus and rail transfers;
- Customer amenities (e.g. weather protection, seating, and retail kiosks) can typically be accommodated within the platform; and
- Platform can generally be sized to accommodate large number of bus bays, long customer queues, and high customer transfer volumes.

Design recommendations for centre platform exchanges include:

- Provide safe pedestrian crossings along desire lines and minimize number of crossings to and from the platform;
- Design a compact platform to reduce customer walking distance and minimize land requirement;
- Provide adequate weather protection near the bus stop pole, where customers will likely form queues, especially on bus routes that have high chance for pass-ups, long distance, or low customer turnover; and
- Provide good visibility along platform, for better customer safety and security.

4.2.2.2 Multiple Parallel Loading Exchange

This type of bus exchange consists of multiple parallel platforms that accommodate bus passenger pick-up and drop-off. Generally, multiple parallel loading exchanges are located off-street and are not accessible to general purpose traffic. Layover, like pick-up and drop-off, may be located in bays adjacent to the customer platforms. It may also be accommodated around the perimeter of the bus circulation area or off-site. Figure 4.2.3 shows the general layout, while Figure 4.2.4 shows an example of a multiple parallel loading exchange.

Figure 4.2.3 Multiple parallel loading transit exchange layout

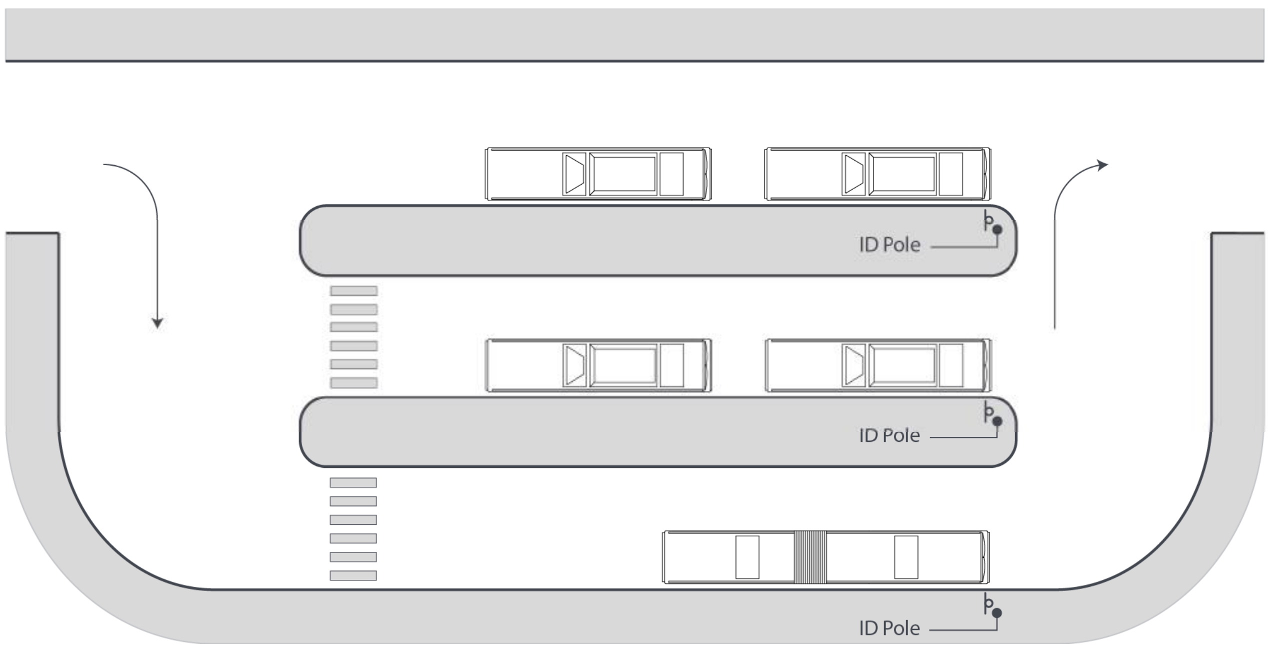


Figure 4.2.4 SFU Exchange (multiple parallel loading platforms)

Site characteristics:

- May be more suitable for terminus where transferring customer volumes are relatively low, as fewer customers will be required to cross between drive aisles; and
- At location where space is constrained, large number of bays can generally be designed in a spatially efficient manner.

Design recommendations for multiple parallel platforms exchanges include:

- Provide safe crossings along desire lines and minimize number of crossing within/to-from transit exchange;
- Assign bus routes with high customer transfers on the same platform, to optimize customer transfer movement and minimize pedestrian crossings;
- Incorporate measures (e.g. landscaping) to discourage customers from jaywalking between drive aisles within the bus exchange;
- Provide sufficient platform space for queuing, boarding/alighting, and customer amenities; and
- Consider various operating plans to optimize number of bus bays and layover required at the exchange, depending on land availability.

4.2.2.3 Perimeter Exchange

A perimeter bus exchange consists of a continuous customer platform with pick-up and drop-off bays on a single side or multiple sides – depending on number of bus bays and layovers required, with an adjacent bus drive aisle for circulation. Layover, like pick-up and drop-off, may be located in bays adjacent to the customer platform. It may also be accommodated around the perimeter of the bus circulation area or off-site. Figure 4.2.5 shows the general layout, while Figure 4.2.6 shows an example of a perimeter exchange.

Figure 4.2.5 Perimeter transit exchange layout

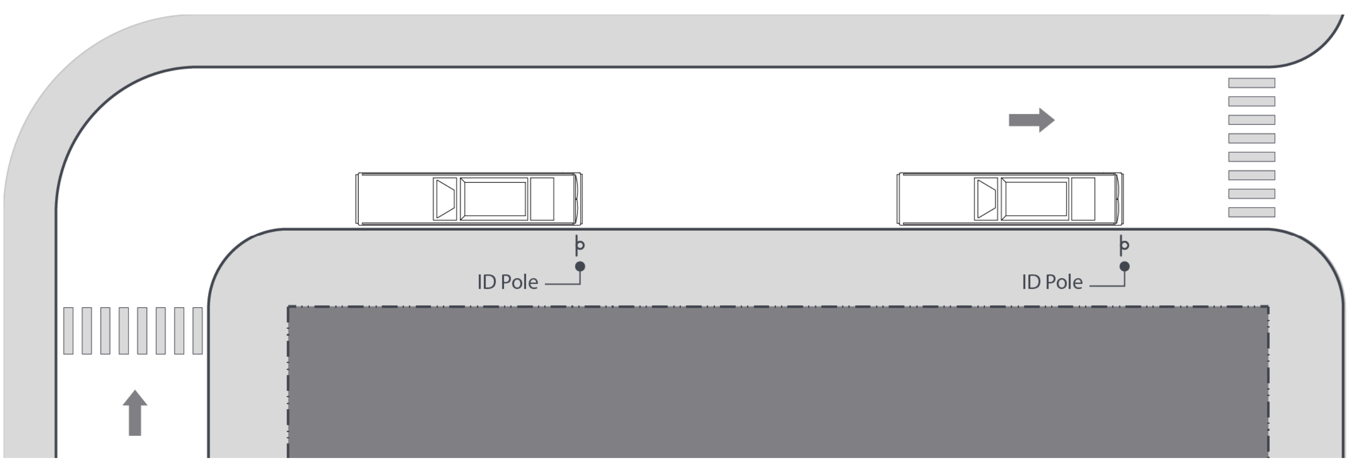


Figure 4.2.6 Moody Centre Station Exchange (perimeter loading platform)

Site characteristics:

- Bus-pedestrian conflicts are reduced if most customers are approaching the exchange from a single direction of the platform (e.g. rail station, park & ride, shopping mall); and
- Customer amenities can typically be accommodated on a single platform.

Design recommendations for perimeter exchanges include:

- Provide safe crossings along desire lines and minimize the number of crossings to the transit exchange if pedestrians are expected to access it from directions other than the platform; and
- Consider the possibility of increased walking distance for bus to bus transferring customers if the exchange has a large number of bays.

4.2.2.4 On-Street

An on-street transit exchange locates passenger pick-up/drop-off areas on a street that shares the roadway with general purpose traffic. Layover may be located either curbside or in a separate, off-street area. Figure 4.2.7 shows an example of an on-street exchange, while Figure 4.2.8 shows the general layout.

Site characteristics:

- When a large number of destinations are distributed around the exchange area, customer desire lines can be accommodated through the urban street network; and
- A small number of layover bays can be accommodated on street.

Design recommendations for on-street exchanges include:

- Provide sufficient sidewalk space for both customer queues and pedestrians. In high-volume queue locations, line markings or other queueing systems may be required to keep pedestrian through zones free from customer queues;
- Consult with nearby residents and business owners, if bus stops or layover bays will be placed in front of residential or commercial entrances;
- Design bus bay location that channels customers to use intersection crosswalks;
- Incorporate measures (e.g. landscaping) to discourage customers from jaywalking across roadway for bus to bus transfers;
- Consider possibility of increased walking distance for bus to bus transferring customers, if the exchange has large number of bays;
- Consider combination of off-street and on-street layover if large amounts of layover bays are required;
- Consider transit priority measures, such as a bus lane, if buses must circulate on city streets between drop-off, layover, and pick-up; and
- Provide wayfinding to help customers identify bus bays locations and accessible routes.

Figure 4.2.7 Burquitlam Station Exchange (on-street loading platform)

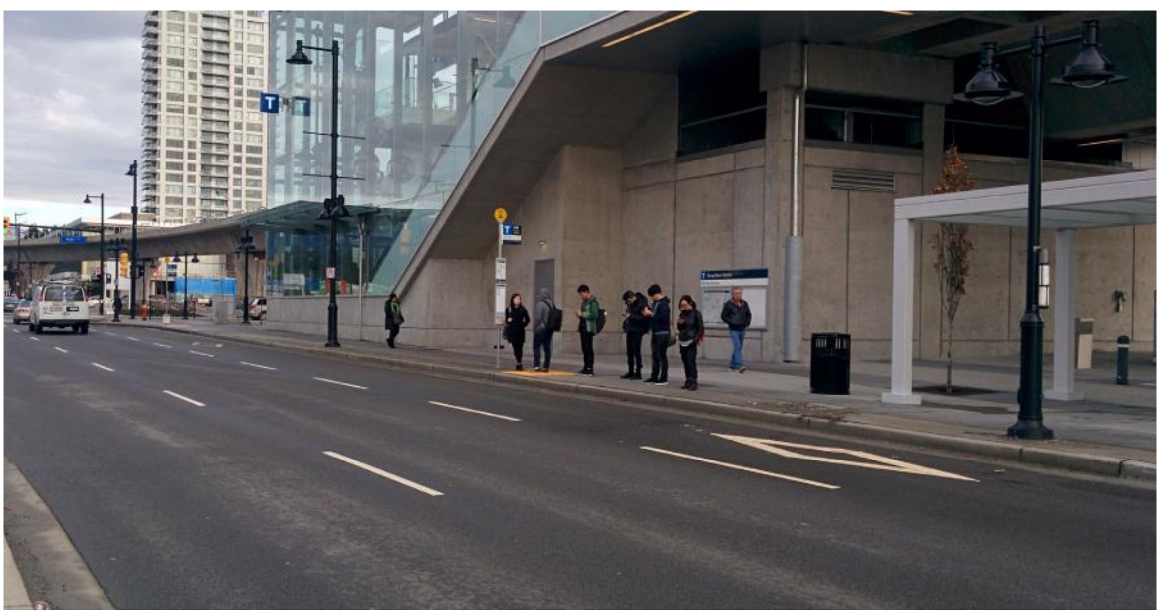
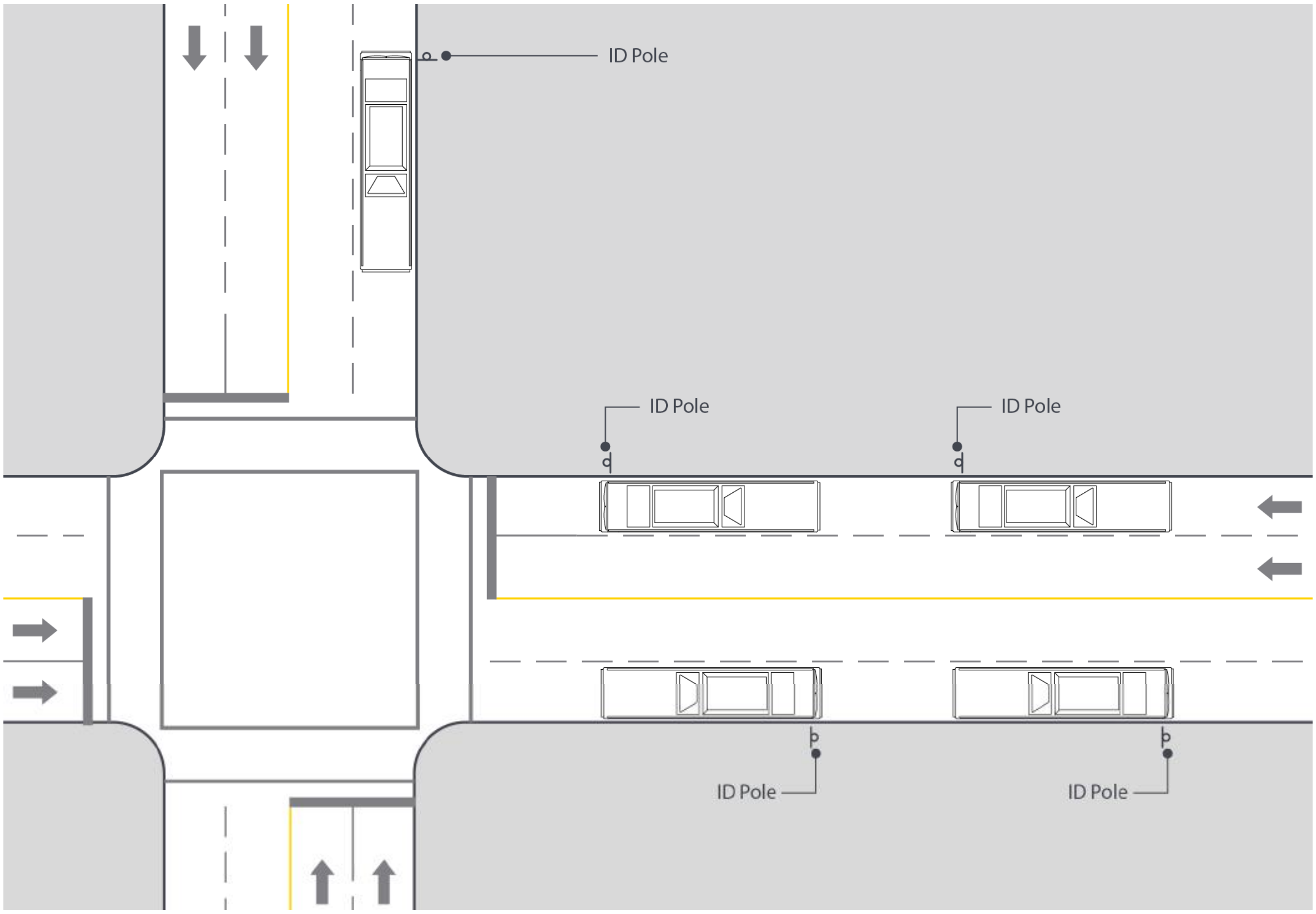


Figure 4.2.8 On-street transit exchange layout



4.2.2.5 Bus Mall

A bus mall exchange locates passenger pick-up/drop-off areas on a street that does not accommodate general purpose traffic. Bus stops may be located either curbside or on a central median. Layover may be located either curbside or in a separate, off-street area. A bus mall can provide additional exchange capacity and reduce conflicts with private vehicles. Figure 4.2.9 shows the general layout, while Figure 4.2.10 shows an example of a bus mall.

Site characteristics:

- Conflict with general purpose traffic is reduced since roadway is typically restricted to buses only;
- When a large number of destinations are distributed around the exchange area, customer desire lines can be accommodated through the urban street network; and
- A small number of layover bays can be accommodated on street.

Figure 4.2.9 Bus mall transit exchange layout

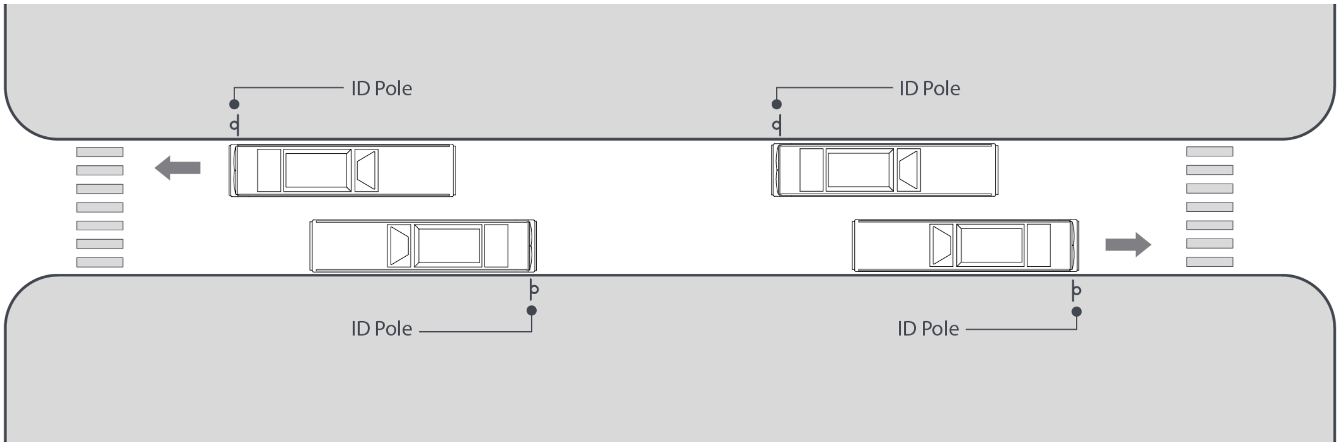


Figure 4.2.10 Granville Street (bus mall)

Design recommendations for bus mall include:

- Provide sufficient sidewalk space for both customer queues and pedestrians. In high-volume queue locations, line markings or other queueing systems may be necessary in order to keep pedestrian through zones free from customer queues;
- Consult with municipalities to restrict general purpose traffic on bus mall;
- Consult with nearby residents and business owners, if bus stops or layover bays will be placed in front of residential or commercial entrances;

- Channelize customers and pedestrians to use designated crosswalks;
- Minimize conflict between buses and pedestrians, by incorporating measures (e.g. landscaping) to discourage customers from jaywalking across roadway for making bus to bus transfers;
- Consider possibility of increased walking distance for bus to bus transferring customers, if the exchange has large number of bays;
- Consider transit priority measures, such as bus lane, if buses must circulate on city streets between drop-off, layover, and pick-up; and
- Consider combination of off-street and on-street layover if large amounts of layover bays are required.

4.2.2.6 Hybrid Exchange

A hybrid exchange has on-street bus stops along one or more sides of the transit exchange and some bus stops located off-street. The bus layover areas can be placed on the off-street side of the transit exchange. Figure 4.2.11 shows the general layout, while Figure 4.2.12 shows an example of a hybrid exchange.

Site characteristics:

- When majority of customers are transferring between buses, customers are not required to cross the drive aisle, therefore reducing bus-pedestrian conflicts;
- When associated with an elevated rail station, vertical circulation from the station can land on the island, facilitating bus to rail transfers;

Figure 4.2.11 Hybrid exchange layout

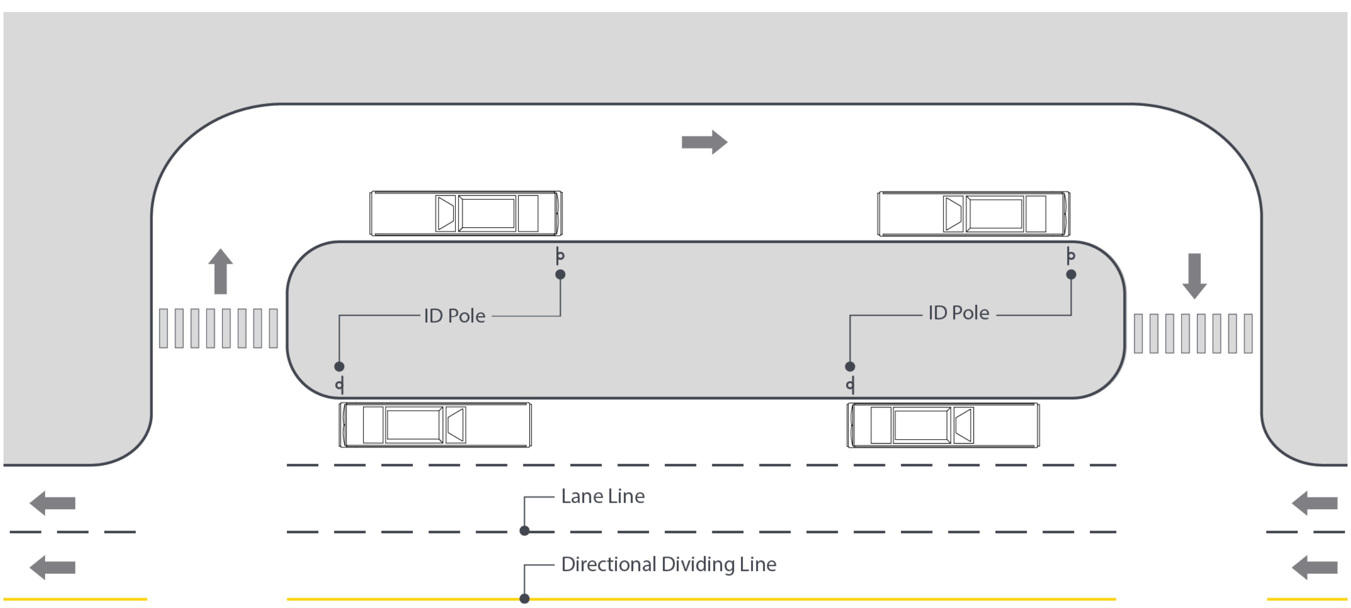
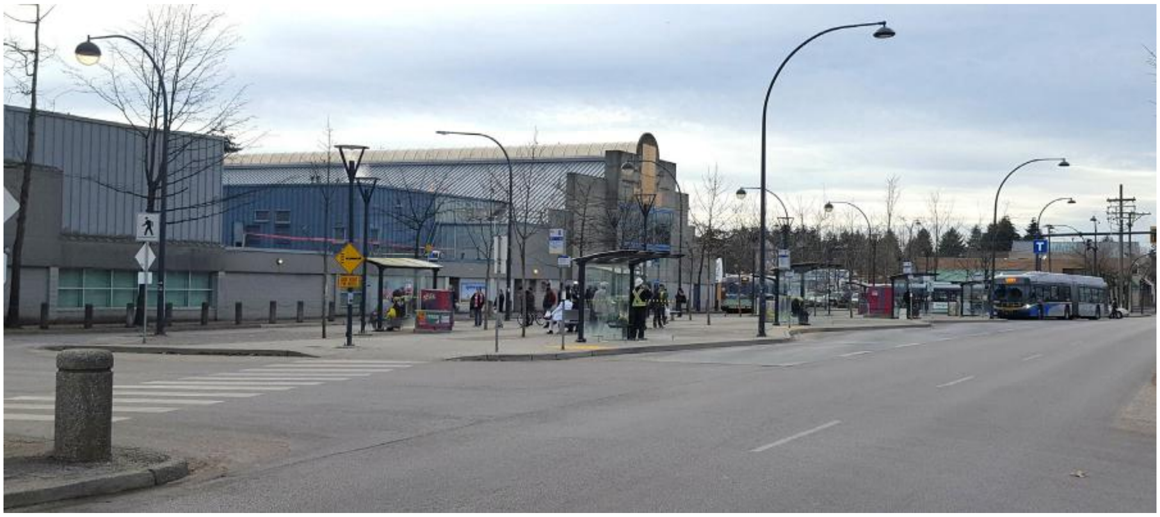


Figure 4.2.12 Newton Transit Exchange (hybrid loading platform)



- Customer amenities (e.g. weather protection, seating, and retail kiosks) can typically be accommodated on single platform; and
- Platform can generally be sized to accommodate a large number of bus bays, long customer queues, and high customer transfer volumes.

Design recommendations for centre platform exchanges include:

- Provide safe crossings along desire lines and minimize number of crossing within/to-from transit exchange;
- Design a compact customer waiting platform to reduce customer walking distance and minimize land requirement;
- Provide weather protection near bus stop pole, as customers will likely form queue on long distance or low-turnover bus routes;
- Size exchange to accommodate future service demand;
- Provide good visibility within customer waiting platform, for better customer safety and security; and
- Provide separate washroom facilities and waiting area for bus operators.

4.2.3 Geometric Requirement of Bus Bays

The geometric design of bus bays is determined by the size and shape of the space available for the exchange, the types of buses being operated, and the number of customers who will be using the facility. There are two commonly used loading/unloading bay layouts for a transit exchange; (i) Parallel Bay and (ii) Sawtooth Bay. Refer to Section 3.4.3 for the typical design requirements for these two types of loading bays.

An unobstructed width of the transit exchange area should accommodate towing operations. Check using AutoTURN to ensure there is enough lateral distance for towing operations.

4.2.4 Loading Area Estimation

The number of bus bays to be provided at a transit exchange is determined on a case-by-case basis and is generally governed by the forecast number and scheduling of bus routes being served over the required planning horizon. There may be requirements that warrant the provision of additional space, such as for layover space (if not provided in a separate lane) and parking space for maintenance and/or service vehicles.

The Transportation Research Board's (TRB) *Transit Capacity and Quality of Service Manual* contains guidance for calculating the theoretical capacity of a bus stop (parallel loading). The derived capacity can be used to assess against the desired number of buses per hour using the same bus stop.

According to the TRB's *Transit Capacity and Quality of Service Manual*, the capacity of a linear loading area is expressed by the formula found in Table 4.2.1

Table 4.2.1 Loading area bus capacity formula

Loading Area Bus Capacity (buses/ hour)

$$BI = \frac{3{,}600\left(\frac{g}{C}\right)}{t_c + t_d\left(\frac{g}{C}\right) + Z(c_v)(t_d)}$$

Variable	Meaning
3,600	Number of seconds per hour
$\frac{g}{C}$	Green time ratio (ratio of effective green time to total traffic signal cycle length, equals 1.0 for unsignalized streets and bus facilities)
t_c	Clearance time (s)
t_d	Average (mean) dwell time (s)
Z	Standard normal variable corresponding to a desired failure rate (assumed to equal 1.0 minus the failure rate, where typical failure rate is 0.25)
c_v	Coefficient of variation of dwell times (typically 0.6)

The resulting capacity (BI) is then compared to the desired provision of buses per hour (typically derived from arrival headway). If the resulting capacity is less than the desired provision of buses per hour, additional loading area (in the form of extra storage length) must be provided for the route. This equation also applies to drop-off bays where buses may be arriving simultaneously due to schedule unreliability.

The site characteristics, desired access, and desired circulation pattern will determine the arrangement of the various loading areas, given the various lengths that may be required. Nonetheless, there are circumstances that warrant the provision of additional loading areas, such as layover space for routes that terminate at the transit exchange and/or vehicles that may be stored overnight at the facility.

4.2.5 BUS-PEDESTRIAN-CYCLIST CONFLICTS WITHIN A TRANSIT EXCHANGE

The circulation of buses within a transit exchange should be designed to minimize conflicts with pedestrian and cyclist movements. The locations of bus entry and exit points should be segregated from pedestrian and cyclist traffic wherever possible; otherwise, pedestrian and cyclist traffic should be controlled by traffic management measures such as fences or railings.

To avoid any potential sightline problems within a transit exchange, wherever possible, pedestrian and cyclist crossings should be placed at locations behind stopped buses, before bus turning maneuver points, or at the end of a bus turning maneuver, as illustrated in Figure 4.2.13. There should be sufficient stopping sight distance for a bus operator to see pedestrians and cyclists; otherwise, signals or a stop sign should be installed to ensure that buses stop before a crossing and bus drivers can check for pedestrians before proceeding.

The locations where pedestrians step out from the platform should not be located in the visibility impairment zone of the bus operator while the bus is making a turn around the platform.

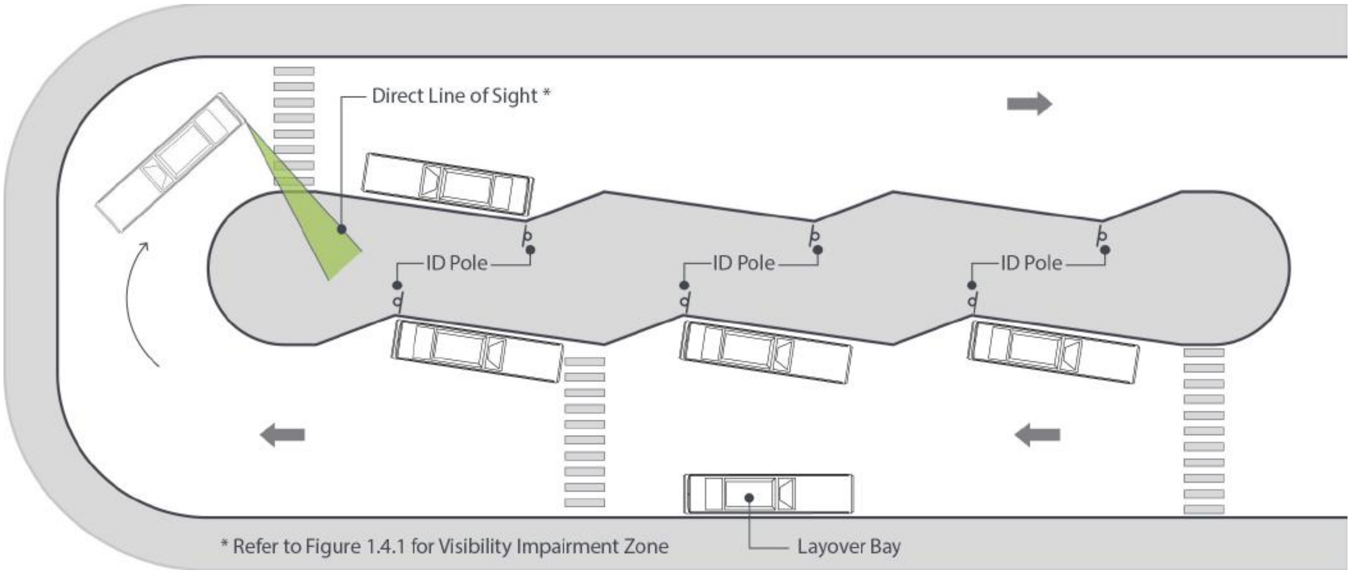
The minimum width of a standard crosswalk is 2.5 m; however, where the pedestrian flow is over 600 pedestrians per hour, wider crossings should be used. In the vicinity of a transit exchange, the design team should engage with TransLink to ensure the appropriate crosswalk width is used.

As much as possible, pedestrian and cyclist crossings should be located on pedestrian/cyclist desire lines so that bus operators will know where to expect people crossing, to minimize the number of people crossing where they are not expected, and to minimize the need for barriers or fences. If barriers or fences are required to prevent unsafe pedestrian/cyclist crossings, consider altering the design or including aesthetically pleasing custom fences and/or landscaping to improve the pedestrian environment. Pedestrians and cyclists should be oriented so they face oncoming buses when entering a crossing; designs where pedestrians and cyclists have their back to oncoming buses should be avoided.

The LOOK LEFT (OR RIGHT) FOR BUSES warning sign, with supplementary tab, is to be used at transit exchanges where buses cross pedestrian crosswalks to alert pedestrians of the direction from which buses will be coming. This sign is included in Section 6.2.2. Figure 4.2.14 illustrates a pedestrian crossing within a bus exchange.

Warning signs, such as the CYCLISTS YIELD TO PEDESTRIANS warning sign can also be used at transit exchanges to alert cyclists of pedestrian and bus traffic. Figure 4.2.15 illustrates the CYCLISTS YIELD TO PEDESTRIANS warning sign at Nanaimo Station.

Figure 4.2.13 Pedestrian and cyclist crossing within a transit exchange



When designing bike crossings at transit exchanges, the design team should refer to the TAC's *Bikeway Traffic Control Guidelines for Canada* to determine how crossings should be designed for different geometric configurations. As per the TAC's *Manual of Uniform Traffic Control Devices for Canada* (MUTCD), green is the optional color surface treatment for a bike facility. Anti-skid treatments should always be used on cycling facility pavements.

For determination of pedestrian sight distance, please refer to Section 2.6.

Figure 4.2.14 Example of pedestrian crossing within a transit exchange at Coquitlam Central Station

Figure 4.2.15 Example of cyclist yield sign at Nanaimo Station

4.2.6 PASSENGER ACCESS, BOARDING AND ALIGHTING ACTIVITIES

Walkways within a transit exchange and connections to the peripheral pedestrian network are important elements in transit exchange design. The alignment of walkways should be as direct as possible. The required walkway width may be determined on the basis of the expected peak pedestrian volumes and the design capacity or service level of the walkway.

The design capacity of a walkway is the maximum volume of pedestrians that can pass through safely per unit walkway width in both directions. Pedestrian flow is normally expressed in LOS, ranging from A (for good conditions) to F (for poor conditions).

Using Figure 4.2.16, the effective walkway width (WE) can be determined on the basis of the expected pedestrian flow rate, if it is known. The design pedestrian volume should be based on the peak 15 minute period when the maximum pedestrian flow rate occurs. A LOS C is typically used for design purposes.

It should be noted that the LOS analysis only considers the WE. Additional width is required on both sides of the walkway if there are lateral restrictions. Figure 4.2.17 shows the additional walkway width required under various conditions.

TAC's GDG, Section 6.3.1.2 recommends a range of widths depending on peak pedestrian flow rate. A range of 1.8 m to 2.0 m is recommended if pedestrian volume is less than 400 pedestrians in the peak 15 minutes. The lower end of this range provides a reasonable width for two pedestrians or wheelchairs to pass, and also provides sufficient space for wheelchair users to make a 180 degree turn. If pedestrian volume exceeds 400 pedestrians in the peak 15 minutes, the recommended width is typically greater than 2.0 m to provide increased capacity and maneuvering space.

Figure 4.2.16 Relationship between pedestrian flow rate and effective walkway width

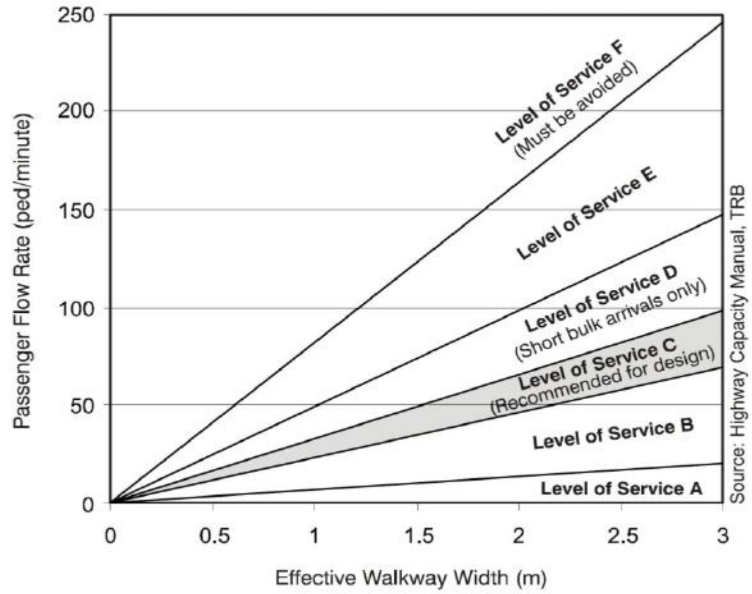
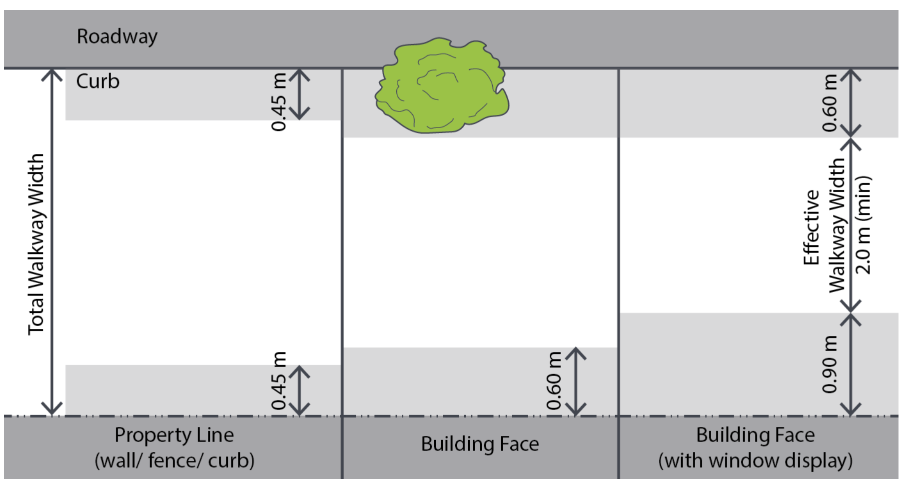


Figure 4.2.17 Effective (WE) and total (WT) walkway widths



For passenger queuing areas where customers stand while waiting for a bus, the preferred service level is LOS B, with an average space of 0.9 to 1.2 m^2 per person, as discussed in Section 3.5.

Other considerations for pedestrian circulation and queuing should include:

- If pedestrian flows are heavy (LOS E or worse) but relatively balanced in both directions, the efficiency of the walkway may be improved by splitting the pedestrian flows with a directional dividing line or barrier;
- Maintaining sufficient walkway width minimizes the need for customers to walk through passenger queuing areas;

- Maintaining sufficient passenger queuing area minimizes the occurrence of queues extending into walkway areas, which may impede customer circulation;
- Queuing accommodations at bus stops with large volumes of customers require special review by TransLink/CMBC regarding proper measure to organize queues;
- In situations where heavy boarding and alighting activity is anticipated on a particular route, separate passenger loading and unloading areas may be considered to minimize customer conflicts and reduce dwell times. This will, in particular, avoid the concentration of customer movements on the loading platform. This separation takes advantage of the ability to unload customers faster than the rate at which they generally can board; and
- The location of weather protection could also affect the queuing of customers. As much as possible, weather protection should be provided at the intended queuing area rather than in or near the circulation area.

4.2.7 LIGHTING LEVELS

4.2.7.1 Lighting Design Criteria

Lighting at transit exchanges and bus stops is intended to provide a safe environment on-site while limiting lighting impacts off-site. This can be accomplished by not over-lighting and by selecting energy efficient luminaries with a suitable optics mounted at suitable heights.

Lighting should typically be controlled using photocells. In areas where a facility has no activity during hours of darkness, it may be desirable to shut off or dim lighting.

4.2.7.2 Is a Lighting Specialist Required?

For simple bus stops, night-time conditions should be considered, but standard street lighting conditions may be acceptable. Since bus stops are associated with increased pedestrian activity, lighting at pedestrian crossing locations should be reviewed.

At transit exchanges or more complicated locations, the assistance of a lighting professional is required. The criteria and standards discussed below provide a starting point for making this decision.

4.2.7.3 Lighting Levels

The TAC's *Guide for the Design of Roadway Lighting (RLG)* and the Illuminating Engineering Society of North America's (IES) *The Lighting Handbook* are recommended references. Currently, the TAC's RLG is being revised and the updated version will include lighting criteria specifically for transit facilities. The lighting criteria suggested in Table 4.2.2 below are based on related applications identified in the current reference documents. Design teams should use the latest lighting requirement for bus exchange design when the updated RLG from TAC becomes available.

Lighting designers are requested to use:

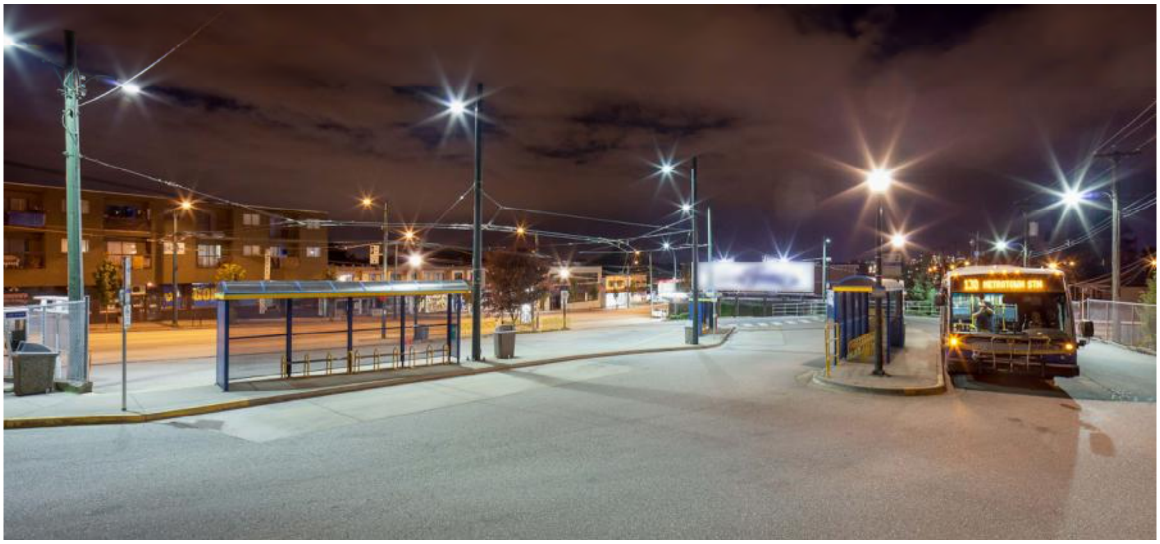
- Illuminance as the primary method of calculation, and a grid spacing of 2 m;
- Light loss factor of 0.6 or less unless the designer can justify a higher factor;
- Luminaires with IES full cut-off optics to improve visibility and reduce off-site impacts; and
- "White light" source or high pressure sodium sources for rural applications (with a light loss factor of 0.72).

Lighting levels for specific elements of Transit Passenger-Pick-Up and Drop-Off Facilities, Transit Exchanges, and Transit Park and Rides are suggested in Table 4.2.2. Figure 4.2.18 shows an example of a well-lit transit exchange.

Table 4.2.2 Typical lighting levels based on pedestrian conflicts

Area	Maintained Average Horizontal Illuminance	Uniformity Ratio (Average: Minimum)	Maintained Average Vertical Illuminance	Reference
Bus Loading/ Unloading Bays and Bus Stops, including waiting areas	15 – 40 Lux	3:1	10 – 20 Lux	TAC's RLG *(*Appendix A) and IES Table 36.2 (Aviation Terminal Bus Pickup/Drop-off). Levels based on those for an arterial roadway or intersection with high pedestrian activity. The higher end of the range applies to higher activity.
Bus Layover Areas	10 – 20 Lux	3:1	n/a	TAC's RLG *(*Appendix A). Levels based on those for an arterial roadway or intersection with low pedestrian activity.
Crosswalks	20 – 40 Lux	3:1	40 Lux	TAC's RLG*,* Chapter 12 (Mid- Block Crosswalks). Levels based on a high pedestrian activity.
Parking Areas	10 Lux	5:1	n/a	TAC's RLG*,* Chapter 16 (Off-Roadway Facilities – Table 16-4). Levels based on a "Basic Parking Lot Illumination Level". Where public security is a concern, or CCTV cameras are required or present, consider "Enhanced" levels of 25 Lux.
Bus Shelters (within the shelter footprint)	10-20 Lux	3:1	n/a	IES's *The Lighting Handbook* Table 4.1 (Recommended Illuminance Targets, Categories F, G, & H, 25-65). Where no power is available, solar power can be considered.

Figure 4.2.18 Kootenay Loop evening lighting level



4.2.8 CONSIDERATIONS FOR COVERED FACILITIES

For off-street facilities that are covered, there are additional considerations for the accommodation of transit vehicles:

- Minimum vertical clearances are 4.5 m for a non-trolley bus facility and 5.8 m for a facility that needs to accommodate for trolley buses.
- Facility must accommodate the minimum width sufficient to accommodate the intended bus travel (one-way or two-way).
- The maximum ramp grade is generally 8%; steeper ramps should be discussed with Transit Centre staff.
- A staging lane (one additional lane width along ramp section) may be required with a long ramp.
- Maximum grade change is 5%, considering the worst case condition of a bus being towed. Refer to Section 2.4.2 for the grade change requirements.
- A clear level area must be provided immediately beyond the top and bottom of a ramp to avoid the need for a bus to stop entirely or partly on the ramp.
- Clear signage may be needed to indicate that access to the underground facility is reserved for buses and authorized vehicles only. The use of security gates may be considered.
- Lighting level should minimize contrast/glare for bus drivers as they enter and exit an underground facility.
- Special design considerations should be given if a covered facility will be used by CNG vehicles, as per Section 1.2.2.

The principles related to the design of customer circulation, boarding, and alighting activities described earlier in Section 4.2.5 also apply to underground facilities or facilities under a roof structure. Additional customer considerations related to an underground facility may include:

- Ventilation/Heating;
- Acoustics;
- Lighting;
- Security;
- Aesthetic experience; and
- Environmental considerations, including oil-water separators.

Refer to TransLink's *Transit Passenger Facility Design Guidelines* for more detail. An example of a covered facility can be seen in Figure 4.2.19.

Figure 4.2.19 New Westminster Transit Exchange covered facility

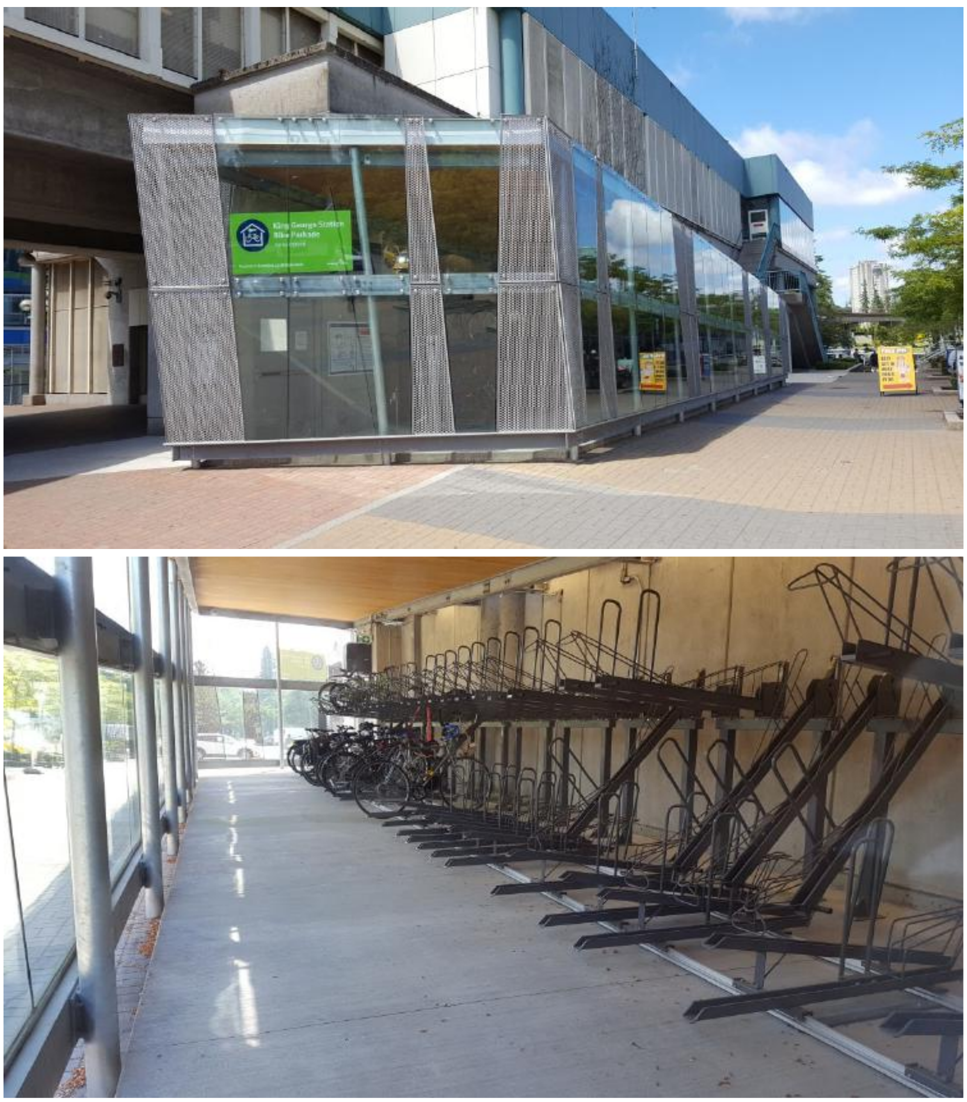
4.2.9 BIKE PARKING AT TRANSIT FACILITIES

When designing a new transit facility, the design team should consult with TransLink staff regarding bike parking facility requirements. Currently, three types of bike parking are available at SkyTrain stations, bus exchanges, and West Coast Express stations throughout Metro Vancouver, and are described below. Examples of a bike parkade, bike locker, and bike rack can be seen in Figure 4.2.20, Figure 4.2.21, and Figure 4.2.22, respectively.

Bike Parkades

- Secure, weather protected storage for the mass storage of bicycles;
- Facility is fee based, available for daily or monthly bike parking;
- TransLink employs a third-party contractor to manage the user fee payment and user access to the bike parkade;
- Minimum bike parkade size accommodates 50 bike parking spaces; and
- Bike parkades can be found at select Skytrain stations, such as Main Street–Science World Station and King George Station.

Figure 4.2.20 King George Station bike parkade



Bike Lockers

- Secure, weather protected storage for bikes and cycling accessories;
- Facility requires users to subscribe to a minimum rental period;
- TransLink employs a third-party contractor to manage the bike locker program;
- Minimum of 3 bike lockers provided to accommodate 6 bike parking spaces; and
- Bike lockers can be found at most SkyTrain stations, some bus exchanges, and some West Coast Express stations.

Figure 4.2.21 Production Way/University Station bike lockers

Bike Racks

- Unsecure, unprotected bike racks for short term parking that meet TransLink's requirements;
- Facility is free of charge for users;
- Minimum number of approved TransLink bike racks to accommodate 10 bike parking spaces, with additional bike racks provided in locations where higher demand is expected; and
- Bike racks can be found at most SkyTrain stations and most bus exchanges.

Figure 4.2.22 Burquitlam Station bike racks

Bike parking facilities should be located in places that minimize conflicts between bikes, buses, and pedestrians. For increased security, bike parking facilities should also be located in places that maximize "eyes on the street", such as adjacent to operator washrooms, retail units, or in other busy and highly visible locations.

Refer to TransLink's *Bicycle Parking Guidelines for Transit Infrastructure* for further details regarding bike parking facility requirements.

4.2.10 Additional Transit Facility Amenities

Passenger activity at a typical transit exchange is considerably larger than of an on-street bus stop. As such, additional customer amenities to those identified in Section 3.5 may be provided to improve passenger experience and the facility environment, as shown in Figure 4.2.23. Refer to TransLink's *Bus Facility Furniture Standards and Guidelines* for details on the design and implementation of these elements at bus exchanges and station plazas.

Litter Receptacle

- Centralized receptacle for garbage, newspaper recycling, and can recycling;
- Provided at all bus and SkyTrain facilities where CMBC and/or BCRTC manage the maintenance of the public realm;
- Should be placed along main circulation paths of a bus exchange or rail station;
- Should be placed so as to not impede passenger queueing and circulation;
- Supplemental garbage receptacles should be placed at bus ID poles throughout a bus exchange; and
- Supplemental litter receptacles should be provided if facility is large enough to result in long walking distances from the centralized litter receptacle.

Newspaper Corrals

- Centralized enclosed corral for several newspaper boxes;
- Provided in bus and SkyTrain facilities where TransLink Commercial Programs & Partnerships determines there is adequate demand from passengers and newspaper suppliers;
- Advertising on outer walls of corral incorporated where viable and in accordance with the Advertising section below;
- Should be placed within the sightline of passengers approaching a station or bus boarding area; and
- Should be placed so as to not create visual clutter or impede passenger queueing and circulation.

Wayfinding

- Provided at all bus and SkyTrain facilities;
- Should be consistent with TransLink's *Wayfinding Standards Manual*;
- T-Markers make exchanges visible in urban landscapes and should be in the line of sight for major approaches;
- Exchange circulation signage should both orient users at a facility and assist in planning the next stages of their journey:
  - Facility information directs people to relevant bus bays or to major streets;
  - Journey planning information should be provided on a two-sided freestanding information wall or along the wall of a structure;
  - Should be placed so as to be visible to customers and to not impede passenger queueing and circulation;
- Bus stop signage:
  - Distinct ID signs make bus stops visible from a distance;
  - Provides route and other customer information from closer up;
- Bus shelter maps assist users in planning the next stages of their journey:
  - Map cases affixed to back or side of shelter, facing inward, preferably beside the bench; and
  - If accessible, an additional map case should be affixed to the back of the shelter for additional customer benefit and to cover up the back of the front-facing case.

Advertising

- Provided at bus and SkyTrain facilities where TransLink Commercial Programs & Partnerships determines there are viable advertising opportunities;
- Should be consistent with TransLink's Advertising Policy;
- Should be designed and placed so as to not impede passenger circulation and sightlines, or crime prevention through environmental design;
- Should be placed on opaque surfaces to maintain transparency function of glazed surfaces;
- Should be located where it does not contravene other advertising agreements, such as municipal contracts;
- Should be located where it does not impede or displace wayfinding signage; and
- Placement should be coordinated with public art.

Public Art

- Provided at bus and SkyTrain facilities in accordance to TransLink's current public art policy; and
- Should be designed and placed so as to not impede passenger circulation and sightlines.

Figure 4.2.23 Scott Road Station Transit Exchange amenities

4.3 Park-and-Ride Lots

TransLink developed a policy for park-and-ride facilities in 2012. This section describes general considerations and parameters for a park-and-ride facility, which generally includes a transit exchange or station, vehicle parking, bicycle parking, and passenger pickup and drop-off areas.

4.3.1 General Considerations

The location and capacity of a park-and-ride lot is governed by the nature of the transit service and regional transportation objectives. There are several general considerations for the design of a park-and-ride facility:

- Design should optimize the efficiency of routing to and from the park-and-ride;
- The park-and-ride should be located upstream of any "bottleneck" or other source of delay;
- Auto, transit, and bicycle accesses should be segregated;
- Parking should be located in close proximity to the transit exchange or station. Motor vehicle parking should generally be within about 400m, and bicycles as close as possible;
- Bus/HOV lanes or other transit priority measures that allow buses to bypass congestion should be planned in the vicinity of the park-and-ride;
- Consideration should be given to providing dedicated priority parking for carpool vehicles;
- Pedestrian connections between the parking areas and the transit exchange should be safe and direct; and
- Wayfinding signage may be provided.

4.3.2 Layout and Design Parameters

The design of a park-and-ride should include the following parameters:

- Arrival and departure characteristics and access routes of park-and-ride users;
- Required number of vehicular access points;
- Traffic control method at the access intersections;
- Traffic conditions of the adjacent road network;
- Storage length available at the access points between the roadway and parking aisles;
- Bicycle access routes, access points, and circulation to minimize conflicts with other modes;
- Locations of bicycle parkades, lockers, or racks;

- Pedestrian walkways to/from transit pickup and drop-off points; and
- Passenger drop-off and pick-up area (if they share the same facility).

The required number of access points is normally determined first. This depends on the number of parking stalls provided, the traffic control method at the access intersections, and the forecast peak inbound/outbound traffic volumes. The width of the access driveway depends on the required number of entry and exit lanes based on capacity and movement considerations. Typically, the desirable width for the access driveway is 8.5 m for a 2-lane access and 11.0 m for a 3-lane access.

To maintain efficient traffic circulation within the park-and-ride lot, the magazine length (i.e., conflict-free queuing distance) at the access driveway should be long enough to accommodate the expected maximum queue on the exit approach.

Stalls for persons using wheelchairs should be provided in accordance with the requirements of TransLink's *Universal Accessibility Guidelines for Transportation Facilities* and of the municipality in which the Park-and-Ride is located (often found in municipal zoning bylaws). An example of accessible parking stalls is shown in Figure 4.3.1.

Figure 4.3.1 Coquitlam Station Accessible Parking Stalls

Figure 4.3.2 shows an example of design layout that accommodates 481 parking stalls with two vehicular access points. Pedestrian connections between the parking lot and the adjoining transit exchange are provided at two locations, with minimum conflicts with buses and other road traffic. Pedestrian crossings should be provided along desire lines, where safe. Measures such as planters or custom fences can be used to channel pedestrians to safe crossing locations where necessary.

Figure 4.3.2 Carvolth Transit Exchange Park and Ride

4.4 PASSENGER-PICKUP AND DROP-OFF FACILITIES

TransLink currently has no formal policy guiding the provision of passenger pickup and drop-off (PPUDO) spaces. However, PPUDO facilities (also known as “kiss and ride” facilities) should be incorporated into station and bus exchange design to accommodate customers arriving and departing by this mode, to address possible neighborhood impacts, and to ensure that transit operations are not compromised by private vehicles using bus stops as pickup or drop-off spaces. Considerations should be given to providing dedicated taxi stands where demand warrants. Refer to **Appendix H** for an example on estimating the required PPUDO spaces at a facility.

4.4.1 GENERAL CONSIDERATIONS

The location and capacity of a PPUDO facility is governed by the transit services available and the surrounding land uses. There are several general considerations for the design of a PPUDO facility:

- Design should optimize the efficiency of routing to and from the PPUDO, otherwise, transit customers will likely be dropped off or picked up at locations that are more convenient to the driver, creating potential conflicts and/or congestion;
- Availability and cost of alternatives, including:
    - Cost and availability of nearby all-day parking opportunities, including Park-and-Ride lots;
    - Surrounding and connecting bike facilities, availability of secure bike parking, and policies allowing bikes on transit;
    - The cost of driving (e.g., fuel and tolls);

- Catchment area land-use, density, and size (catchment area should *not* include the area within walking distance of the station/exchange); and

- Prevent crime by designing usable, active, and secure facilities for day and night use.

4.4.2 Layout and Design Parameters

The design of a PPUDO facility should include the following parameters:

- The number of PPUDO spaces needed may be estimated on the basis of the hourly pickup and drop-off vehicle flow rates and the average drop-off and pickup times (accumulation);

- Drop-off locations should be as close as possible to the transit service entrance, while pickup locations may be located further away, but no further than one street-crossing;

- Peak arrival/departure rates of connecting transit/rail service;

- Efficient connections to and from transit services;

- Minimize potential conflicts between PPUDO, transit, pedestrian, and bicycle access routes;

- Signage to clearly indicate the spaces are for PPUDO use only and have a maximum time limit;

    - A 5-minute parking limit will typically accommodate 80 percent of waiting drivers (see Section 6.2.1 for sign sample); and

- Oil-water separators installed to mitigate environmental impacts.

Refer to the TransLink's *Transit Passenger Facility Design Guidelines* for more information.

4.4.3 PPUDO Demand

Based on traffic surveys conducted at select stations on the Expo SkyTrain line, PPUDO peak hour demand to/from stations can be characterized as shown in Table 4.4.1. The volumes and characteristics of SkyTrain ridership at these stations are key parameters in estimating the PPUDO demand. The number of spaces allocated for PPUDO should be actively managed in response to demand.

Table 4.4.1 Observed PPUDO demand at SkyTrain stations

Parameters	Peak Hour	SkyTrain Station
PPUDO Customer Demand (% of total peak hour ridership)	AM	10%
	PM	5-10%
PPUDO Vehicle Occupancy Rate (customers per vehicle, excluding driver)	AM	1.05
	PM	1.15
PPUDO Pickup Vehicle Demand (% of total PPUDO vehicles picking up customers (no drop-off)	AM	15%
	PM	50-80%

CHAPTER 5. TRANSIT PRIORITY MEASURES

5.1 INTRODUCTION

Traffic congestion and environmental pollution have become important issues to be resolved within Metro Vancouver. Since buses carry more passengers than other vehicles in relation to their use of road space, the efficiency of the transportation system as a whole can often be improved by giving priority to buses over other vehicles for the use of limited road space. The application of transit priority measures has become more popular in Metro Vancouver.

The purposes of transit priority measures are (i) to maximize the 'people carrying' capacity of the road system and (ii) to minimize overall person travel times. As priorities are given to buses, other traffic may incur additional delay or inconvenience. Hence, it is also important to maintain a reasonable balance in the design so that the overall service level is acceptable to both bus and other road users, and that an overall net gain is achieved in the performance of the road system. A test for the reasonableness of transit priorities is that the combined auto and transit passenger volumes in the direction(s) and for the time period(s) will not be reduced below the existing level. Another criterion is that the total person-delay will be reduced.

5.2 TYPES OF PRIORITY MEASURES

There are three categories of transit priority measures:

- Lane Reservations – involving the reservation of road space exclusively for public transit vehicles (e.g., bus lanes, queue jumper lanes, etc.);
- Traffic Control Measures – giving public transit vehicles preferential treatment in the general traffic flow (e.g., transit signal priority, bus only signals, etc.); and
- Legislative and Regulatory Measures – priorities resulting from traffic regulations, national and local acts, and rules of the road by convention (e.g., priority to buses leaving stops, turn exemptions, etc.).

5.2.1 LANE RESERVATIONS

The reservation of road space to provide priority for public transit vehicles can take several forms, from queue jumper lanes to exclusive bus lanes, as discussed below.

5.2.1.1 Exclusive Bus Lanes (Curbside or Median)

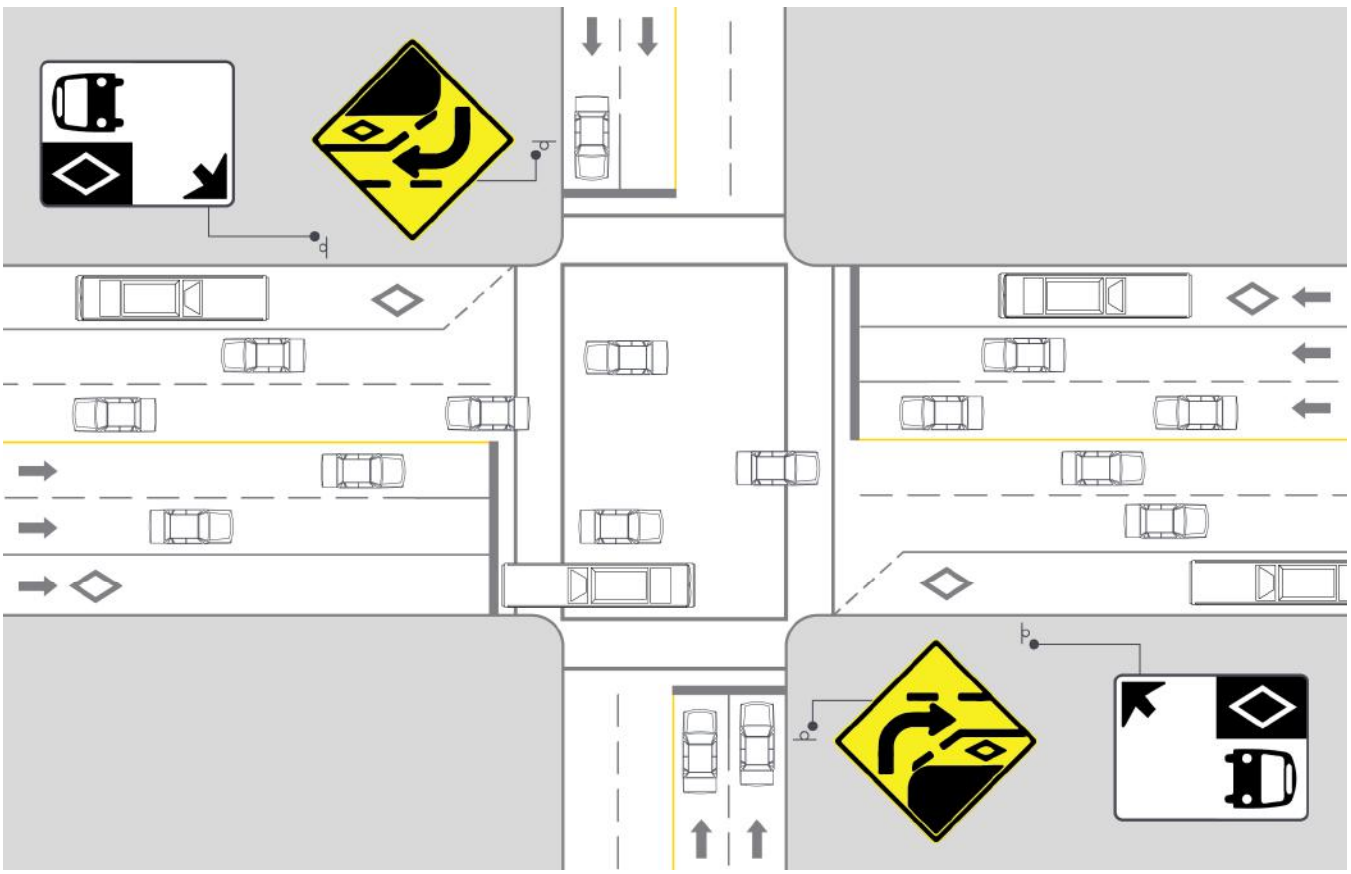
Typically, exclusive bus lanes cover long travel distances that allow transit vehicles to bypass congested travel lanes. They are provided either in the curb or median lane and can be in effect full time or during peak periods only. The design of an exclusive bus lane is dependent upon several factors:

- Availability of adequate right-of-way;
- Roadway geometric alignment;

- Cross street access and access to adjacent developments;
- Traffic volumes; and
- Bus operating speeds.

Figure 5.2.1 shows the layout of a curbside bus lane, while Figure 5.2.2 shows an example of a bus-only lane. The recommended minimum lane width for a curb bus lane on city streets is 3.3m. When a curb parking lane is converted to exclusive bus use, it may be necessary to flatten out the street crowns at cross streets to avoid the "roller-coaster" effect that occurs when traveling on the curb lane. Physical obstructions, such as utility poles and signs, should also be set back far enough from the curb to allow space for vehicle "tilt" on high crowned roadway sections. When right-turn movements are allowed at intersections, the bus lane should be set back far enough from the stop bar to provide the required right-turn capacity. In locations where right-turn and conflicting pedestrian volumes are high, an advanced right-turn arrow should be considered to minimize the bus delay on the bus lane.

Figure 5.2.1 Bus lane typical layout



For a median bus lane (or busway), the minimum lane width for bus operation on city streets is 4.0 m where design speed is greater than 60 km/h and 3.7 m to 4.0 m where design speed is equal to or less than 60 km/h. Median bus lanes are normally controlled by traffic signal phasing designated for 'with-flow' through traffic.

When a bus lane is provided independent of the normal street network, such as in Park-and-Ride facilities, the preferred minimum lane width is 3.7 m for a single lane and 7.0 m for two lanes in two-way operation.

For operational efficiency and safety reasons, a bus lane should not be less than 3.3 m in width if it is adjacent to a bike lane (also see the TAC's GDG, Table 5.3.7 for shared traffic/bicycle lane widths).

Figure 5.2.2 Example of bus-only lane (West Georgia Street)

5.2.1.2 Bus-Only Streets

Bus-only streets (or transit malls) are entirely reserved for public transit use. A bus-only street is normally restricted to transit, pedestrians, bicycles, taxis, loading/unloading vehicles, and emergency vehicles. In designing a bus-only street, special attention should be given to property access requirements on both sides of the bus-only street, such as loading/unloading and parking needs. An example is the Granville Mall in downtown Vancouver, at which loading activities are accommodated in the commercial lanes or by allowing vehicles to load on the wide sidewalks. Figure 5.2.3 shows the layout of a bus-only street, while Figure 5.2.4 shows an example of a bus-only street.

Figure 5.2.3 Bus-only street typical layout

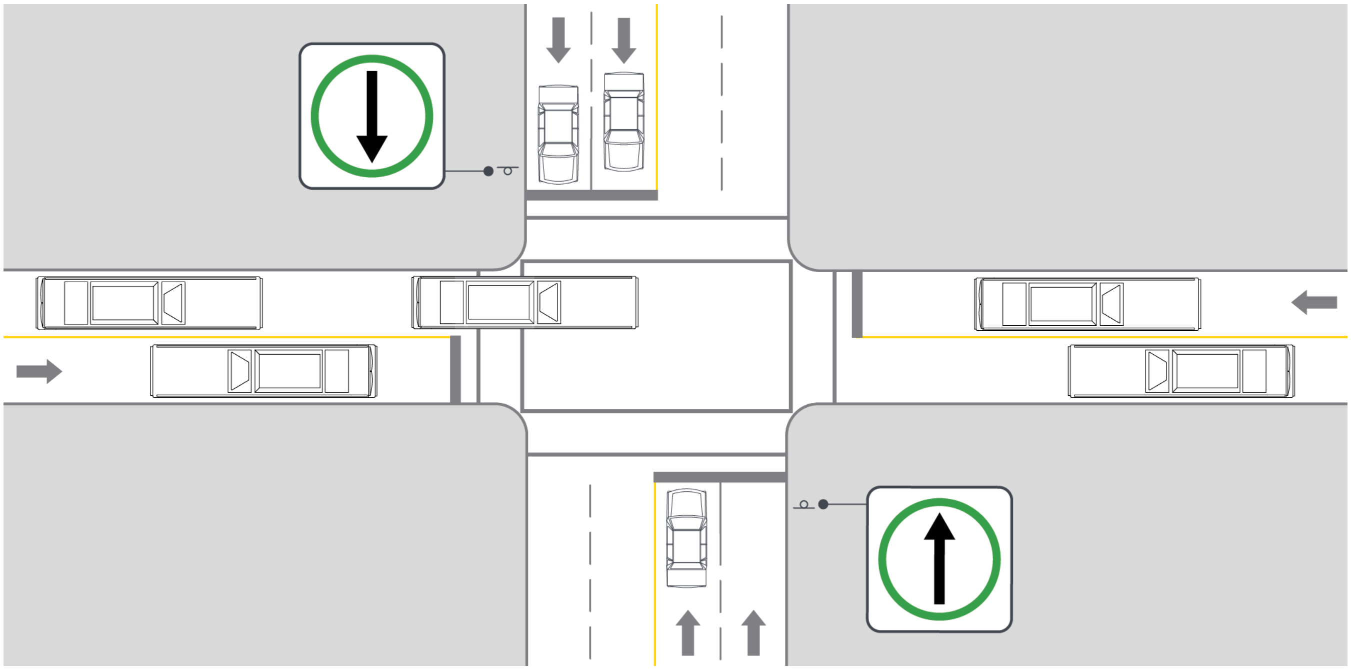


Figure 5.2.4 Example of bus-only street (Granville Street)

5.2.1.3 Queue Jumper Lanes

A queue jumper lane refers to a special lane for transit buses to bypass the general traffic queue, usually at a location where queues frequently form. In designing a queue jumper lane, it is important to ensure that the entry to the lane is not blocked by the traffic queue in the adjacent travel lane and that it is long enough to accommodate the expected bus volumes. In some cases, a queue jumper is provided for transit vehicles through the regulation of “Right Turn Only Except Buses” on an exclusive right-turn lane to transit vehicles to continue through the intersection.

A queue jumper lane at an intersection can be facilitated by a bus-only traffic signal phase (for example, a bus-activated phase) so that buses using the queue jumper lane can leave the queue jumper lane safely and access the travel lane on the far side of the intersection ahead of other traffic. Sufficient intersection clearance time is required for the bus to clear the intersection before the conflicting traffic signal turns green. The green times available to other traffic may be slightly reduced. However, a net gain in system performance can often be achieved where the reduction in total bus passenger delay is greater than the increased delay to other road users. Figure 5.2.5 shows the layout of a queue jumper lane, while Figure 5.2.6 shows an example of a bus queue jumper lane.

The recommended minimum lane width for a queue jumper lane on city streets is 3.3 m.

Figure 5.2.5 Queue jumper lane typical intersection layout

Figure 5.2.6 Example of bus queue jumper lane (King George Boulevard at 88 Avenue)

5.2.1.4 High Occupancy Vehicle Lanes

High Occupancy Vehicle (HOV) lanes are used by carpools, vanpools, and buses. These lanes may be newly constructed lanes on expressways or freeways, or converted from parking lanes on arterial streets. They may be in effect on a full-time or peak-period-only basis. HOV lanes are considered at locations where exclusive bus lanes are not justified. Similar to exclusive bus lanes, HOV lanes allow more people rather than more vehicles to be carried on the roadways.

The determination of the minimum number of occupants in the HOV lane depends on the ultimate goal of reducing the volume of road traffic, the intended service level of the HOV lane and the safety needs of motorists. HOV lanes are normally limited to vehicles with 2+ or 3+ occupants. The minimum width for a HOV lane should be 3.3 m, as per the TAC's GDG.

For operational efficiency and safety reasons, an HOV lane should not be less than 3.3 m in width if it is adjacent to a bike lane (see the TAC's GDG, Table 5.3.7 for shared traffic/bicycle lane widths). Figure 5.2.7 shows the layout of an HOV lane, while Figure 5.2.8 shows an example of an HOV lane.

Figure 5.2.7 HOV lane typical layout

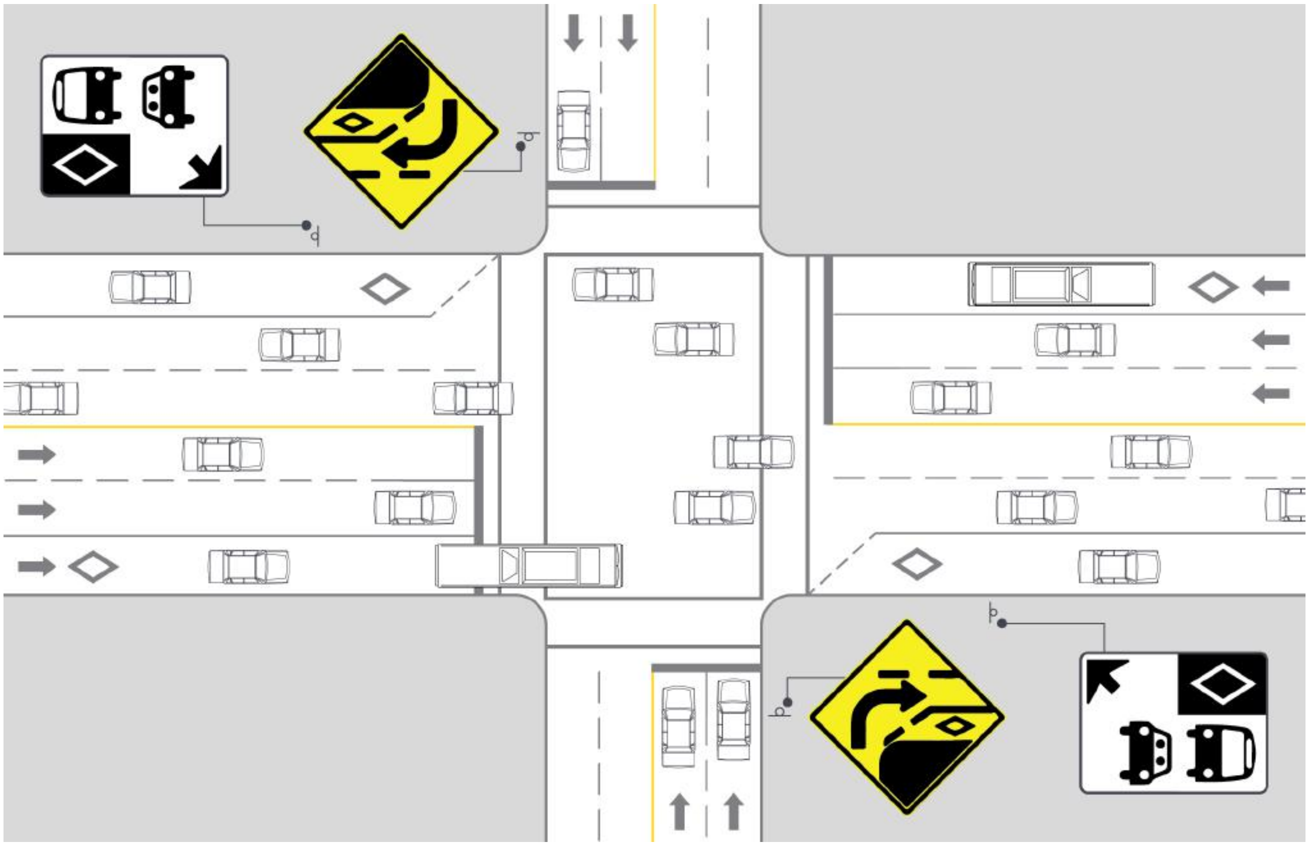


Figure 5.2.8 Example of HOV lane (Highway 1 at 202 Street)

5.2.2 TRAFFIC CONTROL MEASURES

Traffic control measures are used to give transit preferential treatment in the general traffic flow through traffic management schemes. Various forms of traffic control measures are illustrated in the following sub-sections, including:

- Bus-only signals;
- Bus-actuated signals; and
- Transit signal priority.

5.2.2.1 Bus-Only Signals

Bus-only signals are typically used in conjunction with a bus lane (or a queue jumper lane) on the near-side of the intersection. Under this type of transit priority treatment, buses are given an exclusive traffic signal phase (i.e. protected movement) to clear a congested intersection ahead of the main traffic stream.

One example of a bus only signal is a bus-only left-turn turn signal that may be used to allow a bus to make an otherwise prohibited left-turn movement or to make a protected left-turn movement to ensure the bus progresses through an intersection. This left-turn may be from a left-turn lane or could be provided ahead of vehicular traffic to allow a bus to make a left-turn from the curbside lane.

Another example of a bus-only signal is a bus queue jumper signal which, used in conjunction with a queue bypass lane at the intersection approach, allows buses to call for an early green phase that starts ahead of the vehicle green phase. This exclusive early green allows buses to proceed into the intersection and merge back into a mixed-flow traffic lane with no conflict prior to the vehicular traffic proceeding through the intersection. In cases with a farside bus stop, the transit vehicle is able to reach the farside stop more quickly and provide service to the stop ahead of vehicle queues.

At locations where there is no travel lane to receive the bus in the farside of the intersection, a bus-only signal phase is used to allow transit buses to pull out of a queue jumper lane (or a bus lane) and then enter the regular travel lane safely and ahead of other vehicles.

Figure 5.2.9 shows the layout of an intersection with a bus-only signal, while Figure 5.2.10 shows an example of a bus-only signal.

Figure 5.2.9 Bus-only signal phase typical intersection layout

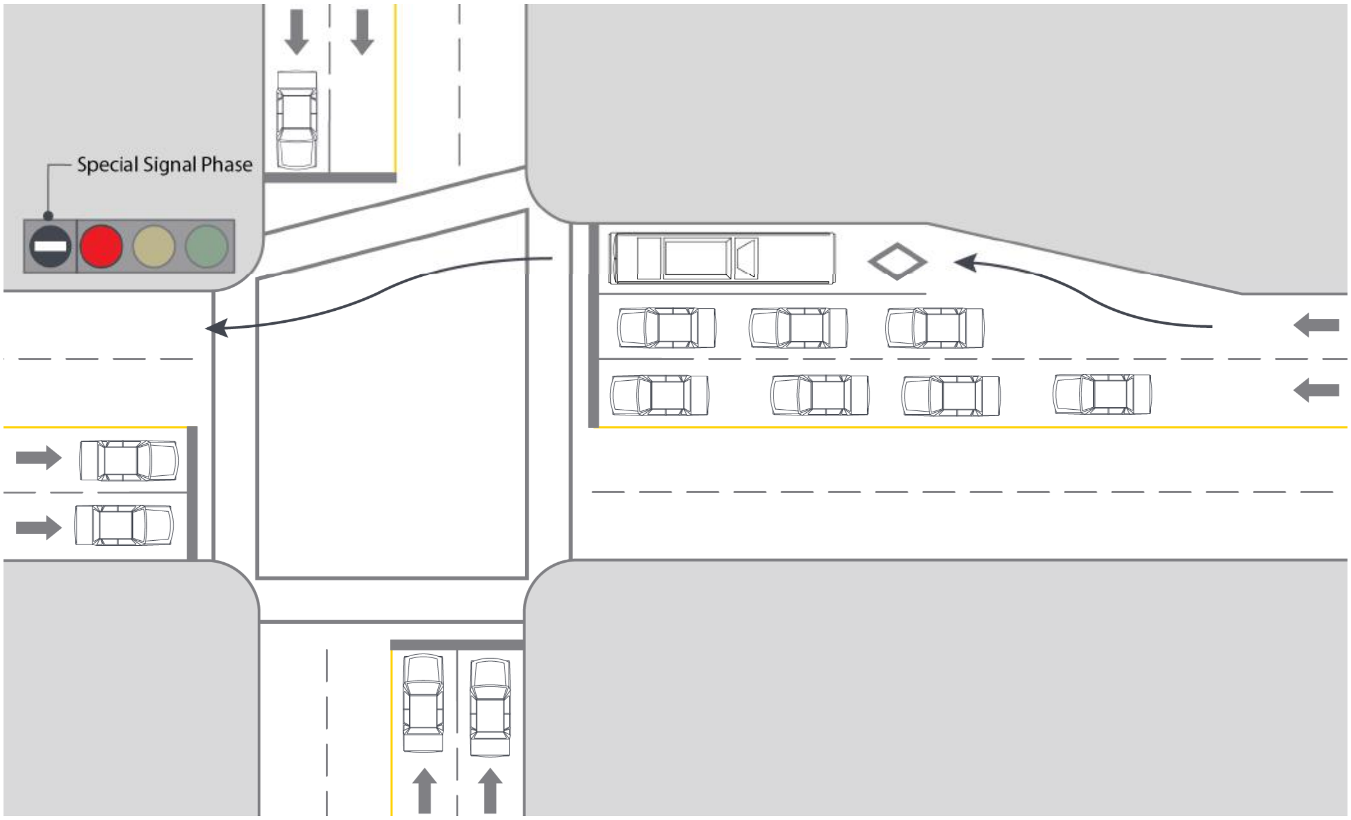
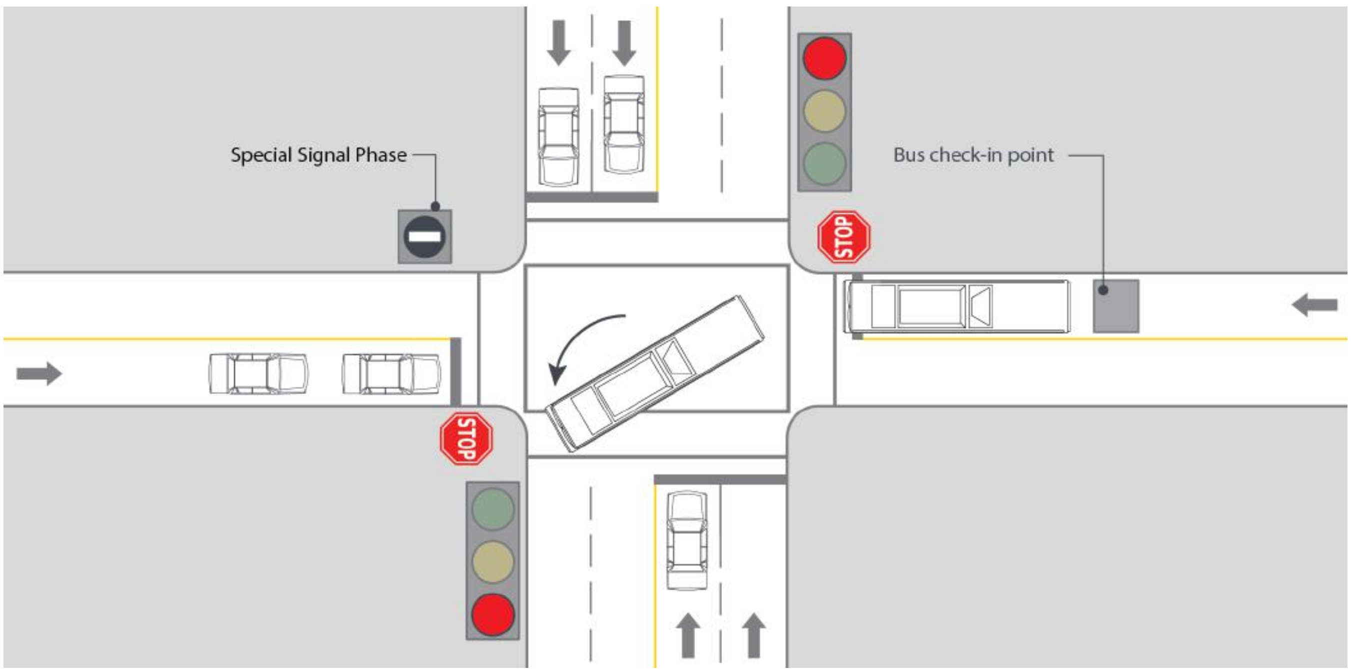


Figure 5.2.10 Bus priority signal at Lougheed Highway and Holdom Avenue

5.2.2.2 Bus-Actuated Signals

Priority for transit buses turning onto a major street from a minor street can be provided through traffic signals that can only be actuated by buses. The actuation may be achieved by physical loop detectors, video detectors way-side, or wireless detectors that communicate with a transmitter on the buses. When the presence of an approaching bus is detected, a special protected signal phase is provided allowing the transit bus to proceed safely through the intersection. This phase may or may not be associated with a pedestrian walk phase. Typically, the minor street operates under a "stop sign" control when no bus is detected. Figure 5.2.11 shows the layout of an intersection with bus-actuated signals.

Figure 5.2.11 Bus-actuated signal typical intersection layout



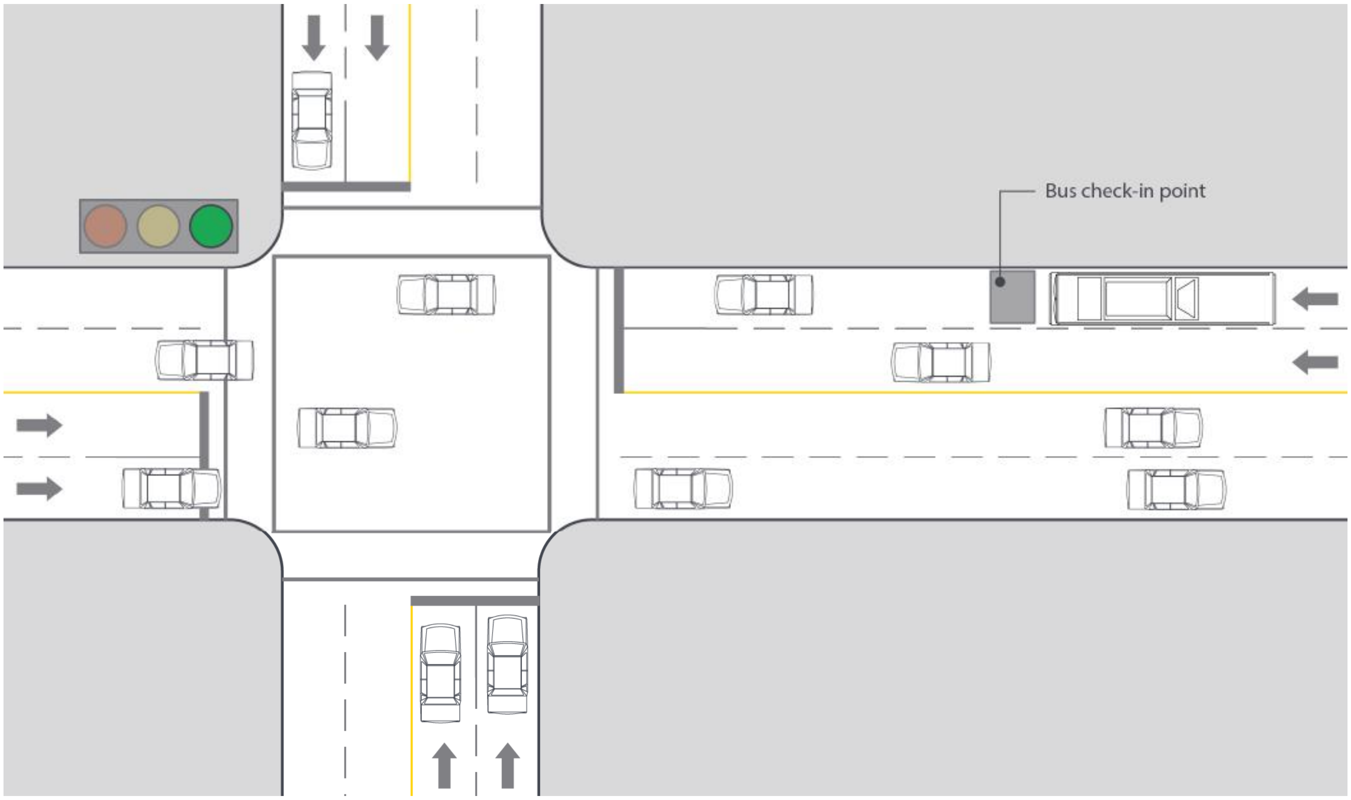
5.2.2.3 Transit Signal Priority

Transit signal priority (TSP) is an operational treatment that assists transit vehicles through signalized intersections through Passive (non-bus-activated) or Active (bus-activated) measures. TSP measures have been implemented in the past for various routes across the region, but have since fallen out of common usage in recent years. Figure 5.2.12 shows the layout of an intersection with transit signal priority.

Passive TSP involves re-optimization of signal timing and adjustment of phases, splits, and /or off-sets to provide a green band that reflects the travel time of buses along the transit corridor. This is a passive measure because the optimized signal timings will be there regardless of the presence of the bus.

Active TSP is more involved and based on the presence of transit vehicles. Priority is provided only when a bus is detected on an intersection approach. Priority is then given to the bus through one of three methods:

Figure 5.2.12 Transit signal priority typical intersection layout



1) For buses approaching the intersection during a green interval, the green time for that approach will be extended to allow the bus to proceed through the intersection prior to the amber phase. This is often referred to as "green extension".

2) For buses approaching the intersection during the red interval, the green time for the other phases is reduced to provide an earlier green to a bus approaching the intersection on the red interval. This is typically referred to as "red truncation".

3) Pre-emption is the most disruptive form of TSP as it immediately provides a green phase to the bus when the bus is detected approaching an intersection. Pre-emption takes signals out of their coordination plan and it often takes multiple cycles for the intersection to recover and return to coordinated operations. Pre-emption is generally reserved for emergency vehicles but has been implemented in various locations to accommodate transit lines, typically to service light rail transit, and is still considered an alternative TSP measure.

Two types of active priority exist as well:

1) Unconditional TSP: Unconditional priority is provided whenever a bus is present, regardless of the status of the bus. Typically, there are limits to the priority (i.e. not pre-emption). For example, buses may be granted priority up to a specific amount of green extension time.

2) Conditional TSP: Conditional priority is provided only under pre-defined terms, often based on parameters such as the lateness of the bus, number of customers, or other pre-determined parameters.

5.2.3 LEGISLATIVE AND REGULATORY MEASURES

Various legislative and regulatory measures can be applied to provide transit priority. The major forms include:

- Exemptions from prohibited or forced turns: Exemptions from turns that general traffic are prohibited from making or forced turns (i.e. designated right turn lanes) at intersections allow transit vehicles to service their designated route with minimal detouring.

- Priority to bus leaving stops: the YIELD TO BUS sign on the back of buses gives them a priority right-of-way when leaving a bus stop or bus bay, thereby reducing the delay in re-entering the general traffic flow. Some jurisdictions have also implemented rules that vehicles must give way to buses under all traffic conditions (i.e. lane changes). A “yield to bus” rule was implemented in 1998 under both the South Coast British Columbia Transportation Authority Act (SCBCTAA) and the Motor Vehicle Act. This rule requires drivers to yield to a bus only when indicated by a sign or signal device and after the bus operator signals the intention to move into the traffic stream. The rule does not remove bus operator responsibility to maneuver safely (e.g., the bus operator must wait for the vehicle driver to “yield” right of way to the bus, not take the right of way from the vehicle).

- Stopping bans in bus zones: Stopping bans at bus stops are the most common legal transit priority to prevent pick-up and drop-off activities by other vehicles at a bus stop. This becomes important if the stop is to maintain wheelchair accessibility since the space required by the buses to stop parallel to the curb for the deployment of wheelchair ramp or lift is very specific.

- Exempting transit vehicles from roadway infrastructure with size or weight limitations: Exempting transit vehicles from weight restrictions on bridges, or length or width restrictions on narrow roads, allow buses to travel along the most desirable route. These measures may only be considered where bridge or roadway conditions can safely accommodate transit vehicles.

CHAPTER 6. SIGNS AND PAVEMENT MARKINGS

6.1 Introduction

This chapter describes signs and pavement markings relevant to transit operations.

The design and placement of signs and pavement markings for transit operations should be in accordance with the TAC's MUTCDC and other relevant standards as required by the approving agency. For those signs and pavement markings used by TransLink that are not included in the MUTCDC, reference to TransLink practice should be made.

Signs and pavement markings should be properly maintained so that they are clean and visible during both daytime and nighttime conditions. To avoid confusions to visitors, national and international standards in signs and pavement markings (such as symbols) should be used, wherever possible.

6.2 List of TransLink Transit-Related Signs

There are two categories of bus-related signs that are currently used by TransLink at transit facilities or on roadways: (1) MUTCDC bus-related signs, and (2) special signs developed specifically by TransLink and not in the MUTCDC. Refer to TransLink's *Way-Finding Standards Manual* for guidance on way-finding signs.

6.2.1 MUTCDC Transit-related Signs

Many bus-related signs used at transit facilities or on roadways are conventional MUTCDC signs. Table 6.2.1 and Table 6.2.2 present some of the commonly used signs at TransLink transit facilities. Refer to the MUTCDC for detailed descriptions and applications of these signs. Figure 6.2.1 and Figure 6.2.2 are two examples of the MUTCDC transit related signs.

Table 6.2.1 MUTCDC transit related regulatory signs

	**Stopping Prohibited Except Buses (RB-58)** Stopping is prohibited at all times, bus excepted. This sign is typically used at bus stop locations.
	**5-Minute Parking Limit Control (RB-53)** Parking is permitted to a maximum duration indicated on the sign. A maximum parking duration of 5 minutes is usually used at Passenger Pick-up/Drop-off facilities.

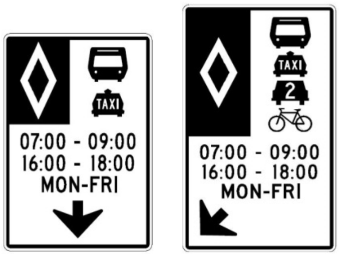
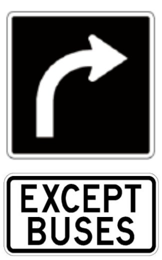
	**Reserved Lane (RB-80, RB-81, RB-80A, or RB-81A)** The lanes are reserved for use by specific vehicles such as buses, taxis, high occupancy vehicles (HOV), and bicycles. For full-time reserved lane, the appropriate sign, without days or times is used.
	**Right/Left Turn Prohibited (RB-11) with supplementary tab (RB-11S1, RB-11S2)** Turning is prohibited for all traffic except buses during the specified period(s) of time.
	**Turns Prohibited (RB-15) with supplementary tab (RB-11S1)** Only buses are allowed to turn left or right at an intersection. Figure 6.2.1 shows an example of a turn prohibited sign.
	**Right/Left Turn Only (RB-41) with supplementary 'Except Buses' tab (RB-11S1)** All traffic, except buses, have to turn right or left from the lane. This is typically used on right-turn lane where buses are allowed to go straight through the intersection.
	**Entry Prohibited (RB-23) with supplementary tab (RB-11S1)** All traffic cannot enter, except buses. Figure 6.2.2 shows an example of an entry prohibited sign.

Figure 6.2.1 Turns prohibited sign

Figure 6.2.2 Entry prohibited sign

Table 6.2.2 MUTCDC transit related warning signs

	**Reserved Lane Ahead (WB-7) with Distance Advisory Tab (WA-30S)** Warning to drivers that they are approaching a reserved lane.
	**Reserved Lane Crossing (WB-8)** Warning to drivers that they are approaching a cross street on which there is a near-side reserved (bus) lane.

6.2.2 SPECIAL SIGNS SPECIFIC FOR TRANSLINK BUS OPERATION

A list of the special signs currently in use is provided in Table 6.2.3, Table 6.2.4, Table 6.2.5 and Table 6.2.6. These signs are developed for specific application in TransLink's bus operations and are not included in the MUTCDC.

Table 6.2.3 TransLink special signs – Signs at bus stops

	**Bus stop symbol** Used at bus stops as an identifying symbol for transit service.
	**Bus bay assignment** Used at customer loading platforms in a transit exchange. The platform number is shown on the sign.
	**Bus stop ID sign with route numbers, destinations, and other information** Used at bus stops where several routes merge together or some, but not all routes, stop. The height of the bottom of the bus stop sign is typically located 2.1 m (7 feet) above the ground. Information on the sign may include: • Bus route numbers and destinations; • Wheelchair decal on stops that are wheelchair accessible; • Periods of operation, such as periods of the day, days of the week, etc., by route, if applicable; • Mode of operation, such as pick-up only, etc.; and • Information telephone numbers, TransLink web site address, TransLink logo.
	**Bus bridge** Used at bus stops (or transit exchanges) to inform customers that buses will be stopped at this location to pick up passengers between SkyTrain Stations during service disruptions.

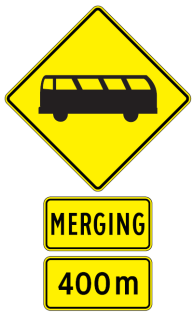
Table 6.2.4 TransLink special signs – Regulatory signs

	**No Passenger Pick-up Notice** Used at bus stops (or transit exchanges) to inform customers that bus operators are instructed not to pick up customers after leaving the bus stop.
	**Bus-Only Signal** Used at bus lanes to indicate that only buses (and other permitted vehicles, if any) in the bus lane could proceed when the bus-only signal display is indicated.

Table 6.2.5 TransLink special signs – Warning/information signs

	**Watch For Buses From Right/Left** Used in transit exchanges where buses approach from the right (or left) of pedestrians. A tab sign LOOK LEFT FOR BUSES or LOOK RIGHT FOR BUSES is also used. The sign should be located near a crosswalk or pedestrian route, facing the crossing pedestrians and oriented in a way so that it is highly visible to pedestrians.
	**Bus Entrance** Indicates to motorists that they are approaching a location where buses are entering, leaving or crossing the road in an unusual maneuver, or physical condition such as inadequate sight distance or steep grades, which presents an uncommon challenge for operators.

Table 6.2.6 Ministry special signs – Warning/information signs

	**Yield to Buses Warning (W-319-7)** Provides advance warning to drivers to yield to buses where freeway ramp crosses the bus lane.
	**Buses Warning (W-319-1R) with Merge (W-319-1-Tb) and Distance Advisory Tabs (W-319-1-Tc)** Provides advance warning ahead of a point where bus merging movements may be encountered. A tab sign may also be used to indicate the distance in advance of the merging point.

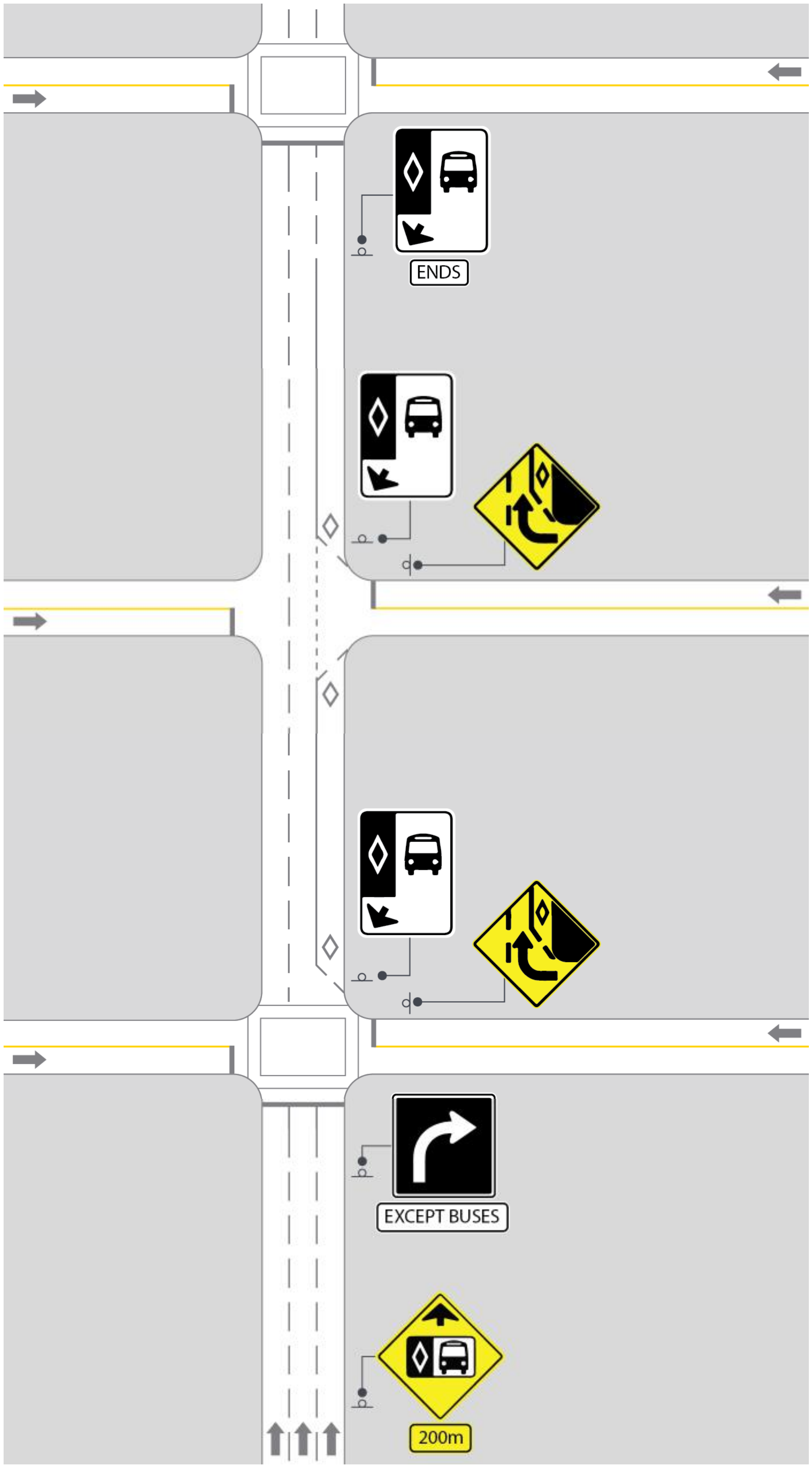
6.3 PAVEMENT MARKINGS

6.3.1 BUS LANES

When designing bus pavement markings, the following situations should be considered: i) general purpose traffic turning from the street with the bus lane across the bus lane and ii) general purpose traffic entering the street with the bus lane from cross streets or driveways. Further details are specific in the MUTCDC Section C2.7.3 (September 1998).

Figure 6.3.1 illustrates the bus lane configuration and operational requirements for a full-time curbside reserved bus lane. The MUTCDC manual provides details on placement of transit-related markings, such as longitudinal lines, 'diamond' symbols and word markings.

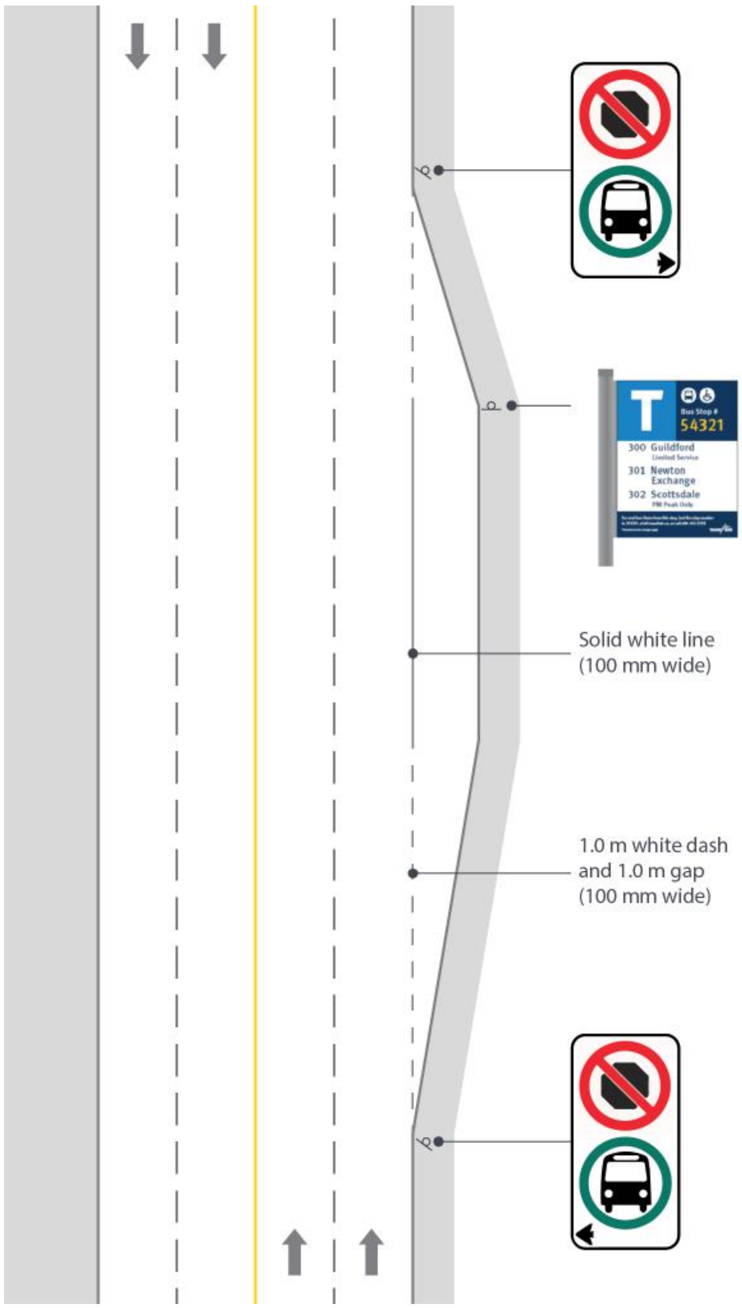
Figure 6.3.1 Typical markings and signing for bus lanes (full-time, with-flow)



6.3.2 Bus Bays

Typical bus bay markings and signing are shown in Figure 6.3.2. The length of a bus bay should be determined in accordance with the guidelines given in Chapter 3. A broken lane line is provided in both the pull-in and pull-out sections of the bus bay. Typical bus stop signs include BUS STOP ID sign and NO STOPPING ANY TIME BUS ZONE sign.

Figure 6.3.2 Typical bus bay markings and signing

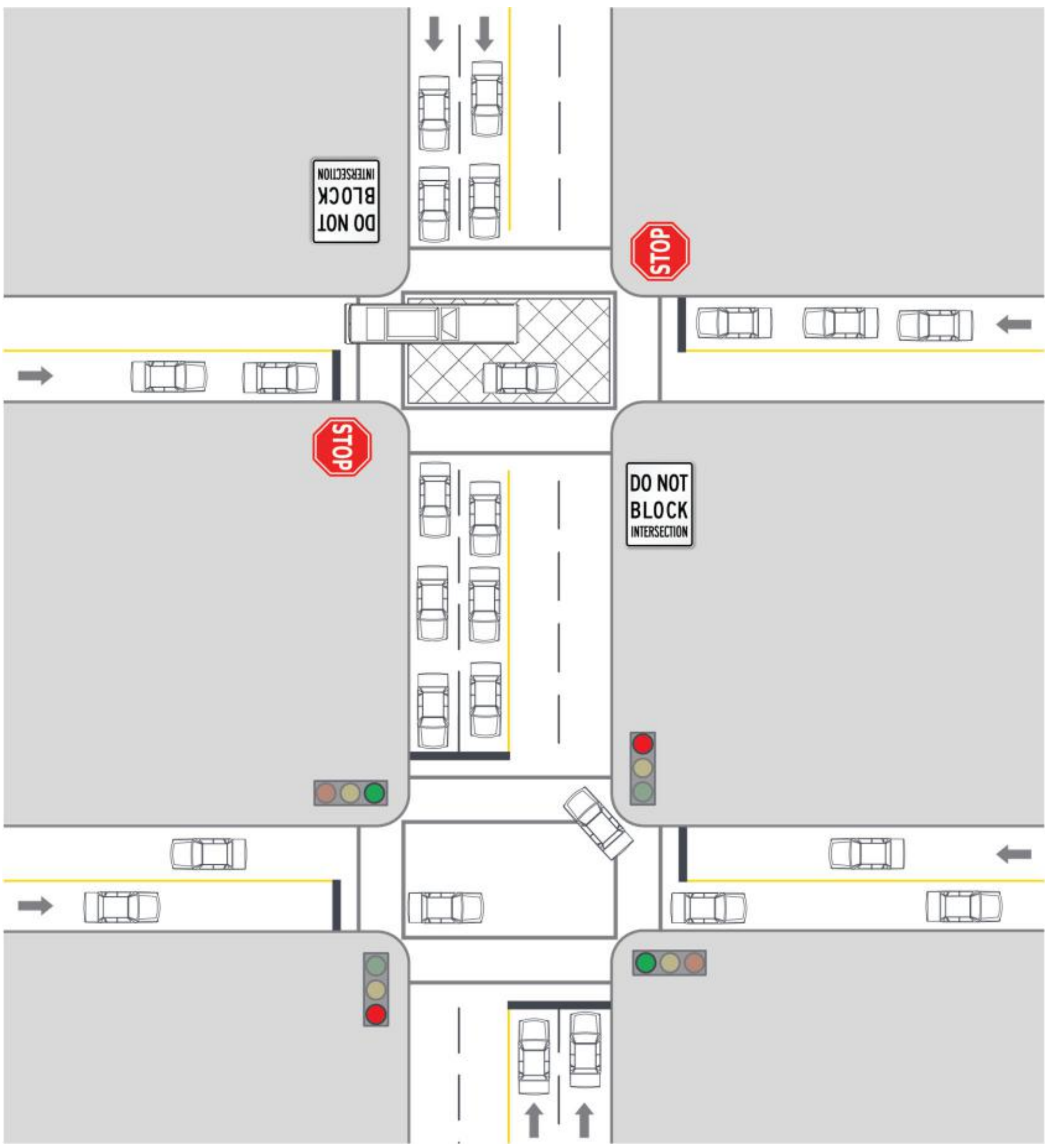


6.3.3 'Do Not Block Intersection' Box

DO NOT BLOCK INTERSECTION box markings (or penalty box) are used at intersections where traffic queues frequently block the efficient operation of the intersection. This is often the case when the spacing to the downstream intersection is relatively short and different traffic control methods are used at the two intersections. Figure 6.3.3 shows an example of the application of DO NOT BLOCK INTERSECTION box markings to protect buses and other traffic on the cross street from incurring unnecessary delays. DO NOT BLOCK INTERSECTION signs should also be placed in advance of the intersection.

A DO NOT BLOCK INTERSECTION box may be applied to the entire intersection area or on part of the intersection area in the critical direction of travel only.

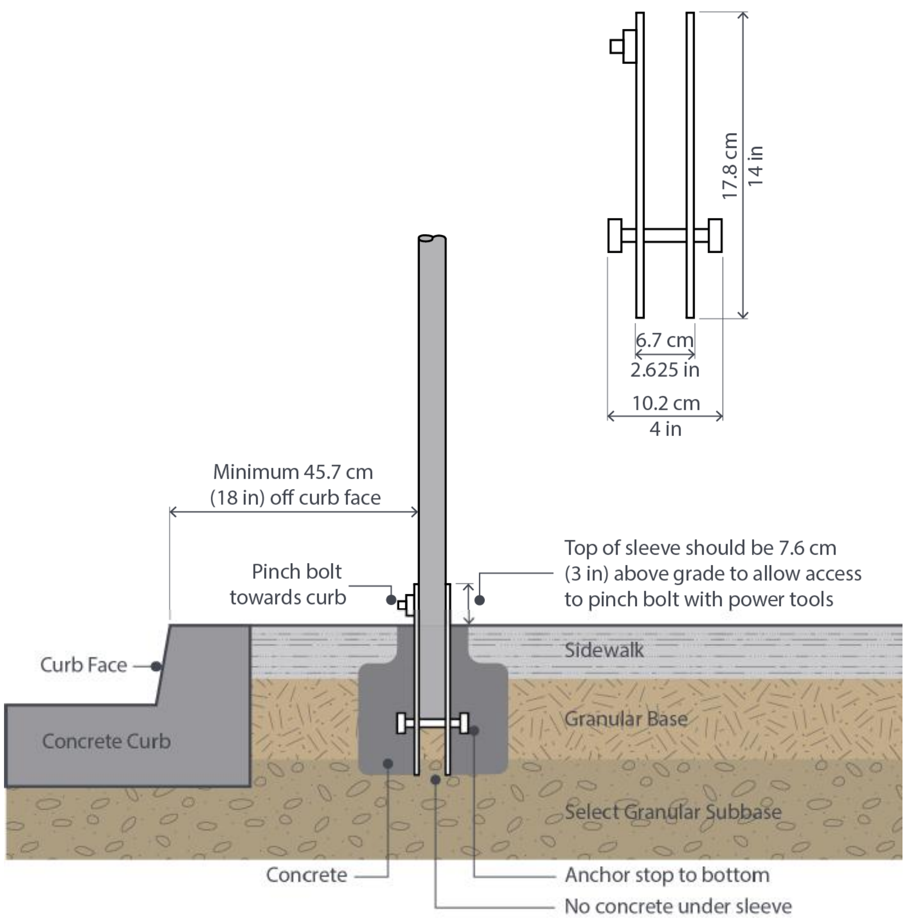
Figure 6.3.3 Typical DO NOT BLOCK INTERSECTION box markings and signing



6.4 Sign Sleeves

Refer to Figure 6.4.1 for information regarding the installation of bus stop ID pole sleeves.

Figure 6.4.1 Bus stop sleeve installation guide



APPENDIX A

DESIGN CHECKLIST

APPENDIX A: DESIGN CHECKLIST

The following serves as a checklist of the key design aspects of a bus stop. The relevant section(s) where guidance is provided is shown next to the key design aspects. This checklist can be referred to at the onset of design and/or towards the end of the design process to ensure that all aspects have been considered.

Table A1 Bus stop design checklist

Key Design Aspect	Relevant Section(s)
☐ Stop spacing	3.2
☐ Far-side, near-side, or midblock configuration Advantages and disadvantages	3.3.1 to 3.3.4
☐ Bus stop layout • Parallel to curb, bus bay, bus bulge • Sightline	3.4
☐ Passenger amenities • Passenger zones • Passenger landing pads • Wheelchair pads • Bus shelters • Benches • Accessible features • Other street furniture	3.5.1 to 3.5.4
☐ Lighting	4.2.7
☐ Sign Sleeves	6.4

All bus stop designs within TransLink's jurisdiction must be reviewed by a CMBC Bus Stop Technologist. The design must be approved by CMBC prior to construction.

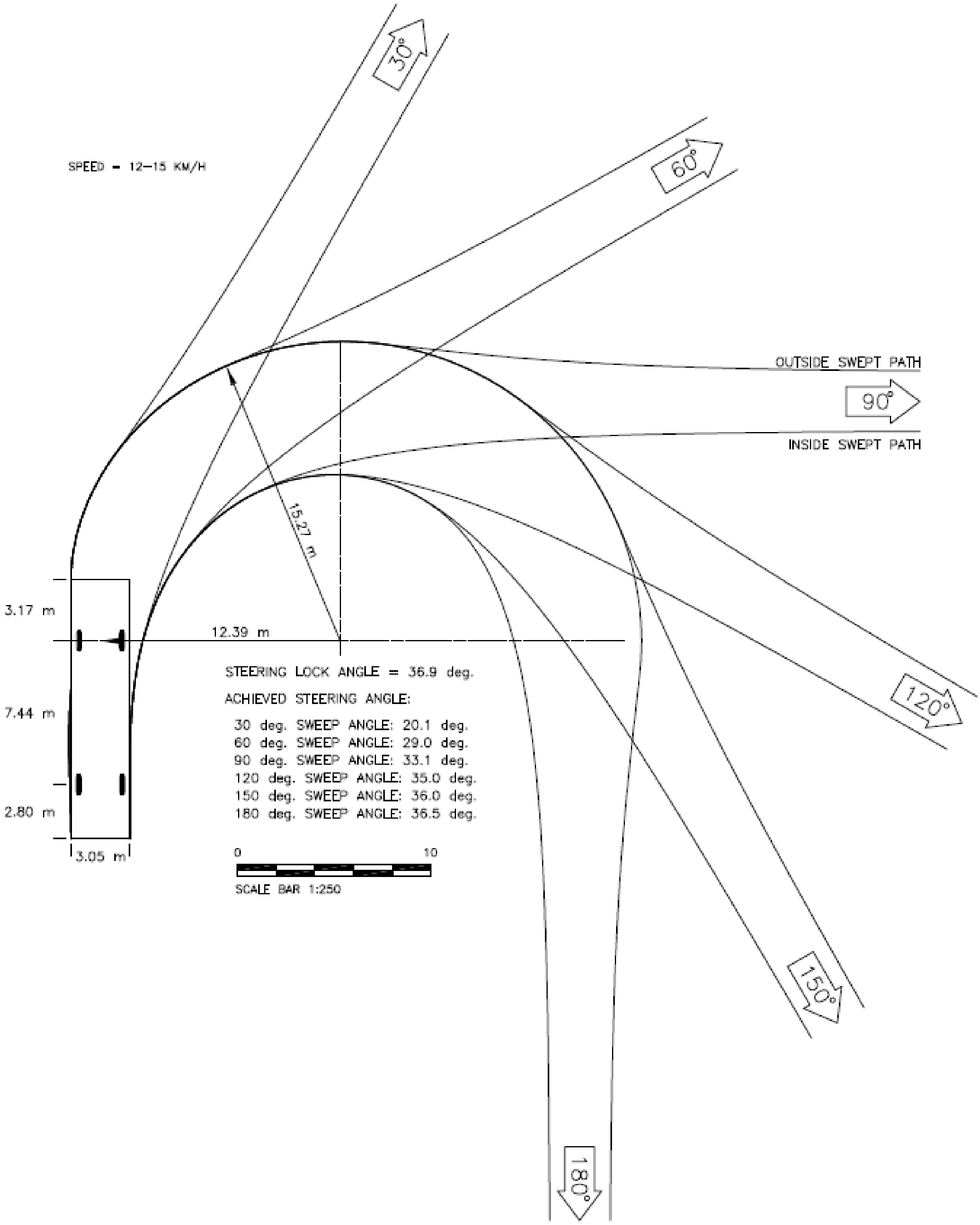
CMBC Head Office can be contacted at 778-375-6400.

APPENDIX B

BUS TURNING TEMPLATE

APPENDIX B: BUS TURNING TEMPLATE

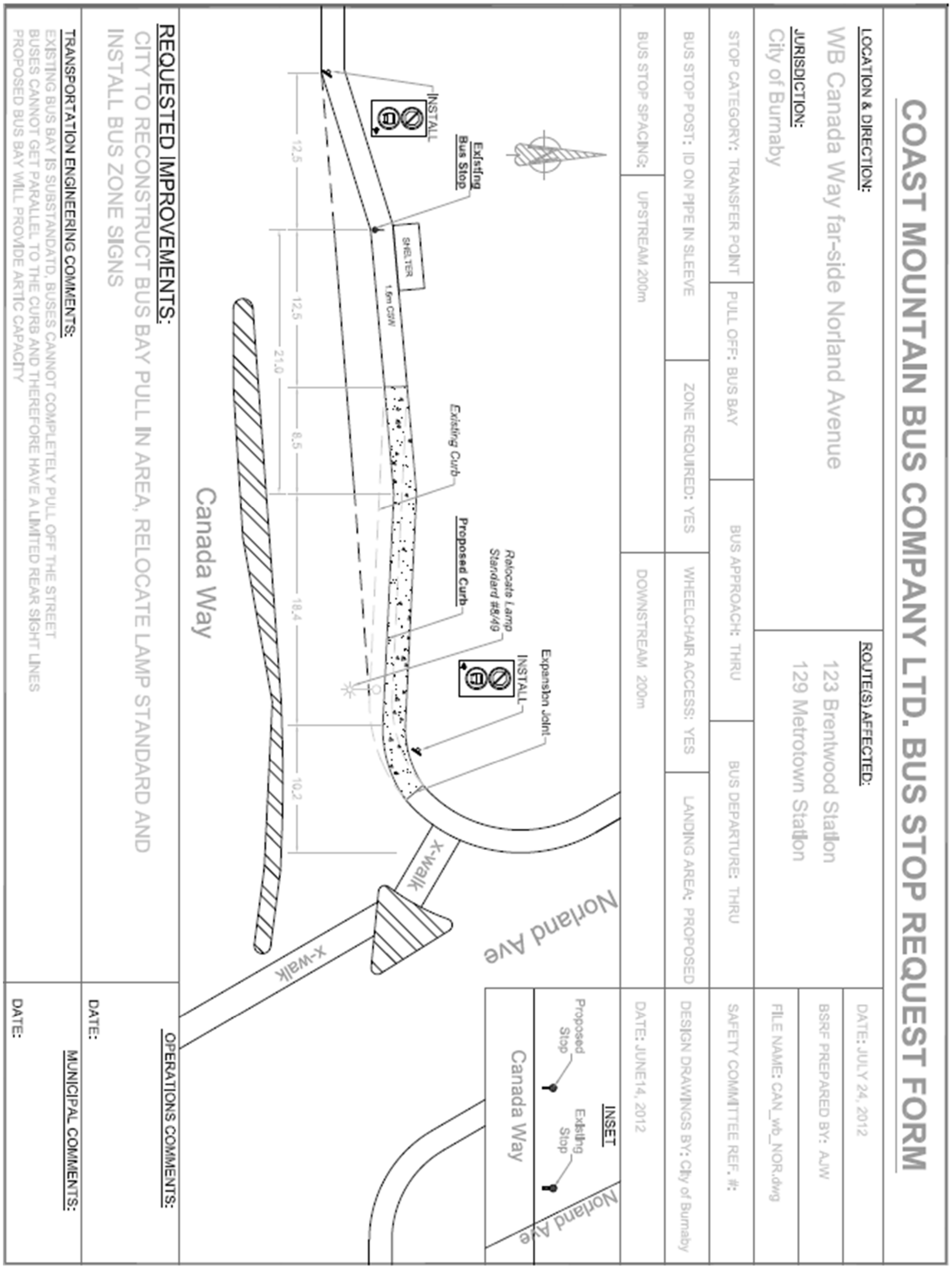
Figure B1 Standard bus turning template



APPENDIX C

BUS STOP REQUEST FORM EXAMPLE

APPENDIX C: BUS STOP REQUEST FORM EXAMPLE



APPENDIX D

TYPICAL CONCRETE & ASPHALT PAVEMENT SECTIONS

APPENDIX D: TYPICAL CONCRETE & ASPHALT PAVEMENT SECTIONS

Figure D1 Typical Concrete Pavement Section

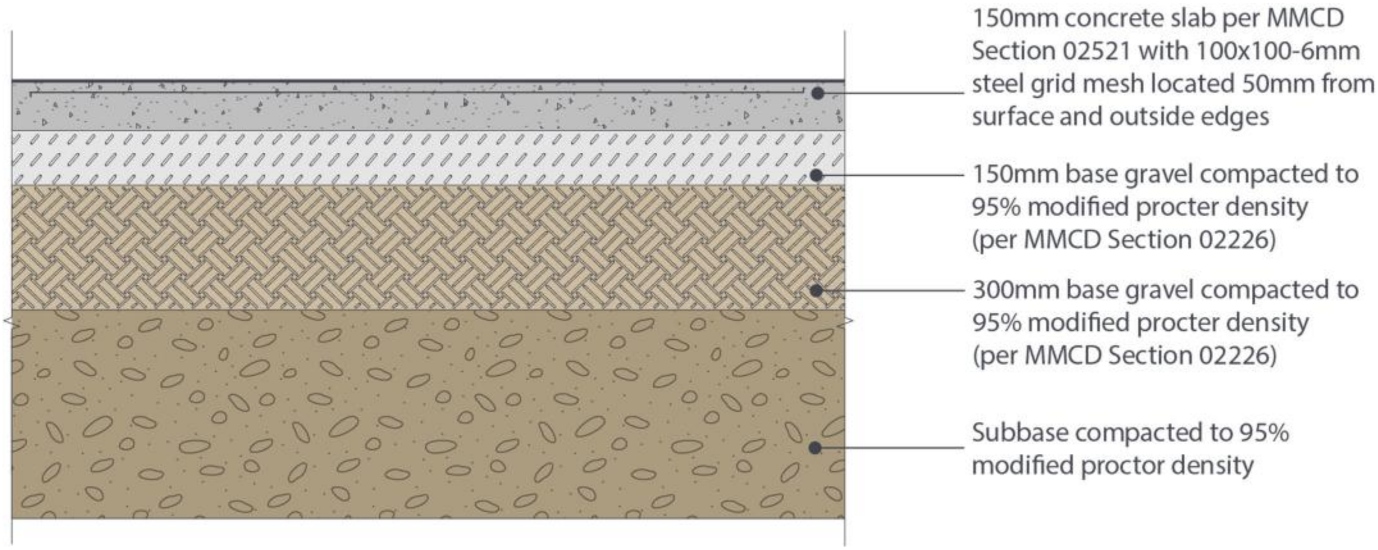
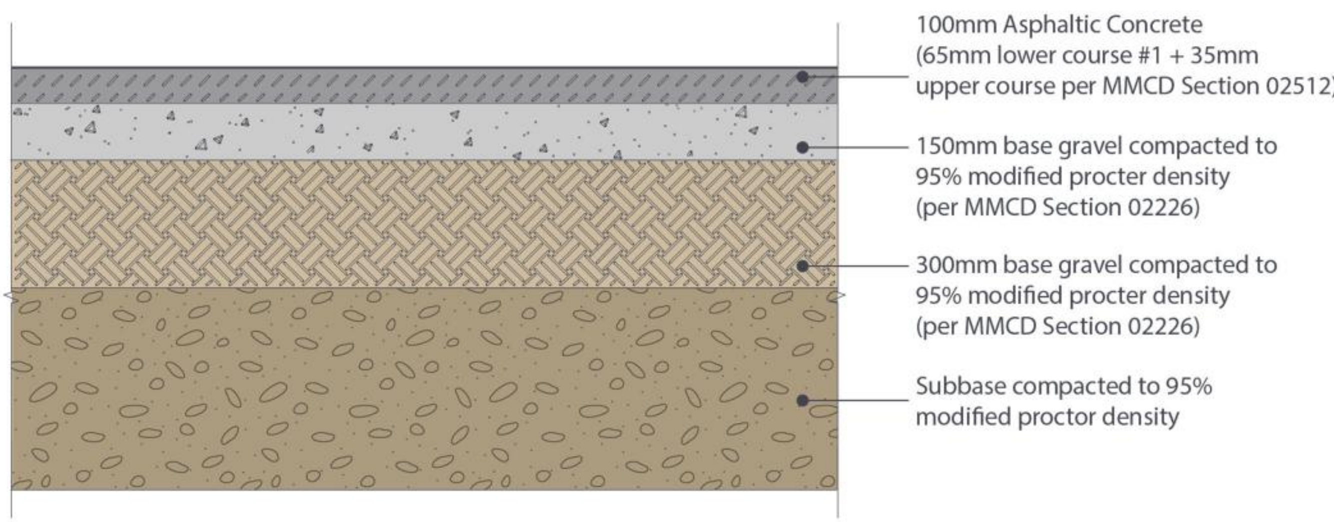


Figure D2 Typical Asphalt Pavement Section



APPENDIX E

TACTILE WALKING SURFACE INDICATORS

APPENDIX E: TACTILE WALKING SURFACE INDICATORS

In accordance with the Canadian Standards Association (CSA), the Tactile Walking Surface Indicators (TWSIs) shall be composed of flat-topped, parallel, elongated bars having:

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

Table E1 Flat-topped elongated bar dimensions

Width of flat-topped elongated bars (mm)	Base width spacing (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 Standards B651-12

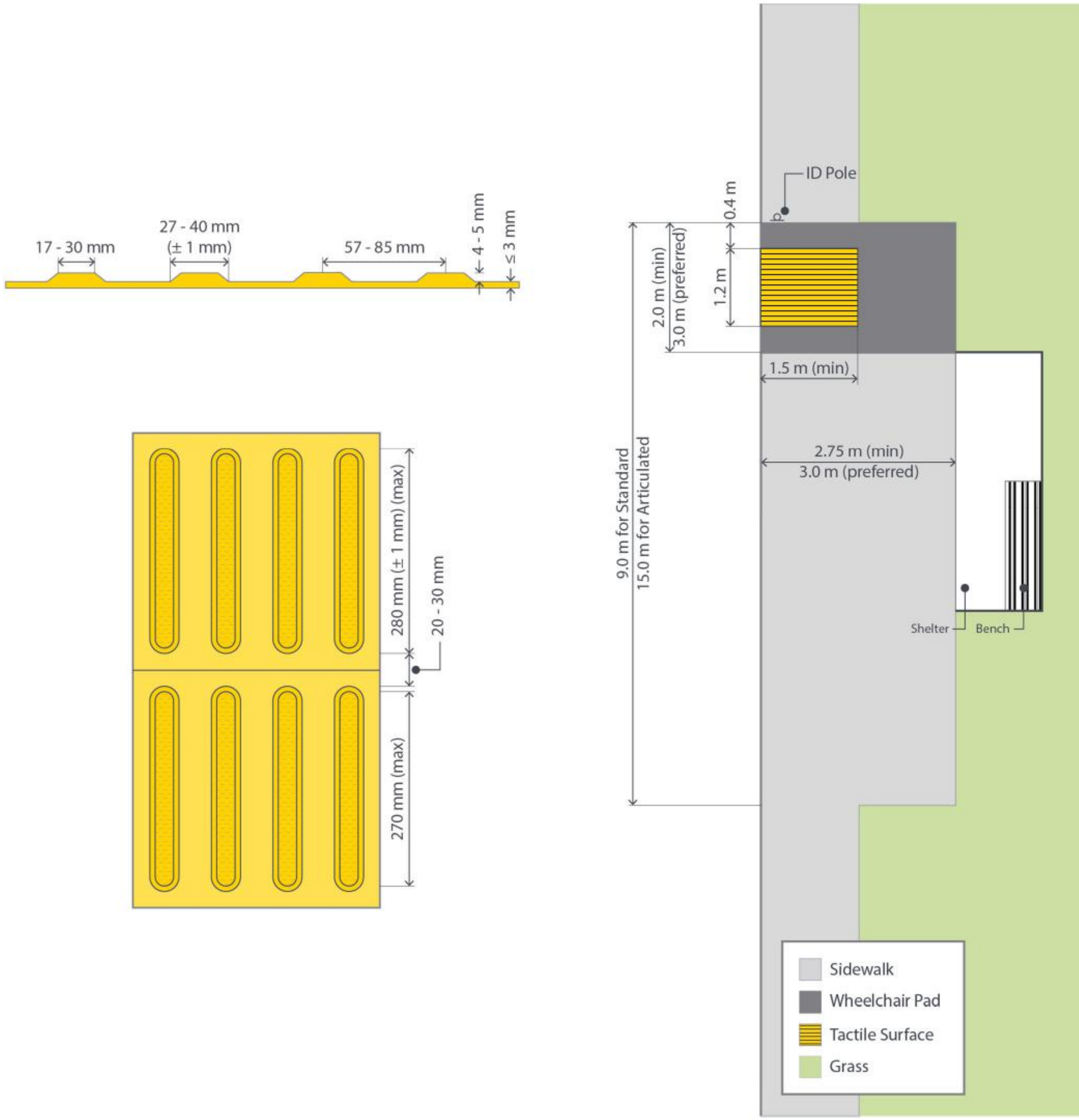
For application at bus stops, the TWSIs should be:

- Placed in parallel groups and oriented in the direction of travel (perpendicular to the curb or roadway edge in the case of directing customers to a bus stop);
- Located at the point where the front door of a bus (or front door for Mini Bus) in line with the bus stop ID pole;
- Installed with its base surface levels with the surrounding surface, or not more than 3 mm above or below it;
- A minimum of 1.2 m in length along the sidewalk and be the entire width of the sidewalk;
- In a contrasting color to surrounding surfaces (yellow is preferred); and
- In slip resistance material.

It is important to note that TWSIs can only be installed at bus stops that provide a hard-surfaced passenger zone and wheelchair pad.

APPENDIX E: TACTILE WALKING SURFACE INDICATORS

Figure E2 Typical layout of bus stop configuration with TWSIs

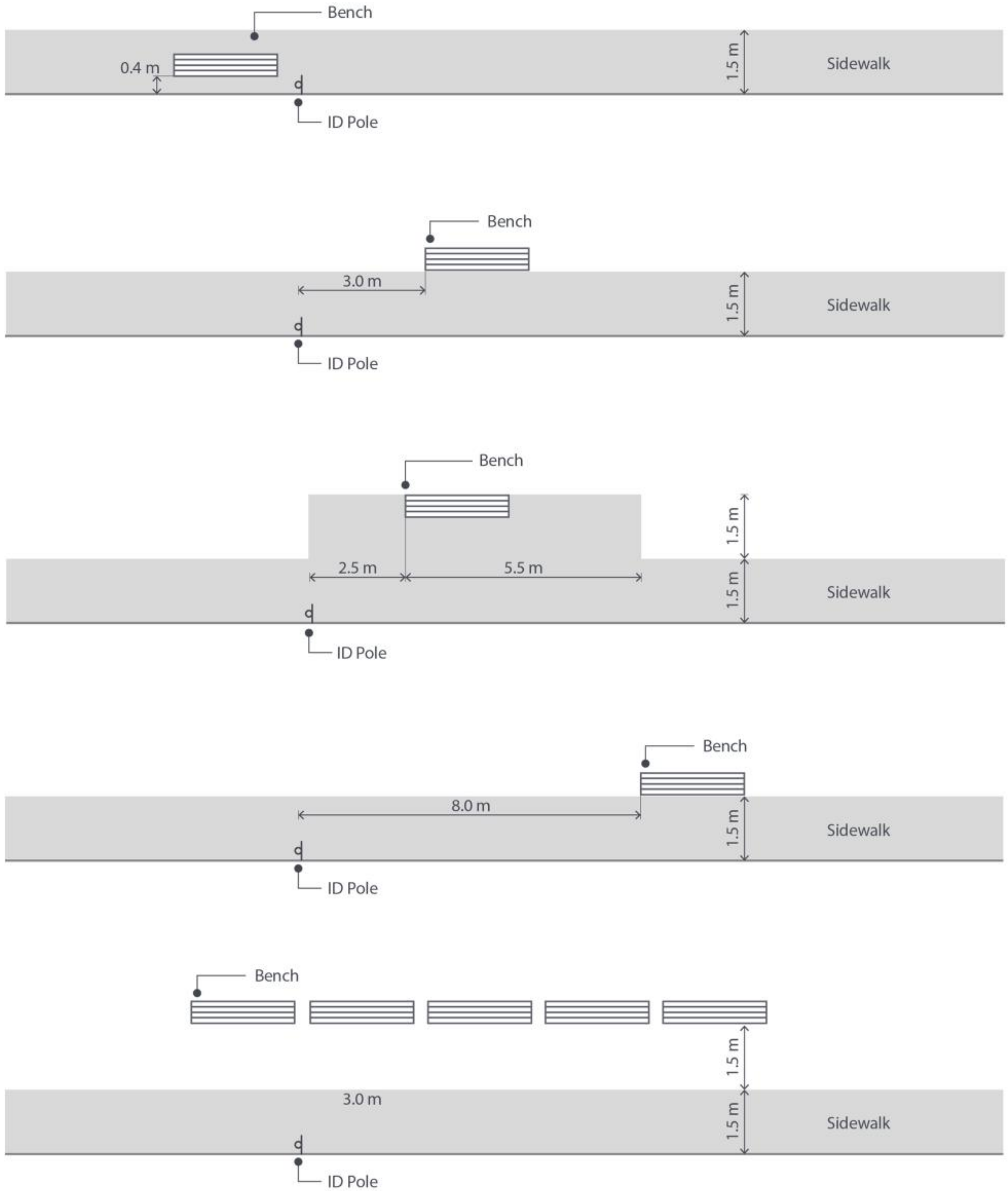


APPENDIX F

BENCH LOCATION AT BUS STOP

APPENDIX F: BENCH LOCATION AT BUS STOP

Figure F1 Bench location at bus stop



APPENDIX G

OPERATING PLANS

APPENDIX G: OPERATING PLANS

G 1.0 Operating Plans

Operating plans outline the use of space at a bus exchange, determining where, how and which bus routes will drop-off, layover, and pick-up, and if any bays will be shared between bus routes. It is important that operating plans are developed in conjunction with geometric designs as the operating plan will affect how many bus bays are required and how they can be configured in relation to each other. In addition to the aspects of bay allocation described in this section, scheduling practices can impact bay requirements and should be confirmed in conjunction with geometric design.

G 1.1 Approach to Operating Plan Development

Development of an operating plan should be included as part of the multi-stakeholder, multidisciplinary, and iterative design process. Participation of operations professionals from TransLink and its subsidiaries in development and refinement of the operating plan is therefore required throughout the exchange design process.

Although a great number of characteristics should be considered in allocating bus routes to bays at exchanges, a few are particularly influential:

Number of routes serving the exchange

Where very few routes serve an exchange, buses can be assigned to individual bays without requiring transferring passengers to walk long distances. When an exchange serves a large number of routes or where space is constrained, there are more benefits to be realized in consolidating bus functions into fewer bays.

Frequency of routes serving the exchange

Generally, when buses are less frequent, more routes and/or functions can be accommodated in a single bay. As discussed below, an exception is when low-frequency buses have high boarding volumes, particularly when passenger trips on these routes are long.

Passenger boarding volumes

The anticipated volume of customers queuing can affect the number of routes that can share pick-up bays. When routes are frequent and passenger trips are short, a larger number of routes can share a bay as customer queues clear often and customers may choose to mill about instead of queuing. However, where routes are infrequent and passenger trips are long, customers may prefer to queue. In these cases, queue area may need to be defined if several routes are to share a bay.

Bus bay allocation

In addition to these service characteristics of bus routes, characteristics related to the exchange, its configuration, the transit network which it serves and operational policies also influence decisions about bus bay allocation. At new exchanges, some of these characteristics may be considered in conjunction with bay allocation. At existing exchanges these characteristics may be relatively immutable and therefore constrain the options for bay allocation. These include:

- Direction of bus circulation around and in the exchange;
- Routes that need to access layover bays (i.e. terminating vs through routes);
- Land value and ease of land acquisition;
- Network characteristics (ex. timed transfer vs random meets); and
- Operator layover area separate from passenger areas.

G 1.2 Alternative operating plans

In some cases, such as when a site is constrained, it may not be possible to develop a geometric design and operating plan that accommodate an exchange's bus program. In these cases, planning and operational changes can be explored. For example, it is possible to explore through-route and routing to alternative termini to reduce layover requirements. Combining, splitting or rescheduling routes can also be considered to more evenly distribute demand for drop-off, layover, or pick-up bays. Any operational changes, however, require extensive internal consultation throughout TransLink and its subsidiaries and may, in some cases, necessitate public consultation.

G 2.0 Operating Plan Types

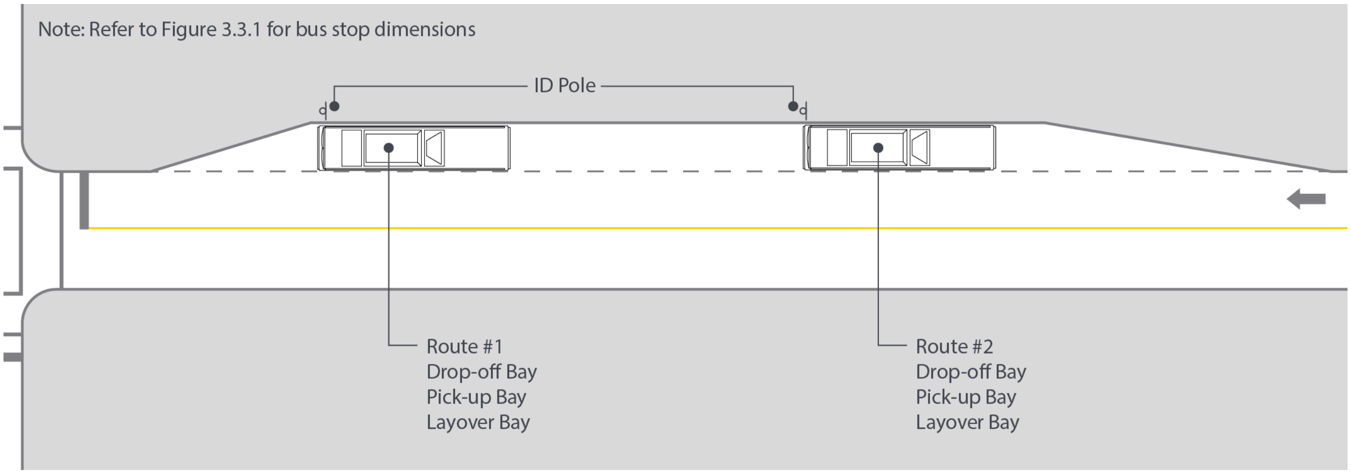
Operating plans outline which bays provide drop-off, layover, and pick-up functions for each route expected to be served by an exchange. The type of exchange chosen does not necessitate a particular type of operating plan. However, an operating plan must be developed in conjunction with the geometric design of an exchange as a particular configuration's capacity will depend on how it is intended to be operated.

The sample operating plans described below are primarily distinguished by whether drop-off, layover, and pick-up functions take place in the same or different bays and whether these bays are shared with multiple routes.

G 2.1 Assigned, Independent Bays

An operating plan based on Assigned, Independent Bays reserves a single bay for each bus route. Routes drop-off, layover and pick up in this assigned bay. This operating plan is typically utilized for low-frequency bus routes. When routes are frequent, one bus layover will often overlap with the pick-up time for another bus serving the same route. Because of this, it is not possible for a single bay to serve all functions for a route.

Assigned, independent bays provide legible, convenient customer access in cases where few routes need to be accommodated. Where many routes need to be accommodated, customers may need to navigate a large number of bays, resulting in low legibility and high walking distances. In these cases, the large exchange footprint required may be difficult to fit in an urbanized area and may result in large capital costs.



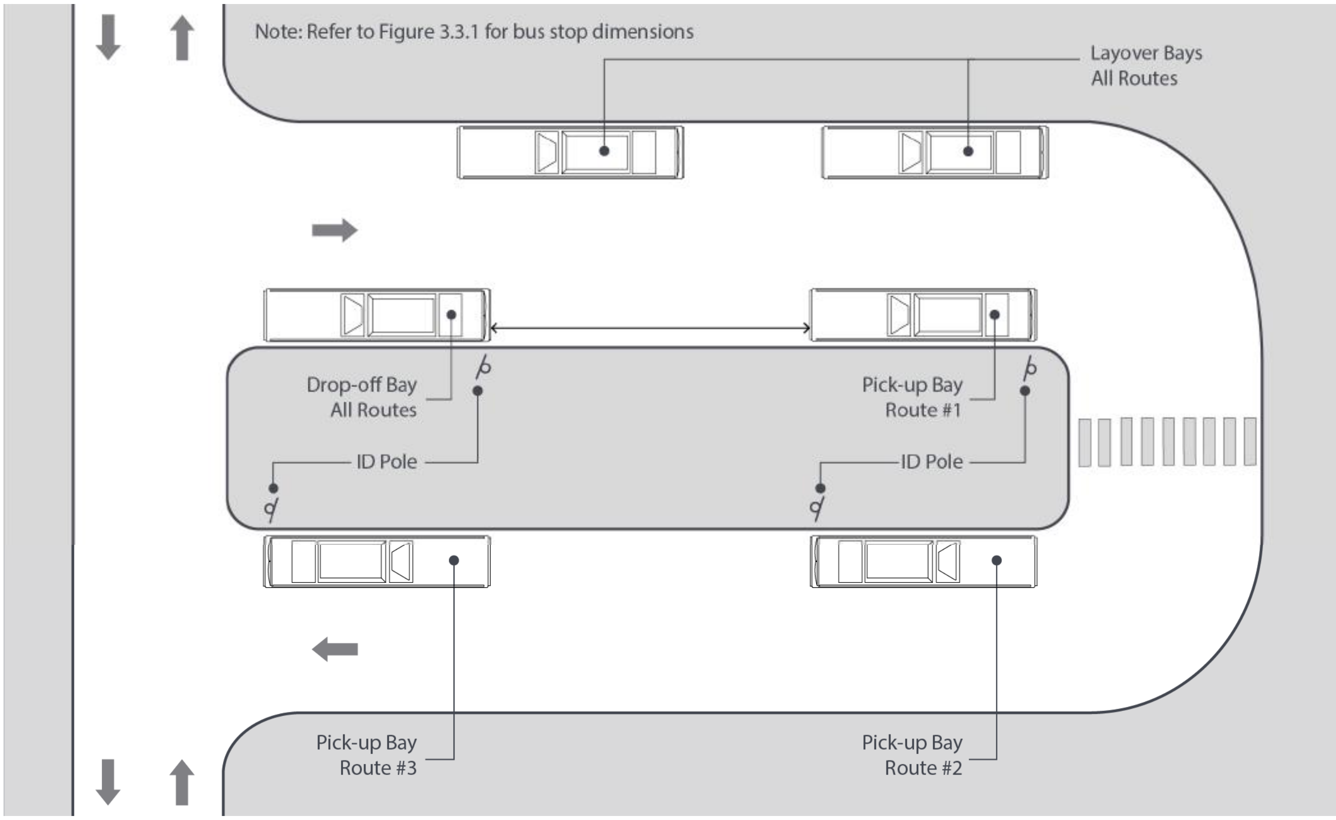
For regular users of facilities with visual impairments, legibility is good as pick-up and drop-off locations do not change. For users unfamiliar with the facility, locating the correct bay may be challenging, particularly as the number of bays increases.

From an operational perspective, this operating plan minimizes run time and operational complexity. However, it does not facilitate operator breaks separate from passenger areas. This can result in exchange facilities being operated in a different way than the operating plan for which they were designed, resulting in additional space requirements and necessitating retrofits.

G 2.2 Assigned, Independent Pick-up Bays

An operating plan based on Assigned, Independent Pick-Up Bays reserves a single pick-up bay for each bus route. Drop-off and layover spaces are shared by multiple routes, for example by all routes served by an exchange or by all routes entering the facility from the same direction. This operating plan is better able to accommodate frequent bus services than an Assigned, Independent Bay plan as it can provide multiple layover spaces for a single route. It can also more easily allow operator break areas separate from the customer areas, which increases the probability that the exchange will be operated as intended. For bus routes where high number of customers need to queue for buses (i.e. customers avoiding pass ups or wanting to have a seat on long routes), this operating plan allows customers to queue at the designated bus stops. A consideration in designing this type of exchange is that circulation distance between the drop-off, layover and pick-up bays be minimized. These areas should be located close to each other, in a direct line as the required circulation time can considerably increase bus operating costs.

From a customer perspective, this operating plan is very similar to an Assigned, Independent Bay plan. Because buses' pick-up and drop-off locations are consistent across time, visually impaired users that regularly use a bus exchange can become familiar with their usual pick-up and drop-off locations.



However, because this operating plan requires additional bus circulation within the exchange, additional attention must be paid to minimizing the points at which pedestrians cross bus traffic. As with the Assigned, Independent Bays operating plan, walking distances for transferring customers can become significant if the exchange serves a large number of bus routes.

Example: Commercial-Broadway Station

The on-street bus exchange adjacent to Commercial-Broadway Station is located in a highly urbanized, central area of Metro Vancouver. The exchange provides pick-up, drop-off and layover space for two of the region's highest-frequency, highest volume routes: the 99 B-Line and the 9. It also provides pick-up and drop-off space for the 20, which runs perpendicular to the 9 and the 99.

The 9 and the 99 share a single drop-off platform (multi-bus bay) on Victoria Drive and a layover area on Grandview Highway. Pick-up for the routes is separated, with each having a separate, assigned bay. The 20, which does layover at this exchange is assigned its own pick-up and drop-off bays.

This exchange balances challenging operational needs with constrained space in a highly urbanized area. The high frequency of both the 9 and the 99 necessitates layover separated from pick-up and drop-off bays.

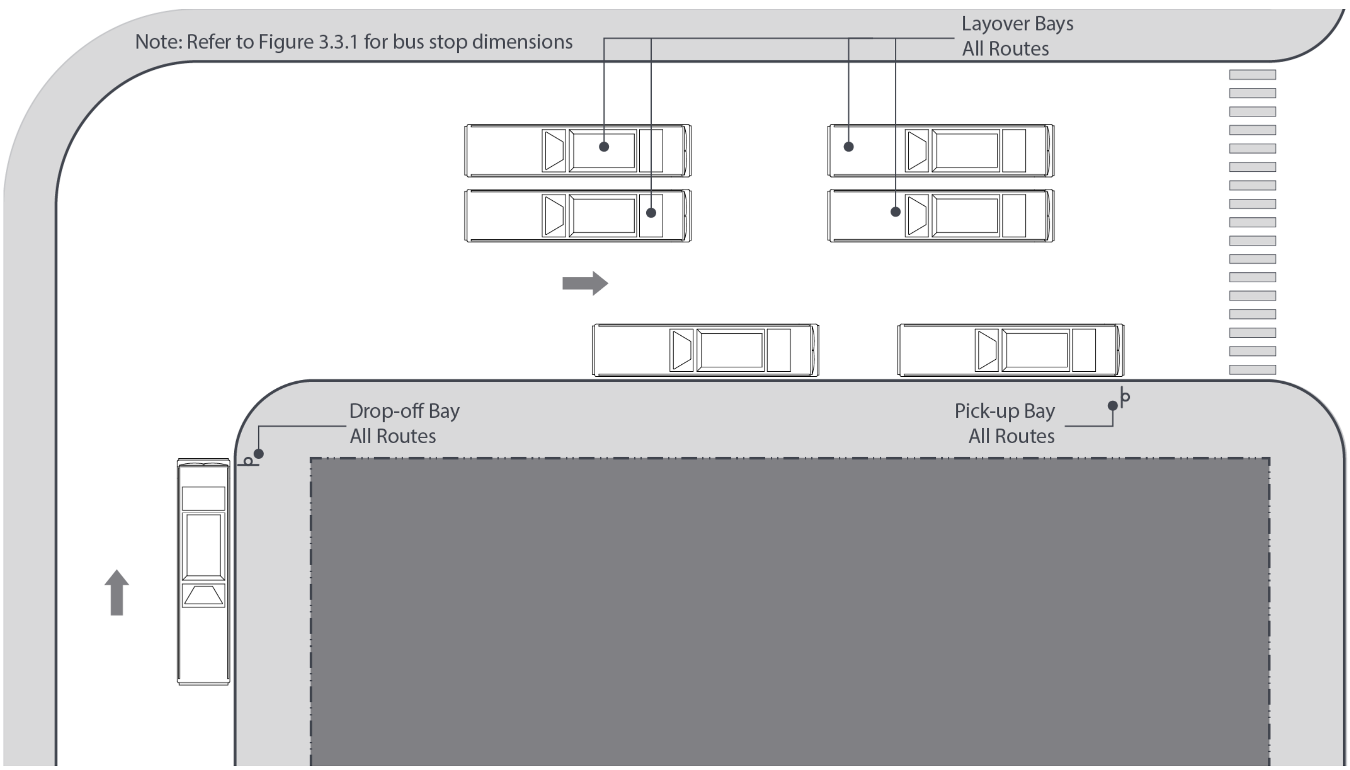
Extremely high boarding volumes for both routes mean that long queues can form for buses despite the short headways. In order to minimize conflicts between boarding customers, separate, designated pick-up spaces have been provided for each bus.

Despite the space requirements necessitated by high frequencies and high volumes, design of the exchange has resulted in a very compact exchange. Minimization of space requirements is aided by allowing both the 9 and the 99 to share a single, on-street drop-off platform.

G 2.3 Assigned, Shared Platform

An operating plan based on an Assigned, Shared Platform designates shared drop-off, layover, and pick-up areas for all bus routes. As with the Assigned, Independent Pick-Up Bay operating plan, drop-off and layover areas may be shared by a subset of bus routes served by the exchange, such as those approaching from a single direction or by all bus routes served by the exchange.

This type of operating plan is more typically used in urbanized areas because it minimizes the exchange footprint required to serve frequent bus routes. As with an Assigned, Independent Pick-Up Bays operating plan, it allows operator break areas separate from the customer areas and allows screening of the layover area from customers. Also similar to the Assigned, Independent Pick-Up Bays plan, the exchange design should minimize operating costs by minimizing the circulation distance between drop-off, layover, and pick-up bays.



This operating plan can be modified to have multiple pick-up bays when shared drop-off and layover are possible, but bus volumes do not allow all routes to share a single pick-up bay.

Since several bus routes will be sharing a bus bay, the possibility of bus bunching will impact bus operation if the bus bays do not have sufficient capacity. Design teams should consider providing sufficient bus bay capacity, depending on the likelihood on several buses arriving or departing at the same time.

This type of operating plan can provide highly legible, convenient access for most people. This operating plan is especially beneficial for exchanges serving a high number of routes as customers can access a couple bus routes in a single bay, which provides a legible service with minimal walking distances. An exception is visually-impaired customers or customers using mobility aids who may find it challenging to determine which bus to board. This can be especially problematic when the platform provides a single ID pole but can accommodate more than one bus as the second bus may not always pull up to the ID pole. Another consideration is accommodating high customer queuing (i.e. customers avoiding pass ups or wanting to have a seat on long distance routes) as customers may not be able to form queues since several routes are serving a single bay.

In order to mitigate these issues, it is recommended that space at the ID pole be demarcated for customers with mobility or visual impairments. Demarcating separate queues for routes may also be helpful if high volumes of queuing customers are obstructing other customers from boarding another bus.

The Marine Drive Station bus exchange was built as part of the Canada Line SkyTrain, which opened in September 2009. Located at the southern edge of Vancouver, the exchange provides layover for five frequent diesel and trolley routes. Four of the routes share a single unloading platform (triple bay) and share a single loading platform (double bay). The four routes which layover at this exchange also share a layover area which is separated from the pick-up and drop-off area. Trolley buses are limited in their movements through the exchange because they share the same set of wires in the loading and unloading areas. Because the shared wires prevent passing, trolley buses operate on a first-in first-out basis.

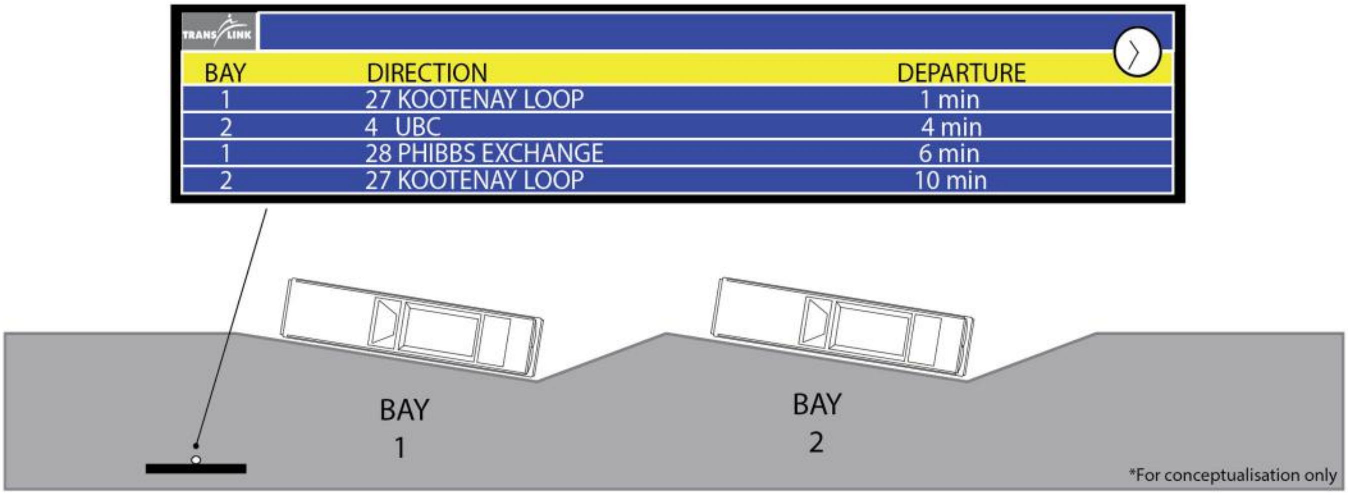
The passenger waiting area consists of three large shelters adjacent to the pick-up area. Because the order of bus arrival is not announced to customers, they do not form queues to board the bus. Customer volumes are moderate at this location due to the frequency of routes and the exchange's location at the less busy end of the north-south routes.

G 2.4 Dynamically Assigned Bays

An operating plan based on Dynamically Assigned Bays designates shared drop-off and layover areas, and dynamically assigns pick-up bays for all bus routes. As with the plans previously described, drop-off and layover areas may be shared by a subset of bus routes served by the exchange, such as those approaching from a single direction, or by all bus routes served by the exchange. Buses are assigned to pick-up bays as they prepare to depart from the exchange. Customers are alerted to their buses' assigned bays through electronic signage and/or verbal announcements.

This operating plan is generally the most space-efficient for exchanges that serve high numbers of frequent routes. However, the necessary electronic systems require higher capital investments and the malfunctioning of electronic systems can make an exchange vulnerable to temporary failure. It can also be more challenging for regular customers who are visually impaired to find their bus as its bay location can be unpredictable.

This operating plan is not currently being used in TransLink's transit system.



G 3.0 Other Considerations

As with geometric design, the development of an operating plan requires consideration of an exchange's context, including its role in the transit network and its relationship to the adjacent urban fabric. Addressing these contextual factors may require several phases of refinement to the operating plan. While undertaking these refinements, it is important to coordinate the operating plan with the geometric design as changes in one influence the other. Engaging planning, scheduling, and operations staff is essential to developing a robust operating plan that aligns with the facility's geometric design.

APPENDIX H

PASSENGER PICKUP/DROP-OFF ESTIMATION SAMPLE

APPENDIX H: PASSENGER PICKUP/DROP-OFF ESTIMATION

Table H1 Passenger Pickup/Drop-off Estimation – Production Way Station

	------ 2002 ------		------ 2012 ------	
	A.M. Peak	**P.M. Peak**	**A.M. Peak**	**P.M. Peak**
Boarding Passengers (from model)	2093	n/avail	1986	n/avail
Alighting Passengers (from model)	484	n/avail	794	n/avail
p.m. peak as a % of a.m. peak*	n/a	145	n/a	145
SkyTrain Ridership	2577	3737	2780	4031
Percentage Kiss & Ride*	10	5	10	5
PPUDO Passengers	257.7	186.8	278	201.6
PPUDO occupancy*	1.05	1.15	1.05	1.15
PPUDO vehicles	245.4	162.5	264.8	175.3
Percentage pick up*	15	65	15	65
Pick up vehicles	36.8	105.6	39.7	113.9
Drop off vehicles	208.6	56.9	225	61.3
Pick up time*	6	6	6	6
Pick up spaces	5.5	15.8	6	17.1
Drop off time*	1	1	1	1
Drop off spaces	5.2	1.4	5.6	1.5
Estimated PPUDO spaces required	11	18	12	19
Trip Generation	245	162	265	175

*Values from SkyTrain Kiss & Ride Traffic Operations Study

n/avail = data not available as model is for a.m. peak hour only
n/a = not applicable as this line applies to p.m. peak hour only

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