G.

INTERSECTIONS + CROSSINGS

Protected Bicycle Lane Intersection, Fort Street, Victoria, B.C.

G.1

GENERAL DESIGN GUIDANCE

This chapter provides general design guidance related to all types of intersections and crossing points, including design principles and design considerations, an overview of the different types of crossings and crossing controls, and a general discussion on design factors such as sightlines, corner radii, and signage and pavement markings. This general design guidance informs the subsequent chapters on signals and beacons (**Chapter G.2**), pedestrian crossings (**Chapter G.3**), on-street bikeway crossings (**Chapter G.4**), off-street pathway crossings (**Chapter G.5**), and additional crossings and conflict areas (**Chapter G.6**).

DESIGN PRINCIPLES

The critical locations for any active transportation facility are at intersections and crossing points. Intersections can often be the most significant real or perceived barriers for people walking, cycling, or using other forms of active transportation. Even if active transportation facilities have been provided along the corridor alignment, if active transportation facilities have been provided through intersections and their conflict points, the facility may continue to feel uncomfortable, unsafe, and inconvenient for many users.

Intersections and crossing points are the connection point between people driving, using transit, walking, and cycling. Intersections have the most conflict points along any active transportation corridor, as they involve complex interactions between all modes of transportation and are generally the locations where most collisions occur.

Turning motor vehicles present a specific risk to people walking and cycling. Special considerations are needed when designing and installing crossing treatments at locations where active transportation facilities intersect with other roads and where active transportation users are directly exposed to motor vehicles. These areas need treatments that distinguish people walking and cycling at intersections, including:

- Reducing the turning speed of motor vehicles;
- Increasing the level of visibility of people walking and cycling;
- Denoting clear right-of-way; and
- Facilitating eye contact and awareness with other modes.

Improving intersections and crossing points for people walking and cycling can allow for a reduction in the total distance travelled, and make walking and cycling more attractive for all.

Pedestrian crosswalk, West Cordova Street,Vancouver, B.C.

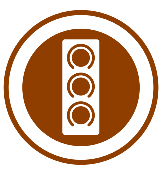
The following design principles should be considered in order to provide safe, comfortable, and accessible intersection and crossing treatments for all users:

Design for all ages and abilities

People of all ages and abilities should be able to safely and comfortably navigate an intersection, crossing, or transition area.

Minimize conflicts between users

Conflicts can be minimized by separating different users in space and/or time. Providing dedicated spaces and/or protected phasing for active modes through intersections and crossing points increases the predictability of movements and supports more compliant behaviour. Minimizing exposure between active transportation users and motor vehicle traffic can also help to reduce conflicts.



Ensure clarity of right-of-way

Providing clear and consistent traffic control devices and visual cues that indicate which user is expected to yield and/or stop ensures clarity of right-of-way. Priority of right-of-way needs to align with municipal bylaws and the *B.C. MVA* and associated regulations. Right-of-way at intersections and crossings should be intuitive for all users.

Reduce speed at conflict points

Reducing the speed differential between different road users helps to reduce the potential for collisions and reduce the severity of injury when collisions do occur. This can include using signage, pavement markings, and geometric design elements such as reducing corner radii and raised crossings to encourage reduced speeds for motor vehicles and people cycling.

Ensure clear sightlines

Sightlines appropriate for the intersection approaches and crossing areas must be provided for all users. Providing clear sightlines ensures that all users have sufficient decision and reaction time to stop or yield to conflicting traffic. Sightlines are especially important at uncontrolled intersections to ensure that all users can see each other upon approaching and entering the intersection.

Make intersection as compact as possible

Compact intersections can enhance safety for active transportation users by increasing visibility for all modes, reducing the exposure of people walking and cycling to motor vehicles, and slowing motor vehicle speeds at conflict points. Intersections may be made more compact by reducing corner radii, limiting the use of dedicated turn lanes, and removing channelized right turn lanes where feasible. Careful consideration should be given to the intersection design vehicle as well as motor vehicle volumes and turning movements prior to implementing any of the above treatments.

DESIGN CONSIDERATIONS

The following variables should be considered when designing intersections and crossing points:

- **Universal accessibility:** Design elements that facilitate access for people with all forms of physical and cognitive impairments should be included. Elements such as detectable surfaces, audible cues, curb ramps, smooth surfaces, and other accessibility features can ensure that all people can safely navigate an intersection or crossing. More detailed guidance on universal design is provided in **Chapter B.3**.
- **User types and volumes:** User types and volumes influence signal timing, user delay, facility width, and safety considerations, including the frequency of conflicts. Active transportation facilities adjacent to roadways with high motor vehicle volumes and/or high numbers of heavy trucks or transit vehicles require careful consideration. High volumes of people walking and/or people cycling also carry unique design considerations.
- **Design speed:** Design speed impacts sightlines, stopping distances, and collision severity. Design elements should be implemented at intersections and crossing points to reduce user' speed to an appropriate level.
- **Traffic controls, signage, and pavement markings:** Traffic controls, signage, and pavement markings should be applied in a consistent manner along corridors and at intersections. This will better meet user's expectations and can lead to improved compliance.
- **User delay:** Facility design should consider user delay for all modes and should balance the impact between them. If any user groups experience unacceptable levels of delay, it can lead to frustration and non-compliant behaviour, which in turn creates safety risks. Along major active transportation routes, active transportation users should be prioritized wherever feasible through favourable signal timing and traffic controls.
- **Topography:** The existing slope of the intersection approaches will impact available sightlines as well as the approach speed for people cycling and for motorists.
- **On-street parking:** On-street parking can act as a buffer between active transportation users and motor vehicle traffic. However, it can reduce sightlines near intersections and crossings, can result in increased crossing distances, and can create conflicts between people cycling and people entering or exiting motor vehicles. It may be necessary to consolidate or remove on-street parking at intersections (including at laneways, driveways, and mid-block crossings) to make active transportation facilities safer and more visible. Consolidation or removal of on-street parking stalls must be done with careful consideration of the surrounding context. On-street parking should not be prioritized over active transportation user safety.
- **Transit stops:** Transit stops are typically found near intersections and can create conflicts between transit vehicles, transit users, and people walking or cycling. Factors impacting designs include the location and type of transit stops, frequency of transit vehicles, number of boarding and alighting transit users, available right-of-way, and assignment of right-of-way in the conflict area. **Chapter H.1** provides further guidance on transit stop design in relation to active transportation facilities.

- **Lighting:** Where feasible, lighting should be provided along the entire active transportation facility. Where this is not feasible, key portions of the facility should be prioritized. Intersections and crossing points in particular need to be adequately lit for all modes to ensure the visibility of all users, clear sightlines, and an appropriate amount of contrast between surface treatments. **Chapter H.4** provides further details regarding lighting design.
- **Drainage and maintenance:** Drainage and maintenance should be considered up front in the design process to ensure that issues can be avoided. Proper maintenance ensures that all users can safely navigate the intersection in all seasons and at all times of the day. Drainage and maintenance are especially important to consider when implementing physical elements such as refuge islands and protected intersections.

Vancouver, B.C.

INTERSECTION & CROSSING TYPES

Intersections

An intersection is defined as the convergence of two or more roads. Intersections are focal points for activity and multi-modal interactions. Geometric design elements and traffic controls, including signage and pavement markings, are crucial for enabling all road users to safely navigate intersections. Design guidance for intersections is provided throughout each Chapter in **Section G**.

Laneway and Driveway Crossings

Laneways and driveways are minor crossing points, with motor vehicles having to cross over active transportation facilities before entering the road. Motorists are legally required to stop before exiting However, in places where motor vehicle encroachment into the Pedestrian Through Zone or Bicycle Through Zone is an issue, additional traffic control signage and pavement markings can be installed to reinforce that people walking, cycling, and using other forms of active transportation have right-of-way. Additional design guidance for pedestrian crossings at laneways and driveways can be found in **Chapter G.3.** Chapter G.4provides additional design guidance for bicycle facility crossings at laneways and driveways.

Mid-Block Crossings

Mid-block crossings are installed where there is demand to cross a road away from an intersection. Mid-block crossings are typically used along off-street pathways and can increase active transportation network connectivity and user convenience. However, special consideration must be given to ensuring that there are adequate sightlines and yielding expectations for both motorists and pathway users. **Chapter G.5** provides design guidance on mid-block crossings for off-street pathways.

Grade Separated Crossings

Grade separation of active transportation facilities from motor vehicle traffic improves safety and allows for the uninterrupted flow of both motorists and active transportation users. However, grade separation requires additional space, higher construction and maintenance costs, and can result in a more indirect active transportation route, which can be a deterrent for use. **Chapter G.6** provides design considerations regarding grade separated crossings.

Alleyway crossing along protected bicycle lane, Vancouver, B.C.

CROSSING CONTROLS

There are three levels of crossing control that can be applied at intersections and crossing points:

- Uncontrolled;
- Stop or Yield control; and
- Signal control.

The choice of crossing control depends on a number of factors, including: road geometry, road classification, collision history, sightlines, motor vehicle volumes, and the number of people walking and cycling. The TAC *MUTCDC* and *Pedestrian Crossing Control Guide* have established warrants (selection criteria) for the use of various traffic control devices. These warrants provide decision support (typically in the form of numeric criteria) for whether or not a traffic control device is justified in a given context and, if justified, what type of control should be used. B.C. specific guidance is also provided in the MOTI *Manual of Standard Traffic Signs & Pavement Markings*, *Pedestrian Crossing Control Manual for British Columbia*, and Section 400 of the *Electrical and Traffic Engineering Manual*.

Warrants help to promote consistency in design and installation. However, warrants are not a substitute for professional judgement, and the installation of a warranted device does not guarantee an active transportation user's safety. In order to provide flexibility in decision making, a holistic and systematic approach to choosing traffic controls that incorporates both numeric criteria and qualitative engineering judgement is recommended.

SIGHTLINES

Intersection Sight Distance

Intersection sight distance considers approach sight triangles and departure sight triangles to assess the necessary sightlines at an intersection. A sight triangle is formed by the line of sight and the sight distances of people driving, cycling, and walking that are approaching an intersection from two intersecting roads. In areas with greater volumes of active transportation users, sightlines should be maximized, and consideration should be made to lower the posted speed limit if the target design speed is lower than posted. Implementing other measures to reduce speed will also support safety at intersections.

Figure G-71 shows typical approach sight triangles for viewing cross traffic approaching from the left and the right for a motor vehicle approaching an uncontrolled or yield-controlled intersection, while **Figure G-72** shows the typical *departure sight triangles* to the left and the right for a motor vehicle stopped on the minor road or facility. The decision point shown is the location where the user on the minor facility should brake in order to stop before conflicting with a user along the major road. This sight triangle can be applied at both intersections and mid-block crossings. These figures are intended only to introduce this concept at a high level. Design professionals should refer to section 9.9.2 of the TAC *Geometric Design Guide for Canadian Roads* for details for determining appropriate sight distances and sight triangles. Sight triangles should be clear of any obstructions such as on-street parking, barriers, and street trees in order to ensure that road users have enough time to perceive and react to potential crossing traffic. Where fixed objects such as signs, buildings, or other obstructions cannot be removed, consideration should be made to implement other measures to increase awareness of active transportation users approaching the intersection. Traffic controls may also be installed to improve safety when fixed objects (such as retaining walls) cannot be removed.

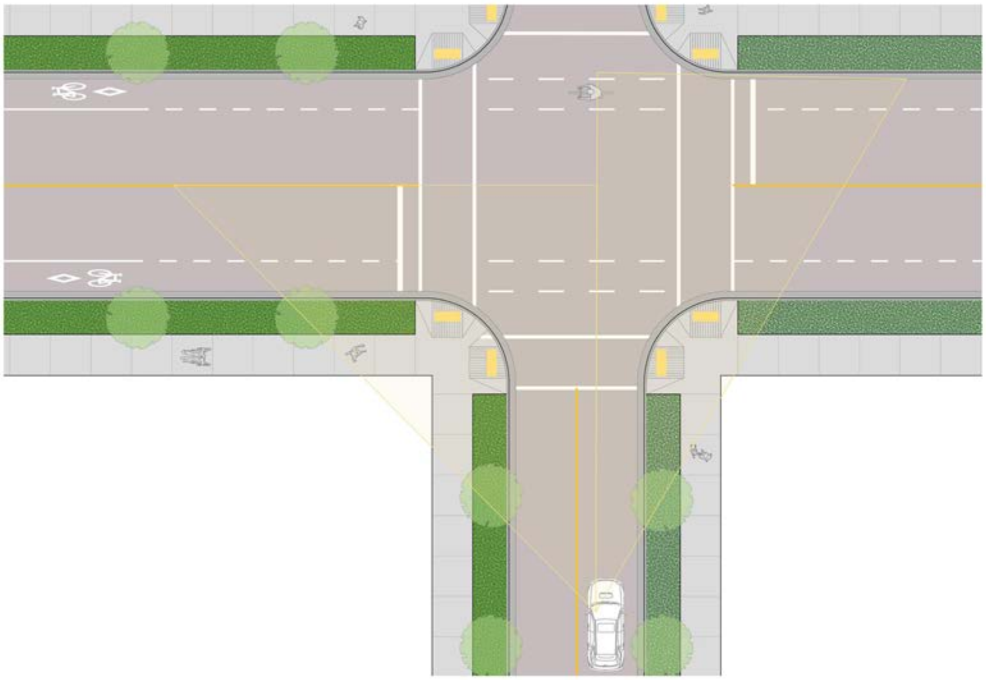


Figure G-71 // Approach Sight Triangle

Source: Adapted from TAC *Geometric Design Guide for Canadian Roads*, Figure 9.9.1

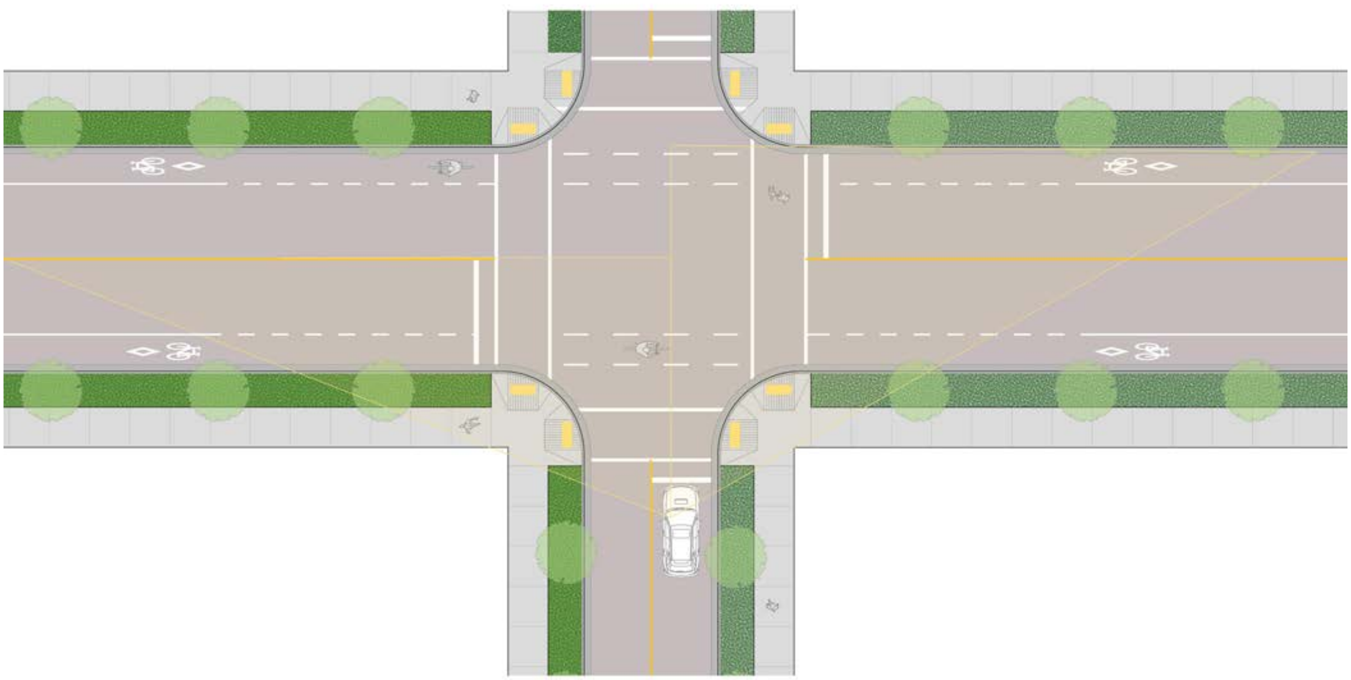


Figure G-72 // Departure Sight Triangle

Source: Adapted from TAC *Geometric Design Guide for Canadian Roads*, Figure 9.9.2

For motorists crossing from a minor road at a stop-controlled approach, it is important that the departure sight triangle to the people cycling and to motorists on the major road be met. If the stopped motorist must enter the crossing path of the active transportation facility in order to achieve the necessary sightline to cross the major road, then signalization should be considered.

Sightline considerations can vary depending on the type of maneuver being conducted in the intersection. For example, for motorists turning left on a two-way road, the provision of adequate sightlines may be insufficient to mitigate conflicts with people walking and cycling on the far side of the intersection. Left turning motorists will be looking for gaps in motor vehicle traffic flowing in the opposing direction, so they may not be paying attention to crossing active transportation users. Additional measures to minimize conflict can include protected signal phasing, conflict markings, and raised crossings.

Stopping Sight Distance

Stopping sight distance is relevant for people cycling and using other active modes other than walking. Minimum stopping sight distance for people cycling is the distance required to bring the bicycle to a controlled full stop. Stopping sight distance is a factor of the bicycle user's speed, the surface material and condition (friction between the tires and surface), bicycle user's perception-reaction time, and facility grade.

The stopping sight distance can be greater for bicycle users than motor vehicle drivers, especially on downgrades, and needs to be considered in the design of bicycle facilities. Skateboards, in-line skates, and other active modes all have slightly different stopping characteristics and should be considered where these modes are expected to make up a large proportion of users.

Section 5.5 of the TAC *Geometric Design Guide for Canadian Roads* provides more details on how to determine the minimum stopping sight distance for bicycles. The stopping sight distance is determined by the formula to the right:

$$SSD = 0.694V + \frac{V^2}{255\left(f + \frac{G}{100}\right)} \quad (5.5.1)$$

Where SSD = stopping sight distance (m)
V = design speed or velocity (km/h)
f = coefficient of friction
G = grade (m/m; % upgrade is positive and downgrade is negative)

The first term in the expression is the distance travelled during a perception-reaction time of 2.5 seconds. The second term is the distance travelled after brakes are engaged.

Source: TAC *Geometric Design Guide for Canadian Roads*, Chapter 5

Table G-1 outlines minimum stopping sight distances for bicycles travelling at a range of speeds, from 10 km/h to 50 km/h. It also shows grades up to 12% on a paved surface under wet conditions. For bi-directional bicycle facilities, the values for the descending direction control the design. A coefficient of friction (f) of 0.25 is recommended for paved surfaces, as this accounts for the poor wet weather braking characteristics of many bicycles.

Curb Radius

The size of the curb radius (also known as corner radius) is an important intersection design consideration that influences the turning speed of motor vehicles, intersection sightlines, and pedestrian comfort and safety. **Figure G-3** shows a curb radius of 3.0 metres. **Figure G-3** also shows the *effective curb radius*, which is the radius of a motor vehicle's path of travel when turning at an intersection. The effective curb radius is related to the design vehicle and intersection geometry, and is typically larger than the curb radius. On narrower roads with curbside travel lanes or roads with curb extensions, the effective curb radius will parallel the curb radius. The presence of on-street parking, bicycle lanes, and multiple receiving lanes can contribute to larger curb radii. Larger vehicles such as trucks, buses, and fire trucks have larger turning radii. Refer to **Chapter G.3** for examples of how different curb radii impact intersection geometry and turning radius.

TABLE G-30 // MINIMUM STOPPING SIGHT DISTANCE FOR BICYCLES (PAVED SURFACE, WET CONDITIONS)

MINIMUM STOPPING SIGHT DISTANCE (M) WITH COEFFICIENT OF FRICTION OF F=0.25									
	DESIGN SPEED (KM/H)								
Grade (%)	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
12	8	13	18						
10	8	12	18	24					
8	8	13	19	25	32				
6	8	13	19	25	32	40			
4	8	13	19	26	33	41	49		
2	8	14	20	26	34	42	51	61	
0	9	14	20	27	35	44	53	63	74
-2	9	14	21	28	36	45	55	66	77
-4	9	15	21	29	38	47	58	69	81
-6	9	15	22	30	39	50	61	73	86
-8	9	16	23	32	42	53	65	78	92
-10	10	16	24	34	44	56	70	84	100
-12	10	17	26	36	48	61	76	92	110

Source: TAC *Geometric Design Guide for Canadian Roads*, Table 5.5.1

Smaller curb radii (≤5.0 metres) have a number of benefits, including:

- Facilitating shorter pedestrian crossing distances;
- Enabling better alignment between the Pedestrian Through Zone, curb ramp, and crosswalk, resulting in a more direct crossing;
- Providing more pedestrian queuing space at the curb, which is especially important in areas with higher pedestrian volumes;
- Making pedestrians crossing and waiting on the corner more visible to motorists; and
- Slowing motor vehicle turning speeds, as a sharper turning motion is required.

As the curb radius increases, pedestrian crossings either become longer or less direct, which can result in lower compliance to crossing within the crosswalk. Indirect crossings are also challenging for people with vision impairments.

Intersection and curb radius design must consider the design vehicle, control vehicle, and managed vehicle that will be using the intersection.

- The **Design Vehicle** is the largest and least manoeuvrable user or vehicle that *frequently uses the road*. The design vehicle directly influences road and intersection design. For more information on design vehicles for roadways under provincial jurisdiction,, see Section 720 of the MOTI *Supplement to TAC Geometric Design Guide*.
- The **Control Vehicle** is the largest and least manoeuvrable user or vehicle that will *infrequently use the road*. It should be accommodated, but not prioritized – the control vehicle may need to operate at lower

speeds and take wide or multi-point turns. For example, along a transit route or designated truck route, a large design vehicle such as truck should be chosen. However, on a local road with no transit, a smaller design vehicle may be appropriate (such as a fire truck).

- The **Managed Vehicle** is the most common vehicle to use the road. It is typically smaller than the design vehicle, which means it is capable of higher turning speeds. In most contexts, personal vehicles are considered the managed vehicle.

When designing an intersection, design professionals should aim to use the smallest possible curb radius that still meets the context and the needs of the design vehicle. Using a smaller curb radius enables the provision of pedestrian benefits without negatively impacting motor vehicle movements. However, careful consideration is required – the curb radius size should be forgiving enough that larger design vehicles do not over-track and hit the curb or any active transportation users. **Chapter G.3** describes strategies to enhance pedestrian crossings by reducing curb radii and using other tools such as curb extensions and median refuge islands.

Emergency vehicle access is an important consideration in all road and intersection designs. Mitigation techniques can be used to accommodate larger control vehicles such as fire trucks and delivery trucks at intersections with small curb radii. These techniques include mountable curb aprons and advance stop bars on cross roads, which enable larger vehicles to encroach into other lanes of travel to complete a wide turn. Flexible bollards and other devices can also facilitate emergency movements while controlling regular motor vehicle movements.

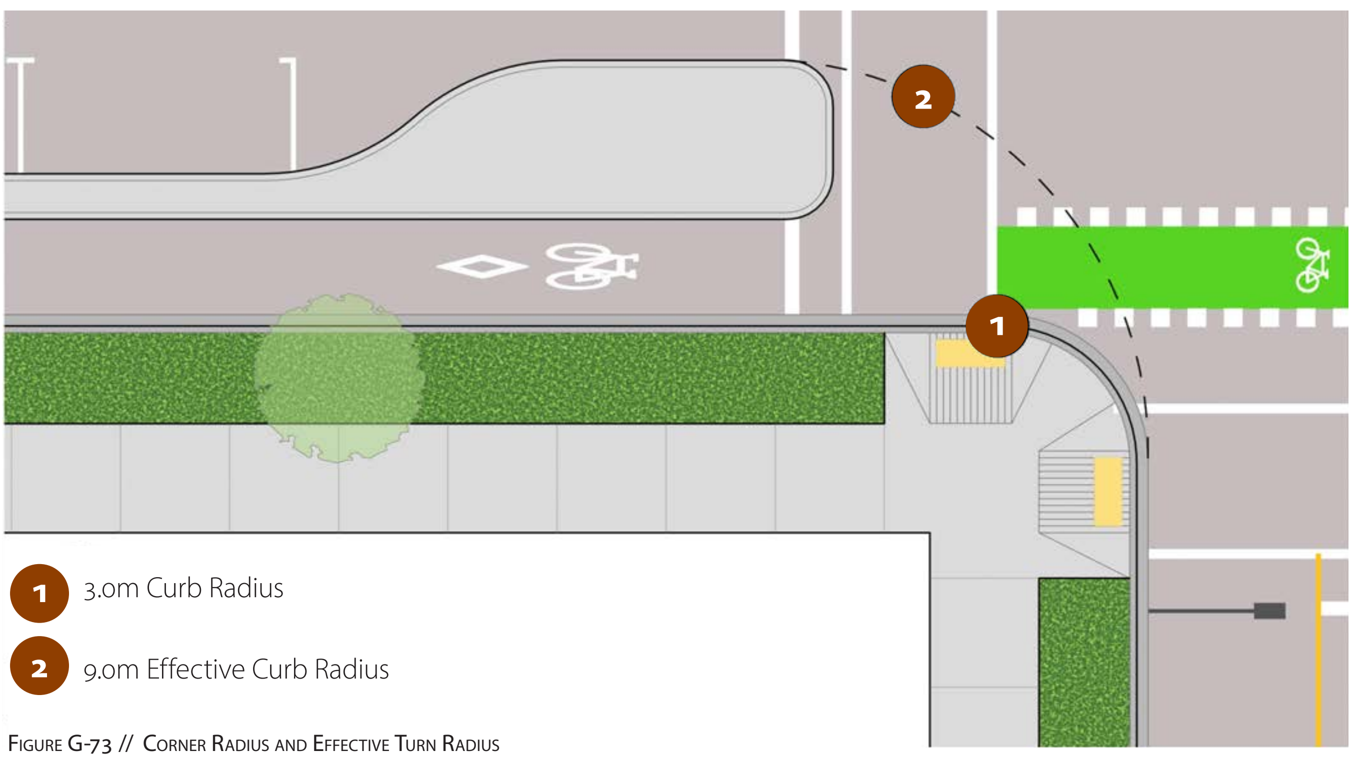


Figure G-73 // Corner Radius and Effective Turn Radius

Temporary Curb Radius Retrofit

Where there is a desire to reduce the curb radius at an intersection but there is insufficient funding available to reconstruct the curb, a new curb radius may be delineated using temporary materials such as bollards, planters, and coloured pavement treatments. Interim curb extensions have been found to be a cost-effective measure to enforce traffic calming goals and create safer pedestrian environments[1]. However, the physical curb should be built as soon as funding is available, as this provides enhanced physical protection between pedestrians and motor vehicles.

Signage and Pavement Marking Considerations

Signage and pavement markings are crucial intersection elements that regulate all modes of travel and provide important warnings, wayfinding, and other information. There are two primary sources of signage in B.C. MOTI oversees the B.C. Provincial Sign Program and maintains the *Catalogue of Standard Traffic Signs and Supplemental Traffic Signs*, which apply on all roadways under provincial jurisdiction. Meanwhile, the TAC *MUTCDC* provides national guidance for the use of traffic control devices, including signage and pavement markings. TAC signage is typically used on roadways that are not under provincial jurisdiction.

The TAC *MUTCDC* and the B.C. Provincial Sign Program use different sign codes: for example, the sign code for a Stop sign is MUTCDC RA-1 (using TAC guidance), or B.C. R-001 Series (using the B.C. Provincial Sign Program). There is overlap between the two systems, but there are also signs that are unique to each system. There are also some signs that have similar meanings but different designs. Where two different codes exist for the same sign, each code has been referenced in the Design Guide. If the sign appears in only guide, that code has been referenced. Design professionals are encouraged to review each signage system and consider the jurisdiction and the most appropriate sign for each application.

It should be noted that the figures provided throughout **Section G** feature only signage and pavement markings that were particularly relevant to highlight specific to active transportation facility design. There are a number of other signs and pavement markings that are required along corridors and at intersections that may not be shown on the figures throughout **Section G**. Design professionals should consult relevant TAC or B.C. guidelines for a full set of required signage and pavement markings. **Appendix B** contains a full list of relevant signage and pavement markings used throughout the Design Guide, including dimensions.

1 Robert Kahn and Allison Kahn Goedecke, "Roadway striping as a traffic calming option," ITE Journal: 81 (September 2011)

Curb radius retrofit that uses flexible bollards and coloured pavement markings to delineate pedestrian space.

North Vancouver, B.C.

Vancouver, B.C.

G.2

SIGNALS + OTHER TRAFFIC DEVICES

Traffic signals and other traffic devices provide traffic control and warning at roadway and pathway crossings. There are a variety of types of signalized crossing systems that can be used to provide various levels of control or warning to gain motorists' attention. The needs of all road users need to be considered in the design of signals and other traffic devices, including people walking, cycling, driving, and using transit. This chapter summarizes considerations for people walking, cycling, and using other forms of active transportation with the design of signalized crossing systems. For projects on roadways under provincial jurisdiction, design professionals must be familiar with the MOTI *Electrical and Traffic Engineering Manual* and MOTI *Pedestrian Crossing Control Manual* to ensure consistency. Design professionals are reminded that any signal timing plans, particularly those involving bicycle signal phasing, shall be signed and sealed by a professional engineer experienced in traffic engineering.

TYPES OF SIGNALIZED CROSSING SYSTEMS

Traffic signals provide traffic control at roadway and pathway crossings. There are a variety of types of signalized crossing systems that can be used to provide various levels of control or warning to gain motorists' attention. These systems are described below. The advantages and disadvantages of each system are summarized in **Table G-31**.

Traffic Signals (Full Signals)

Traffic signals, which are also referred to as full signals, control all approaches and regulate which user can enter the intersection safely at a given time. Traffic signals are used at intersections between a combination of roads that are major and minor in functional classification. The installation of full traffic signals is determined by a warrant process and can be installed wherever warranted.

Pedestrian and Cycling Activated Signals (Half Signals)

Pedestrian and cycling activated signals are traffic signals that include all of the elements of a traffic signal, except for side road vehicle indications. Pedestrian and cycling activated signals are intended to facilitate pedestrian and cycling movements while controlling motor vehicle movements on only one road, rather than two or more roads. They can be used at the intersection of major and minor roads, or they can be used at major mid-block crossings. The decision to implement a traffic signal or a pedestrian and cycling activated signal is determined by a warrant process and can be installed wherever warranted.

Overhead Pedestrian Flashers

Overhead Pedestrian Flashers, also known as Special Crosswalks, are not a traffic signal but are instead a traffic device installed to enhance warning and awareness for motorists of a crosswalk at intersections and mid-block locations The system consists of an overhead illuminated Pedestrian Crossing sign (MUTCDC RA-5) with pedestrian-activated flashing amber beacons. Advanced warning signs and flashers can be installed where sightlines are constrained. Pavement markings and ground mounted signs also supplement the overhead flashers. At intersections, the flashers are typically only installed on one side. When used in conjunction with a bicycle crossing, a custom combined Pedestrian and Cyclist Crossing sign should be used.

Rectangular Rapid Flashing Beacons (RRFB) or Other Side Mounted Flashing Beacons

When activated, Rectangular Rapid Flashing Beacons (RRFBs) or other side mounted flashing beacons have flashing amber lights that alternate back and forth to attract motorists' attention, increasing yielding behaviour. When used, RRFBs or other side mounted flashing beacons should be installed with one on either side of the road and a two-sided RRFB in the median island, if a median exists. RRFBs or other side mounted flashing beacons can be used to mitigate conflicts at challenging crossings such as channelized right turn lanes and roundabouts. For additional information, refer to the TAC *Pedestrian Crossing Control Guide*.

Table G-31 // Advantages and Disadvantages of Signalized Crossing Systems

TYPE OF SIGNALIZED CROSSING	ADVANTAGES	DISADVANTAGES
Traffic Signal (Full Signal)	▪ All users are given a clear signal of when to cross and stop. ▪ Suitable for roads with higher volumes and larger cross sections. ▪ Ability to coordinate/delay/time the actuations and calls. ▪ May be accessible for all users.	▪ Highest installation costs due to more infrastructure required than other traffic devices. ▪ May impact traffic operations and result in delay and congestion.
Pedestrian and Cycling Activated Signal (Half Signal)	▪ People walking and people cycling are given a clear signal when to cross, and motorists on the major road see a conventional signal indicating when to stop. ▪ Suitable for roads with higher volumes and larger cross sections, where crossing opportunities are less frequent and where side mounted systems are less effective. ▪ Less delay for major streets as it is activated on demand only. ▪ Side road motor vehicle traffic can access major road from stop condition, typically with all movements, unless traffic diversion measures are installed (see **Chapter D.2**). However, this can create a conflict between turning motor vehicles from the side street and people walking and cycling proceeding straight through the intersection if motorists are not aware of the pedestrian and cycling indications.	▪ Lower installation cost than a traffic signal, but higher installation cost compared to other traffic devices. ▪ Increased delay for major roads compared to overhead pedestrian flashers or RRFBs. ▪ If located on transit routes, could impact the predictability of transit schedule as pedestrian and bicycle activation will slow motor vehicle traffic. ▪ May increase short-cutting motor vehicle traffic on minor side streets unless implemented with traffic calming and traffic diversion measures (see **Chapter D.2**). ▪ Some concerns of potential confusion with side road being stop controlled. Motorists and bicycle users are still legally required to stop before the intersection, even if the major street has a 'red/stop' condition. This can result in confusion and non-compliance.
Overhead Pedestrian Flasher	▪ Less delay for major road, as it is activated on demand only. ▪ Can be implemented when conventional signal warrant is not met or where a conventional traffic signal is not desired. ▪ Lower installation costs than traffic signals (full or half). ▪ Requires less infrastructure than traffic signals (full or half).	▪ Does not provide a 'red/stop' condition for motorists, and may lead to variation in motorist behaviour. ▪ No platooning of crossing users so unpredictable for motor vehicle traffic. ▪ Less visibility than a traffic signal.
Rectangular Rapid Flashing Beacon (RRFB) or Other Side Mounted Flashing Beacon	▪ Less delay for major road as it is activated on demand only. ▪ Can be implemented when conventional signal warrant is not met or where a conventional traffic signal is not desired. ▪ Requires less infrastructure than all other devices as beacons are side mounted. ▪ Lowest installation cost compared to other traffic devices.	▪ Does not provide a 'red/stop' condition for motorists, and may lead to variation in motorist behaviour. ▪ Wide roads can make side of road signing more difficult for drivers to see. ▪ No platooning of crossing users so unpredictable for motor vehicle traffic.

BICYCLE SIGNALS

A bicycle signal is a three-coloured traffic control device that can be used in conjunction with a traffic signal (see Figure G-4). The signal head can have a conventional circle with a supplementary Bicycle Signal sign (CUSTOM), or it can have a bicycle symbol for each signal with an optional supplementary Bicycle Signal sign (CUSTOM). Alternatively, bicycle traffic can also be controlled with pedestrian signal indications, with a custom Bicycle Use Pedestrian Signal sign as discussed below. See **Appendix B** for custom Bicycle Signal and Bicycles Use Pedestrian Signal custom signs.

Typical Application

There are various ways in which the movement of people on bicycles through an intersection can be controlled using traffic signals. For uni-directional bicycle facilities, bicycle movements often follow motor vehicle traffic signals or pedestrian signals. However, a separate bicycle signal may be installed to provide guidance to bicycle users at intersections where they have different needs from other road users. A separate bicycle signal head and phase may also be used at locations to improve safety or operational concerns, such as where sightlines may not be achieved, where there is a high volume of conflicts with motor vehicles turning, or when there is a bi-directional bicycle facility. A review of existing motor vehicle volumes, traffic signal equipment, and traffic signal timing and phasing should be completed prior to the installation of bicycle signals to ensure that a separate signal phase can be accommodated. Guidance on separate signal phasing is provided in further detail below.

Bicycle Signal Placement

Bicycle signals should be placed in combination with existing signal infrastructure where possible to reduce the number of poles required at the intersection. Co-location of equipment reduces obstructions and improves sightlines. The bicycle signal head should be visible to people cycling, and the placement should not physically impede people walking.

Bicycle signals are typically side mounted on the far side of the intersection within 1.5 horizontal metres of the edge of the bicycle facility. The TAC *Traffic Signal Guidelines for Bicycles* indicates that if the far side of the intersection is greater than 30 metres from the stop bar of the bicycle facility, consideration may be given to the use of 300 millimetre bicycle signal lenses or the installation of a supplementary bicycle signal on the near side of the intersection or on the median of the intersecting road.

The TAC *Traffic Signal Guidelines for Bicycles* also suggests that a near side bicycle signal can include smaller 200 millimetre bicycle signal lenses that are mounted in combination with a supplemental Bicycle Signal sign (CUSTOM). In the United States, the MUTCDC Interim Approval on bicycle signals allows a 100 millimetre bicycle signal head to be used as a supplementary nearside indication. This can be used to increase understanding that bicycle signals are only for people cycling. Overhead bicycle signals can be considered if practical and only when side mounted bicycle signals are not feasible. **Figure G-5** shows an example of the recommended placement of traffic signals and bicycle signals.

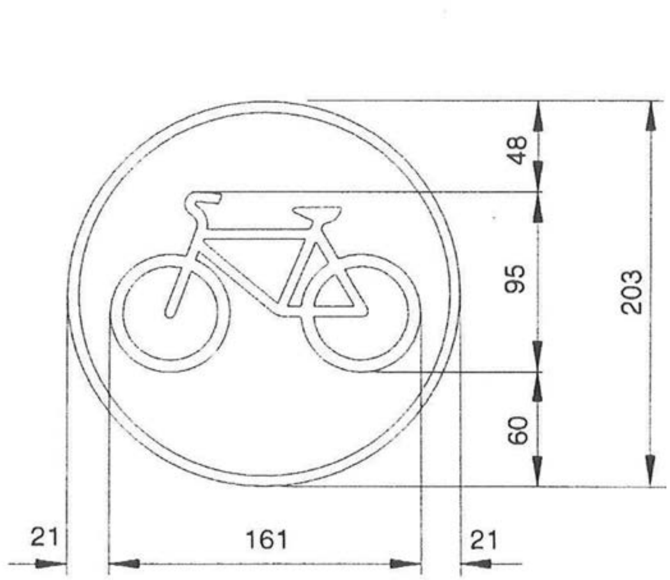


FIGURE G-74 // BICYCLE TRAFFIC SIGNAL HEAD DISPLAY[2]

***Note: All dimensions are in mm*

2 2014 TAC Traffic Signal Guidelines for Bicycle, Chapter 3, Figure 3.1, Page 9 (Original Source: Ministère des Transports du Quebec)

Use of Different Types of Signal Heads for Bicycle Users

Movements through intersections for people cycling are most commonly controlled by the vehicular signal head. Where it is necessary or desirable to control a bicycle movement separately from motor vehicle traffic, people cycling can be controlled by a traffic signal head designated for bicycle use with a custom supplementary Bicycle Signal sign, a bicycle signal head, or a pedestrian signal head with supplemental signs that indicate that people cycling should use the pedestrian signal. Each of these three options are described below. Along a corridor, it is recommended that traffic signal indications for bicycle users are consistent and as uniform as possible. Design professionals are reminded, however, that traffic signals with a bicycle signal head are not currently recognized as a traffic control device in the *B.C. MVA* and, as such, have no legal meaning under current legislation. In addition, traffic signals with a bicycle signal head cannot currently be used for facilities on roadways under provincial jurisdiction.

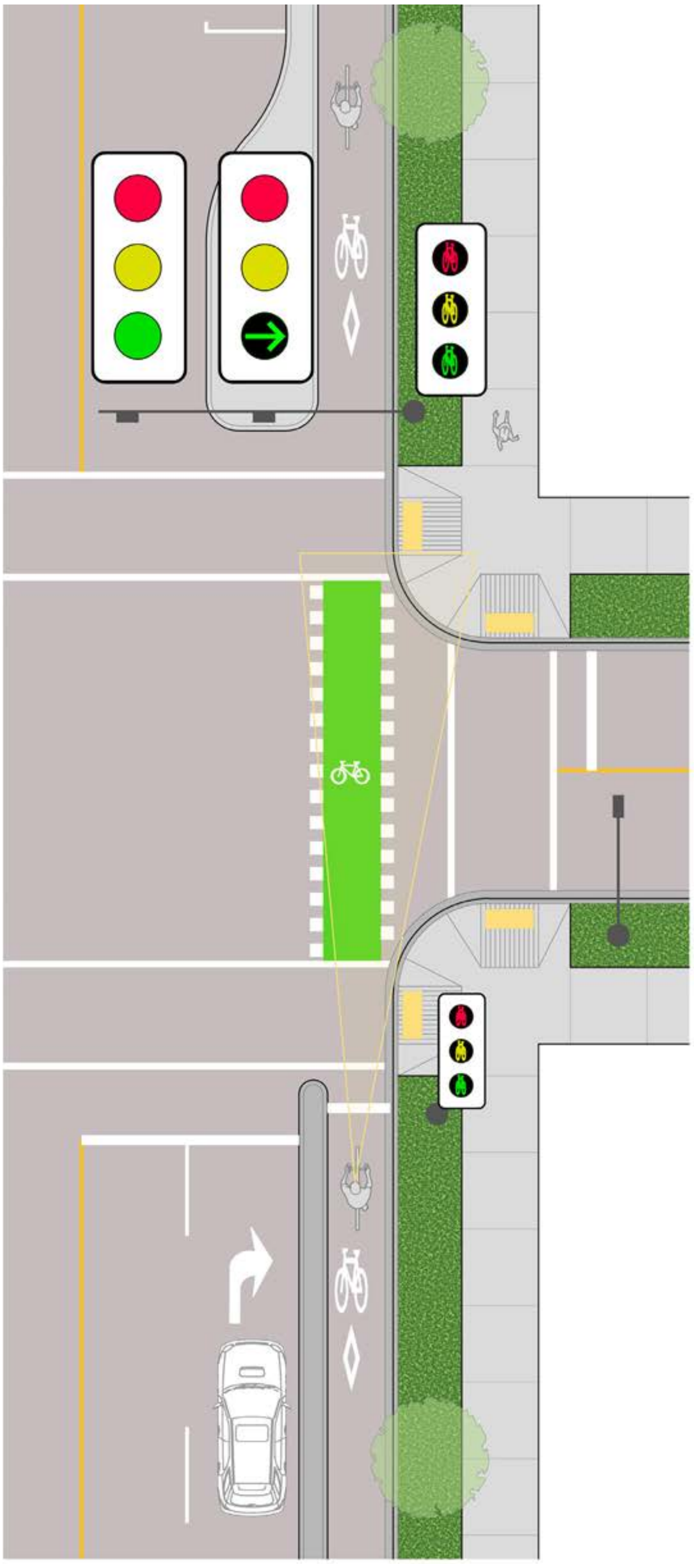


Figure G-75 // Bicycle Signal Placement

Standard Traffic Signal Head Designated for Bicycle Use

A vehicular traffic signal head may be designated for bicycle users by mounting a Bicycle Signal sign (CUSTOM) adjacent to the traffic signal. This may be beneficial at locations where:

- It is necessary to add a signal head where people cycling cannot see existing vehicle signal faces;
- Bicycle users have a separate directional movement, phase, or interval; and
- It is desired to maximize the time a bicycle user may legally enter a crosswalk.

In situations where motorists and bicycle users are on the same parallel approach and on different phases, design professionals should minimize confusion of similar traffic signal displays for approaching road users. Using geometrically programmed louvers can be useful in this regard. Additionally, visual variation in signal head housing for the vehicular signal head designated for bicycle users can increase contrast and awareness and reduce confusion.

Traffic signal heads or bicycle signal heads must be visible to approaching bicycle users. At least one signal head should be visible for a minimum of 30 metres before the stop line based on stopping sight distance for a bicycle traveling at 25 km/h. Where cycling approach speeds are higher, the approach visibility should be lengthened to match the minimum stopping sight distance required for the higher bicycle approach speed. Where bicycle users do not have a continuous view of the signal for the minimum sight distance, a Signal Ahead sign (MUTCDC WB-4; B.C. W-012 Series) should be installed warning of the approaching signal. Where existing vehicle traffic signal heads are anticipated to be the sole source of guidance for people cycling, design professionals should check that the signal faces are located within the cone of vision measured from the bicycle stop line as described in the MUTCDC. If the vehicle signal heads fall outside the cone of vision, supplementary vehicular or bicycle signal faces should be provided. The cone of vision from the bicycle facility is especially important to consider in locations where contraflow or bi-directional bicycle facilities operate on one-way roads. It may be necessary to install new signal faces that are visible to approaching bicycle users

Bicycle Signal Heads

A bicycle signal head can include bicycle symbols on the lenses. However, as noted above, traffic signals with a bicycle signal head are not currently recognized as a traffic control device in the *B.C. MVA* and, as such, have no legal meaning under current legislation. Traffic signals with a bicycle signal head cannot currently be used on roadways under provincial jurisdiction. Local and regional governments should only consider the installation of bicycle signals based on sound engineering and legislative review. Guidelines for application of bicycle signal heads are the same as described above for standard vehicular traffic signal heads with a supplementary Bicycle Signal sign (CUSTOM).

In the B.C. context, common applications of bicycle signals are the use of 200 millimetre and 300 millimetre signal lenses, with the most common being the use of 300 millimetre signal lenses. The recommendation is to provide 300 millimetre signal lenses on the far side of intersections and 100 millimetre signal lenses on the near side of intersections.

Traffic signal mounting heights are based on the type and location of poles and the size of traffic signal heads chosen. Bicycle signal heads should ideally be mounted in line with the bicycle facility. However, there are cases where the conspicuity of the bicycle signal is better mounted adjacent to the bicycle lane. Bicycle signal heads must be mounted so that they do not result in obstructions in the right-of-way for people cycling or walking.

If a 100 millimetre bicycle signal lens is used as a near side supplemental signal, the bottom of the signal housing should be between 1.2 metres and 2.5 metres above the ground. The bicycle signal head should be oriented to maximize visibility to approaching bicycle traffic.

Pedestrian Signal Heads

The use of pedestrian signal heads with a supplemental Bicycles Use Pedestrian Signal sign (CUSTOM) that indicates that people cycling should use the pedestrian signal can be an acceptable alternative for controlling bicycle traffic depending on the local bylaws and regulations associated with bicycle travel. However, due to the inherent conflict in the rights and responsibilities of people walking and cycling in crosswalks, bicycle signal heads are considered the preferred treatment where possible. Bicycle users who operate on multi-use pathways with pedestrians and other active users may be allowed to operate on sidewalks. It should be noted that the *B.C. MVA* indicates that cyclists may not ride on a sidewalk unless authorized by a bylaw made under *B.C. MVA* Section 124 or unless otherwise directed by a sign. In these scenarios, people cycling must follow the indications of pedestrian signal heads where they are crossing in crosswalks unless a traffic signal head or bicycle signal head is located for people cycling.

People cycling can be directed to follow pedestrian signal heads in the following situations:

- Where people cycling are operating in a protected bicycle lane within the roadway and bicycle users cannot see motor vehicle signal heads; or
- Where bicycle users have a separate directional movement, phase, or interval from vehicle movement; To do this, the Bicycles Use Pedestrian Signal sign (CUSTOM) should be mounted adjacent to the pedestrian signal head. Care should be taken to ensure the pedestrian indication is visible to people cycling.

Where people cycling are directed to follow a pedestrian signal, they are only legally allowed to ride in the crosswalk if authorized to do so by local or regional government bylaw. In such cases, they may enter the crosswalk during the walk indication, as the *B.C. MVA* restricts users from entering an intersection

Near side bicycle signal with 100 millimetre lens, Portland, OR during a Flashing "Don't Walk" interval. However, research has found that some bicycle users that see a Flashing "Don't Walk" may still be likely to use this interval to enter the intersection during this indication because it is timed for pedestrians who move much more slowly than people cycling Caution should be exercised when using pedestrian signals to provide guidance to people cycling at locations with long crossings or unique signal timing phases.

Signal Phasing

Traffic signal phasing represents the method by which a traffic signal divides the overall signal cycle to accommodate the turning movements of various users at an intersection. The signal phasing establishes the movements and users that are allowed to operate together at intersections. A phase consists of the necessary intervals of green, yellow, red, Walk, and Don't Walk assigned to a particular traffic movement or combination of movements (i.e. pedestrian crossing, left turn movement, combined left turn and through movements). Evaluating signal phasing options requires an assessment of the benefits of a separate phase and the resulting trade-offs that a protected phase has on efficiency. There are also the other factors that must be considered, including:

- Turning versus opposing through volumes;
- Number of opposing lanes (through or adjacent/turning);
- Cycle length and resulting delay;
- Speed of opposing traffic;
- Sight distance;
- Collision history or potential for future collisions;
- Conflicts (turning paths) between motorists and people cycling; and
- Continuity of bicycle system and proximity to schools, parks for all users and abilities.

Thresholds for Separate Phases

The decision to provide a separate bicycle phase should be based on a need to eliminate conflicts and improve safety at an intersection. **Table G-32 and G-33** provide recommended traffic thresholds in terms of motor vehicles per hour turning across a protected bicycle lane for lower speed and higher speed streets, respectively. These thresholds determine when a time-separated bicycle movement should be considered. At locations where bicycle volume varies and may not meet the minimum required levels whereby bicycle users may not be present each cycle, detection should be used to skip a bicycle phase if not already designed to do so as part of full signal timing plans for fully actuated signals. It should be noted that the volume thresholds for permissive conflicts are lower if a vehicle is crossing a bi-directional protected bicycle lane compared to a uni-directional protected bicycle lane. For left turns on two-way roads, the thresholds vary depending on the number of opposing through lanes. Research shows that as the workload increases for motorists to look for gaps in approaching traffic, they are less likely to be looking towards the crosswalk or left side of the roadway for approaching cyclists or pedestrians.

Table G-32 // Considerations for Time-Separated Bicycle Movements - Low Speed Streets (50km/hr and below)

PROTECTED BICYCLE LANE OPERATION	MOTOR VEHICLES PER HOUR TURNING ACROSS PROTECTED BICYCLE LANE			
	Two-Way Motor Vehicle Road			One-Way Motor Vehicle Road
	Right Turn	Left Turn Across One Lane	Left Turn Across Two Lanes	Right of Left Turn
Uni-Directional	250	150	50	250
Bi-Directional	150	100	0	150

Table G-33 // Considerations for Time-Separated Bicycle Movements – High Speed Streets (>50 km/hr)

PROTECTED BICYCLE LANE OPERATION	MOTOR VEHICLES PER HOUR TURNING ACROSS PROTECTED BICYCLE LANE			
	Two-Way Motor Vehicle Road			One-Way Motor Vehicle Road
	Right Turn	Left Turn Across One Lane	Left Turn Across Two Lanes	Right of Left Turn
Uni-Directional	100	100	0	100
Bi-Directional	50	50	0	0

Bicycle signal with separated phase, Victoria, B.C.

MANAGING TURN CONFLICTS

Signal phasing is a critical element of intersection design to mitigate conflicts between users through separation in time. When considering signal operations, trade-offs between comfort and convenience need to be considered. Design professionals need to consider the various factors and trade-offs when determining how to best manage turn conflicts, including an analysis of corridor and signal timing, review of existing risks and issues at the intersection, and an understanding of how people using the street will respond to the signal phasing.

This section describes various signal phasing schemes that can be considered for reducing conflicts.

Where vehicle movements need to be managed and separate phases are not provided for turning movements, various geometric treatments can be considered to reduce motor vehicle speeds and increase sight distance. Turn conflicts can also be mitigated by time of day restrictions for movements. At locations where conflicts are high and the provision of a separate phase is not feasible or desirable, the following should be considered:

- Install regulatory signs, such as the Turning Vehicles Yield To (or Stop For) Cyclists (or Pedestrians) sign (MUTCDC RB-37, RB-38);
- Install crossing islands, medians, or hardened centrelines to slow vehicle left turn speeds;
- Offset the bicycle crossing to create space for yielding (such as bend out elements of protected intersections and multi-use pathways as discussed in **Chapters G.4** and **G.5**); and
- Prohibit turns by time of day or when gaps are unavailable (through signal detection).

Signal Phasing Schemes for Reducing Conflicts

A bicycle signal phase at a signalized intersection can reduce conflicts between bicycle users and motor vehicles. Comparison of the operational and safety impacts of signal phasing changes are necessary in concert with necessary geometric modifications. Separated movements often require longer signal cycle lengths which may result in reduced user compliance with signal indications.

Case Study

Bicycle Countdown-to-Green Timers

Traffic signal countdown timers (TSCTs) are technologies to assist users in decision-making at signalized intersections with real-time signal duration information. These are commonplace in The Netherlands and Portland, Oregon has installed one in the United States. Traffic signals with countdown to green phase time or a 'WAIT' (WACHT) signal with a countdown circles have been used in the Netherlands with bicycle signals to allow people cycling the ability to make an informed decision on their approach speed and on whether to proceed.[1]

Bicycle signal with countdown timer, Amsterdam, NL

Bicycle signal with WAIT (WACHT) circle countdown to green, Amsterdam, NL
Source: Peter Koonce

1 Mohammad R.Islama, David S.Hurwitza , Kristen L.Macugab, "Improved driver responses at intersections with red signal countdown timers", Transportation Research Part C: Emerging Technologies, Volume 63, February 2016, Pages 207-221.

Exclusive Bicycle Phase

This phasing scheme represents a time-separated bicycle movement. All vehicle movements, including conflicting vehicle turns across the bicycle facility, are restricted during an exclusive bicycle phase (see **Figure G-76**). Exclusive turn lanes for the conflicting motor vehicle turns are not required since all motor vehicle movements are stopped. Some pedestrian movements may be allowed during the split bicycle phase. If bicycle users move independently of pedestrians, this phasing requires the use of a standard traffic signal head designated for bicycle use or a bicycle signal head that is separate from the motor vehicle signal. Alternatively, bicycle users may be directed to follow pedestrian signals during a shared protected bicycle and pedestrian phase. In this case a Bicycles Use Pedestrian Signal sign (CUSTOM) should be used. Right turn on red must be prohibited during the protected bicycle phase. The use of a blanket No Turn on Red (NTOR) sign (MUTCDC RB-17R) should be considered.

Depending on turning volumes, this phasing scheme is more likely to have an impact on motor vehicle operations. To accommodate queues due to an increase in overall inter-green time or cycle length, design professionals may consider the extension of turn lane storage lengths.

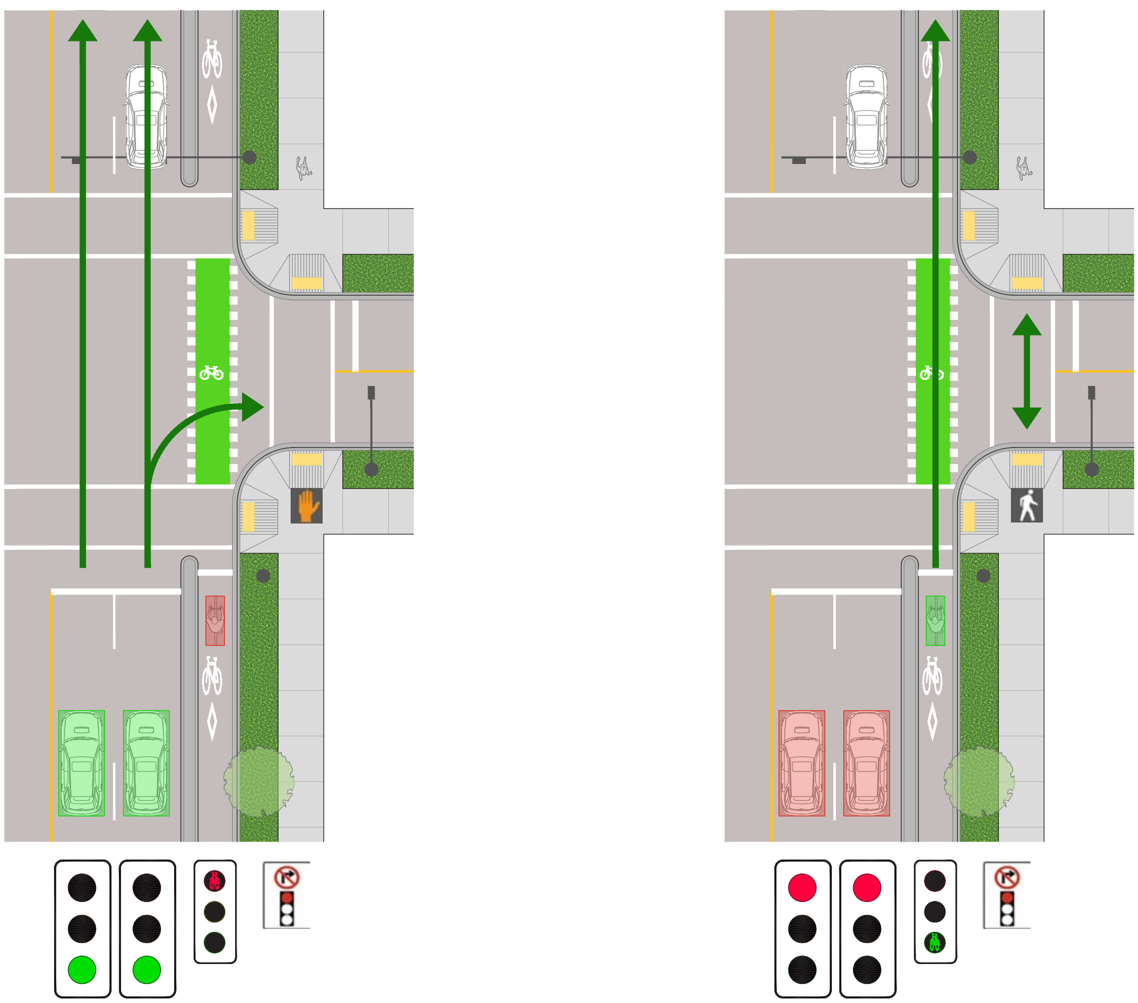


Figure G-76 // Exclusive Bicycle Phase (No Dedicated Right Turn Lane)

Concurrent Protected Bicycle Phase

This phasing scheme also represents a protected bicycle movement. The bicycle phase runs concurrently with parallel through vehicle phases, but conflicting vehicle turns across the bicycle facility are restricted (see **Figure G-77**). Turn movements across the bicycle facility operate under a protected only phase. The provision of exclusive turn lanes for the conflicting motor vehicle turns are desirable for the adjacent through movement while the turning movements are held. In this phasing scheme, a bicycle needs to be controlled by a signal head that is separate from the motor vehicle signal. Right (or left) turns on red should be prohibited during the protected bicycle phase. The use of a blanket No Turn on Red sign (MUTCDC RB-17R) should be considered. The reduction of split times for other phases may require an increase in the signal cycle length. This phasing scheme can be effective for bicycle facilities along roadways with high through movement volumes and low turning volumes.

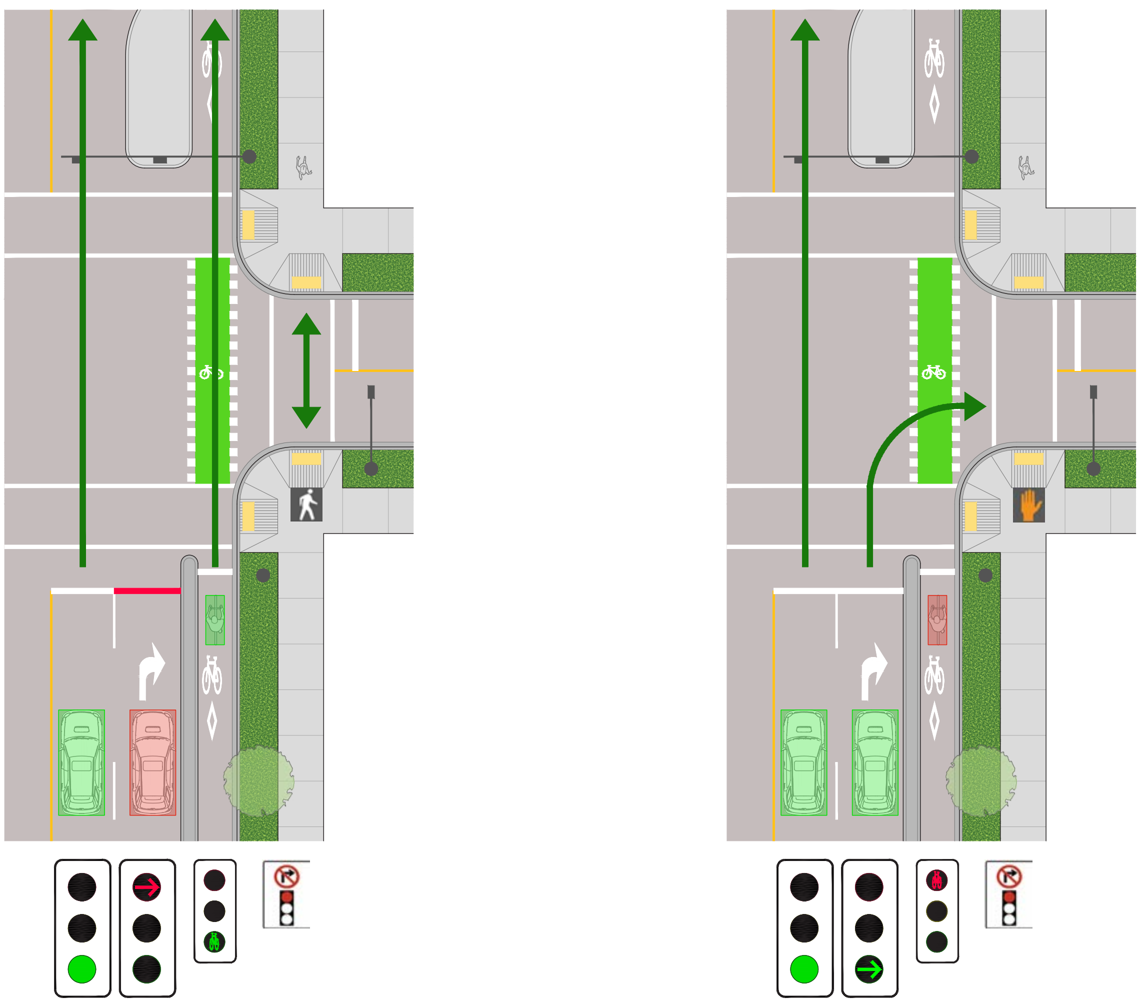


Figure G-77 // Concurrent Protected Bicycle Phase (With Dedicated Right Turn Lane)

Leading Bicycle Interval

At locations where bicycle volumes and/or motorist turning volumes are lower than the threshold to provide a protected phase, or at locations where provision of a protected phase is not feasible, leading bicycle intervals may be considered (see **Figure G-78**). This scheme represents a partially separated bicycle movement. Leading intervals are typically between 3 and 8 seconds long and occur in advance of the green indication for turning motor vehicles. A leading bicycle interval allows a bicycle user to enter the conflict area prior to a turning motorist, improving motorist visibility of the bicycle users A parallel leading pedestrian interval should also be considered where there is a parallel pedestrian crossing (see further details below). In this phasing scheme, a bicycle needs to be controlled by either the pedestrian WALK indication or via a separate signal head from the vehicle signal. Each of the three options outlined previously could be used. Right (or Left) Turn on Red must be prohibited during the leading bicycle phase8

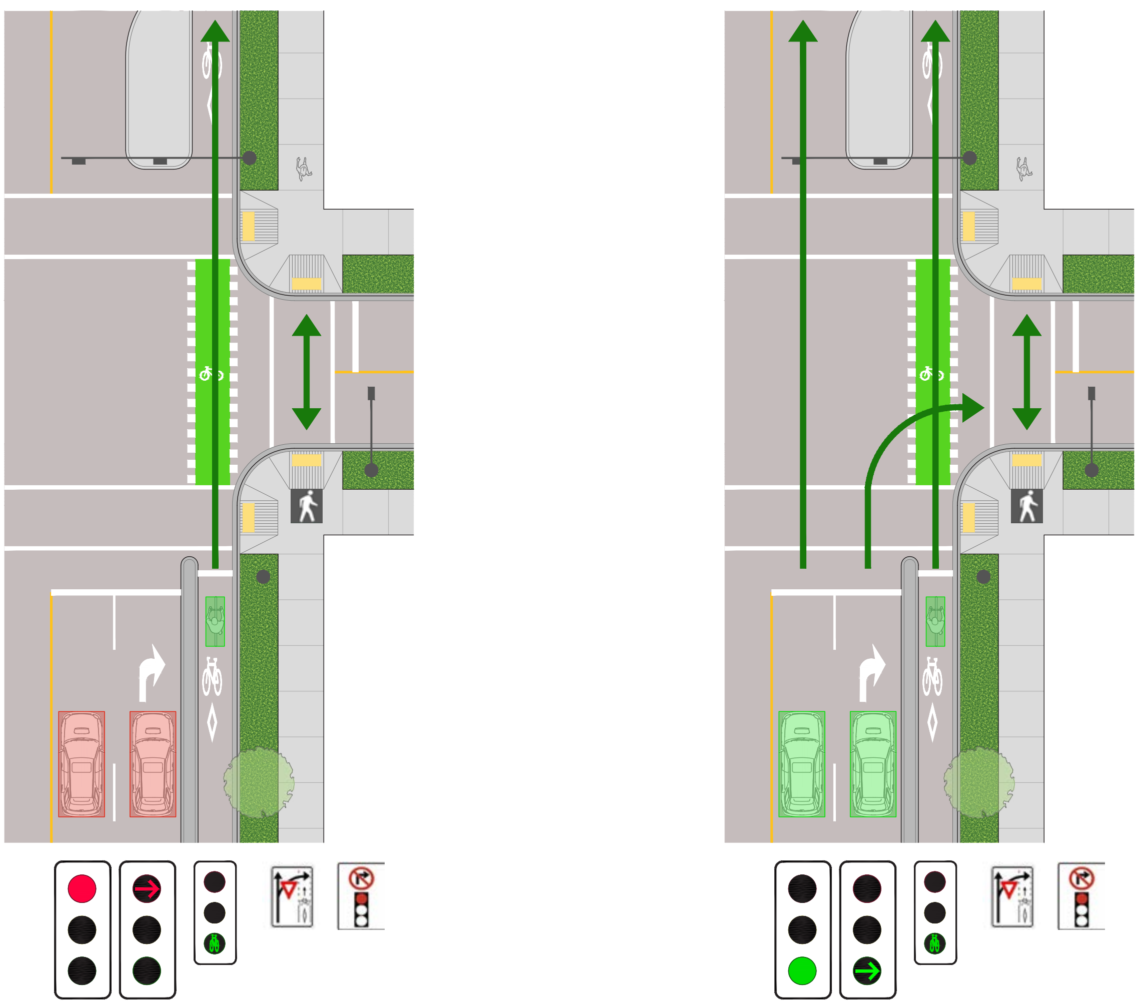


Figure G-78 // Leading Bicycle Interval (With Dedicated Right Turn Lane)

Concurrent Bicycle Phase with Permissive Vehicle Turns

This phasing scheme represents a common scenario at most intersections where bicycle users are not provided any exclusive time in the intersection. In this case, bicycle users are crossing the intersection concurrently with parallel through vehicles, and motorists can make permissive turns (see **Figure G-79**). This phasing scheme has the least impact on motor vehicle operations, but does not enhance bicycle users safety, although the conflict between turning motorists and through moving bicycle users is addressed with the yield requirement. Geometric and signing treatments should be considered with this phasing scheme to improve safety.

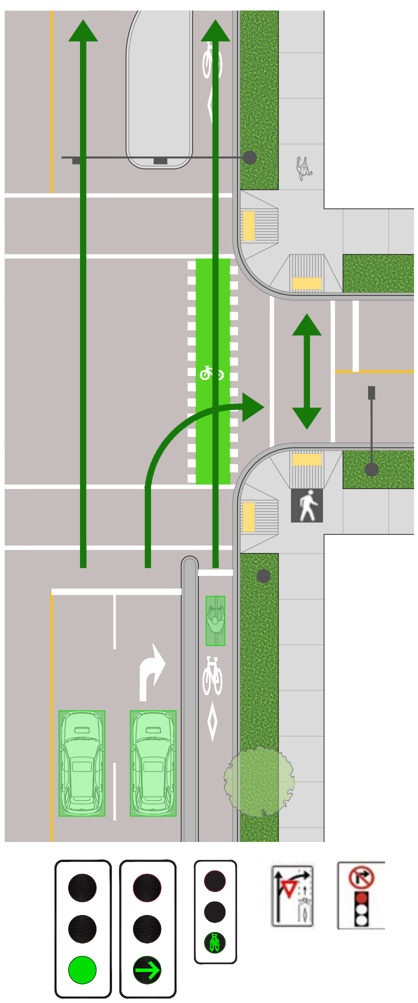


Figure G-79 // Concurrent Bicycle Phase with Permissive Vehicle Turns

No right turn on red, Burrard Street, Vancouver, B.C.

An example of a pedestrian countdown timer

COUNTDOWN TIMERS

Pedestrian Countdown Timers

Pedestrian countdown timers provide information for pedestrians to cross within the allotted green time by informing them of the time until the green phase terminates. With pedestrian countdown timers, people crossing are aware of how much time they have to cross the road. Research has shown that fewer people are in the crosswalk once the countdown timer expires. The added information that pedestrian countdown timers provide to pedestrians can also be used by approaching drivers. Before and after case studies on the effects have been inconsistent among studies, with some studies claiming that timers increase pedestrian compliance,,,[3,4,5] and others reporting increased pedestrian erratic behaviour in the presence of countdown timers,[6] and a decrease in pedestrian compliance[7]. In addition, drivers may behave differently when pedestrian countdown timers are installed compared to when pedestrian countdown timers are not installed.

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3 Arhin, S. A., & Noel, E. C. (2007). Impact of countdown pedestrian signals on pedestrian behavior and perception of intersection safety in the District of Columbia. Intelligent Transportation Systems Conference, 337-342.

4 Eccles, K. A., Tao, R., & Mangum, B. C. (2003). Evaluation of Pedestrian Countdown Signals in Montgomery County, Maryland. Transportation Research Board.

5 Schattler, K., Wakim, J., Datta, T., & McAvoy, D. (2007). Evaluation of pedestrian and driver behaviors at countdown pedestrian signals in Peoria, Illinois. Transportation Research Record, 2002(98), 106.

6 Huang, H., & Zegeer, C. (2000). The effects of pedestrian countdown signals in Lake Buena Vista. Florida Department of Transportation.

7 Botha, J., Zabyshny, A., Day, J., Northouse, R., Rodriguez, J., & Nix, T. (2002, May). Pedestrian Countdown Signals: An Experimental Evaluation. San Jose State University & City of San Jose Department of Transportation Final Report to the California Traffic Control Devices Committee.

Green Time, Change Interval and Clearance Intervals for Cyclists

Traffic signal timing must consider and accommodate all users of the intersection: people walking, cycling, driving, or using transit. Bicycle operating characteristics are significantly different than pedestrians and motor vehicles and design professionals should incorporate those unique operating characteristics. Important factors to consider are the speeds and behaviours of people on bicycles. Some bicycle users, especially children, may use crosswalks and pedestrian push buttons to cross, especially at locations where low-stress bicycle facilities are not provided. At these locations, sidewalk facilities should be accessible to all users. The users and their behaviours have an impact on the selection of signal indication equipment, signal timing parametres, design characteristics, and ultimately the operational performance of the intersection.

Where multi-use pathways are present, the needs of pedestrians should be considered, and in some cases pedestrians should be the design user profile. In the case when a pedestrian is not present, the traffic signal can resort to using timing explicitly for bicycle users. This allows design professionals to use less green time than the pedestrian clearance times would require. This section includes a discussion of the traffic signal options for bicycle users and guidance on green times, yellow change intervals, and red clearance for bicycles. At multi-use pathway crossings, bicycle timing may operate in parallel with pedestrian timing. For this reason, design professionals should consider the operating characteristics for people cycling when calculating minimum green, yellow change, and red clearance interval design. A design speed of 13 km/h and acceleration of 0.76 m/s^2, which is the speed and acceleration of a slow-moving bicycle user, is recommended. In locations where slower moving bicycle users (such as children and seniors) are expected or in locations with relatively steep terrain, design professionals should consider whether alternate design speed and acceleration values are appropriate.

Bicycle Minimum Green

When an approach receives a green indication, a bicycle user waiting at the stop bar needs enough time to cross the intersection before the beginning of the yellow indication. Vehicle minimum green times ranging between 10 and 15 seconds may be based primarily on driver expectancy and queue clearances. It is recommended that the minimum green for a bicycle user is long enough for a person cycling to completely clear the intersection before the signal turns yellow. At some wider crossings, the minimum green time must be longer. When bicycle signals (either a standard traffic signal head designated for bicycle use or a bicycle signal head) are used for bicycle movements that are concurrent with motor vehicle movements, the larger minimum green value should be used for both signals unless the controller and detection can provide a separate bicycle minimum green.

Yellow Change Interval

The yellow change interval is intended to warn approaching vehicles of the end of their right-of-way before the onset of the red interval. The vehicular clearance period is split between yellow and all-red for each phase. Design Professionals should refer to Section 400 of the MOTI Electrical and Traffic Engineering Manual for further detail. If the vehicle yellow change interval is calculated based on the kinematic equation (assuming a higher speed than most cyclists travel), the vehicle yellow change interval will always be sufficient to warn bicycle users and allow them time to stop. The MUTCDC states that vehicle yellow change intervals should have a minimum value of 3 seconds. When bicycle signals are used for bicycle movements that are concurrent with motor vehicle movements, the vehicle yellow change interval calculated for motor vehicles should be used. When bicycle signals are used exclusively for bicycle phases, the minimum yellow change interval should consider the needs of the bicycle user in concert with the red clearance interval discussion below. Based on the kinematic equation, typically a value of 3 seconds is considered sufficient.

Red Clearance Interval

The red clearance interval is the 'all-red' time and is combined with the yellow time. Road users are not permitted to enter an intersection on a yellow indication unless they are unable to stop. The all-red phase provides a buffer to help protect against collisions due to human error, distraction, and poor judgement. The 'all-red' time is calculated based on the vehicle clearance speed (posted speed limit of 10 km/h less for conflicting movements), clearance distance, and conflict distance.

Design professionals should consider where a bicycle user would be positioned and the level of risk at the beginning of green for conflicting traffic. Large or complicated intersections may reduce how visible bicycle users are to drivers, thus making it harder for a driver to appropriately recognize the bicycle user's right of way. These situations may include:

- Intersections with wide medians;
- Unconventional or complex intersections (skews, extra legs);
- Intersections with horizontal or vertical curvature;
- Intersections with poor lighting; and
- Intersections with other sight distance issues.

Bicycle Green Extension

On bicycle facilities that have detection, there is more flexibility with respect to signal timing. Minimum green times should be provided to ensure that a waiting bicycle user can completely clear the intersection. In locations where bicycle volumes are heavy during a particular time of day, additional green time may be needed. In this case, the approach can include a detector in advance of the stop line to extend the green interval to allow the bicycle traffic to move through the intersection. The length of the extension should be determined by the speed of bicycle users, the distance the detector is from the stop line, and the amount of extension time that can be provided. Once the phase has begun, each bicycle user will extend the green time for each bicycle detected up to the maximum green.

SCRAMBLES AND DIAGONAL CROSSINGS

Pedestrian Scrambles

An exclusive pedestrian phase or "scramble" is a type of traffic signal phasing where pedestrians are allowed to use the intersection before or after motor vehicle traffic on all approaches is stopped. Pedestrians can make diagonal crossings (hence the term "scramble") as well as conventional crossings without coming into conflict with turning vehicles. Table G-5 summarizes the advantages and disadvantages of pedestrian scrambles. Limited published evaluations of scramble phasing show the potential for increased pedestrian safety as long as vehicles and pedestrians are compliant with the signals. However, mention of bicycle users in these studies is limited. As both pedestrians and vehicles experience increased delays since the cycle length is increased this may reduce compliance, which may negate the expected safety benefits of scramble phasing.

Bicycle Scrambles and Diagonal Bicycle Crossings

Bicycle scrambles are intersections where traffic signals stop vehicles in all four directions, allowing people cycling to cross laterally or diagonally. Motor vehicles should not be permitted to make right turns on red during scramble phases. Many cities around the world use scrambles to provide safe and accessible crossings in pedestrian-heavy areas, but few countries use them strictly for bicycle traffic. Installing these scrambles can impact vehicle, transit, and pedestrian travel times, but are also expected to improve safety and convenience for people cycling. The United States FHWA explicitly prohibited their use with bicycle signals in their

December 2013 Interim Approval[8], but they can be found in the Netherlands. Bicycle scrambles are not recommended for application in B.C. at this time.

Table G-34 // Advantages and Disadvantages of Pedestrian Scrambles

ADVANTAGES	DISADVANTAGES
▪ Eliminates concurrent pedestrian phases, allowing motor vehicle traffic to make left or right turns without any impedance by pedestrians in the crosswalk. ▪ Provides opportunities for people to walk diagonally which may reduce out of direction and compliance issues.	▪ Requires a longer cycle length to accommodate all movements. ▪ Requires compliance of turn restrictions for vehicles during red. ▪ Increases delay for most users depending on situation.

Bicycle Signal Activation

Traffic signals should passively detect bicycles or allow bicycle users to manually call a phase with a push button. Bicycle users should not have to dismount to use a push button. One of the primary purposes of detectors is to call the signal phase. If detection is used on an intersection approach where bicycle users are expected, it should be designed to sense bicycles whether they are mixed with vehicle traffic or in their own lane. Various technologies are available for passively detecting bicycles, including: inductive loops, microwave, video, and magnetometres. To provide a backup to passive detection devices, a bicycle push button may be used. The detection layout and design should be based on intersection geometry and the intended use and operation of the detectors. The design must reliably and accurately detect bicycle traffic, and should provide guidance on how to actuate detection. Each type of detection should be monitored to evaluate effectiveness and field calibrated as needed to ensure the detection systems are working as intended.5

Bicycle Detection Loop

In-ground induction loops can be used to detect the presence of bicycles to actuate the bicycle traffic signal phase where the intersection is signalized and shared with motor vehicles. In locations where induction loops for motor vehicles are in place, additional induction loops for bicycles may not need to be installed, reducing the cost of installation. However, the sensitivity of the loop must be carefully considered. Additionally, some loops may have difficulty detecting vehicles with limited metal in them (such as carbon fiber bicycle frames). If existing loop systems do not provide enough sensitivity to detect a bicycle, existing loop systems may still need to be updated.

Push Button

Call or push buttons should be used at signalized bicycle crossings of major roads, where the minor road traffic is stopped, and where loop detectors cannot be installed. Compliance at the signals may be greater when push buttons are present as compared to passive detection due to the physical and visual presence of the device and the understanding that the device is intended to be used to change the traffic signal phase. When selecting where to install a push button, consideration should be made so that people cycling do not need to dismount. Consideration should also be made so that the push button can be activated by all bicycle users (including recumbent and hand bicycles without dismounting. Where bicycle push buttons are not intended for the use of pedestrians, push buttons do not have to meet accessibility guidelines for placement. Bicycle push buttons should have a supplemental sign explaining their purpose and use, and the sign should be mounted immediately above or incorporated into the push button. The push button should be oriented in the same direction as the bicycle crossing. Push buttons may also include a detection confirmation light to provide positive feedback to the

8 Lindley, Jeffrey. "MUTCDC – Interim Approval for Optional Use of a Bicycle Signal Face (IA-16)", Federal Highway Administration, December 24, 2013.

user and potentially improve compliance with the traffic signal (see below).

Other Forms of Detection

Infrared, microwave (radar), ultrasonic, video and/or motion detectors can also be used for detection at signalized bicycle crossings of major roads. By lengthening the detection zone, the traffic signal may provide a quicker response time to waiting bicycle users. There are situations where their use may present accuracy problems particularly during periods of poor weather conditions. In other cases, these types of detectors – such as loop detectors – can be susceptible to false detections, so while they can be used, there should be a plan to ensure that accuracy is assured where loops or push button detection is undesirable or not available.

Indicator Light

Indicator lights can be considered with the bicycle signal head. Indicator lights indicate that the person cycling has been detected by the sensor. These lights are relatively small and are mounted at or near the traffic signal face controlling the approach. The purpose of the confirmation light is to reduce concern for users that they have not been detected. This can be particularly helpful at locations with long signal cycle lengths where bicycle users may be required to wait 60 seconds or more for a green signal. Compliance may increase for people riding bicycles when they know that they have been detected. Detector confirmation indications are currently experimental in the United States, but used widely in The Netherlands.

Traffic Signal Control (Actuated and/or Coordinated) and Effects

The use of coordination between traffic signals has primarily been used to move cars through a series of signalized intersections. The effect of coordination on people walking and cycling can be to decrease the respective user's delay. There is limited research on the impacts of operating the signal in free mode compared to traditional coordination.

Cycle length in signal timing refers to the time taken for a complete sequence of signal indications. Research has shown that shorter cycle lengths benefit pedestrians by providing less delay. Guides such as the NACTO *Urban Street Design Guide* recommend the provision of shorter cycle lengths to increase efficiency of multimodal operations and reduce pedestrian delay[9].

Progression Speed for Bicycles (Green Wave)

A corridor traffic signal progression speed may be based on a desired travel speed, the posted speed limit, or an agency policy. In most cases, the signal progression is set at a higher speed than what a person cycling can achieve. As a result, people cycling on the coordinated corridor may not benefit from the progression and will experience delays that motorists do not. The use of a lower progression speed is appropriate to support and encourage bicycle traffic. Signal progression focused on people cycling is referred to as "Green Wave" progression and they allow people cycling to operate at a consistent speed, reduce stopping, and improve compliance. The speed of motor vehicle traffic can also be considered in the design of signal timing that accommodates both users. A bicycle "Green Wave" results in slower travel speeds for motor vehicles which improves safety for all roadway users. The speed for a "Green Wave" depends on the extent of grade and is often in the range of 15 km/hr to 25 km/hr.

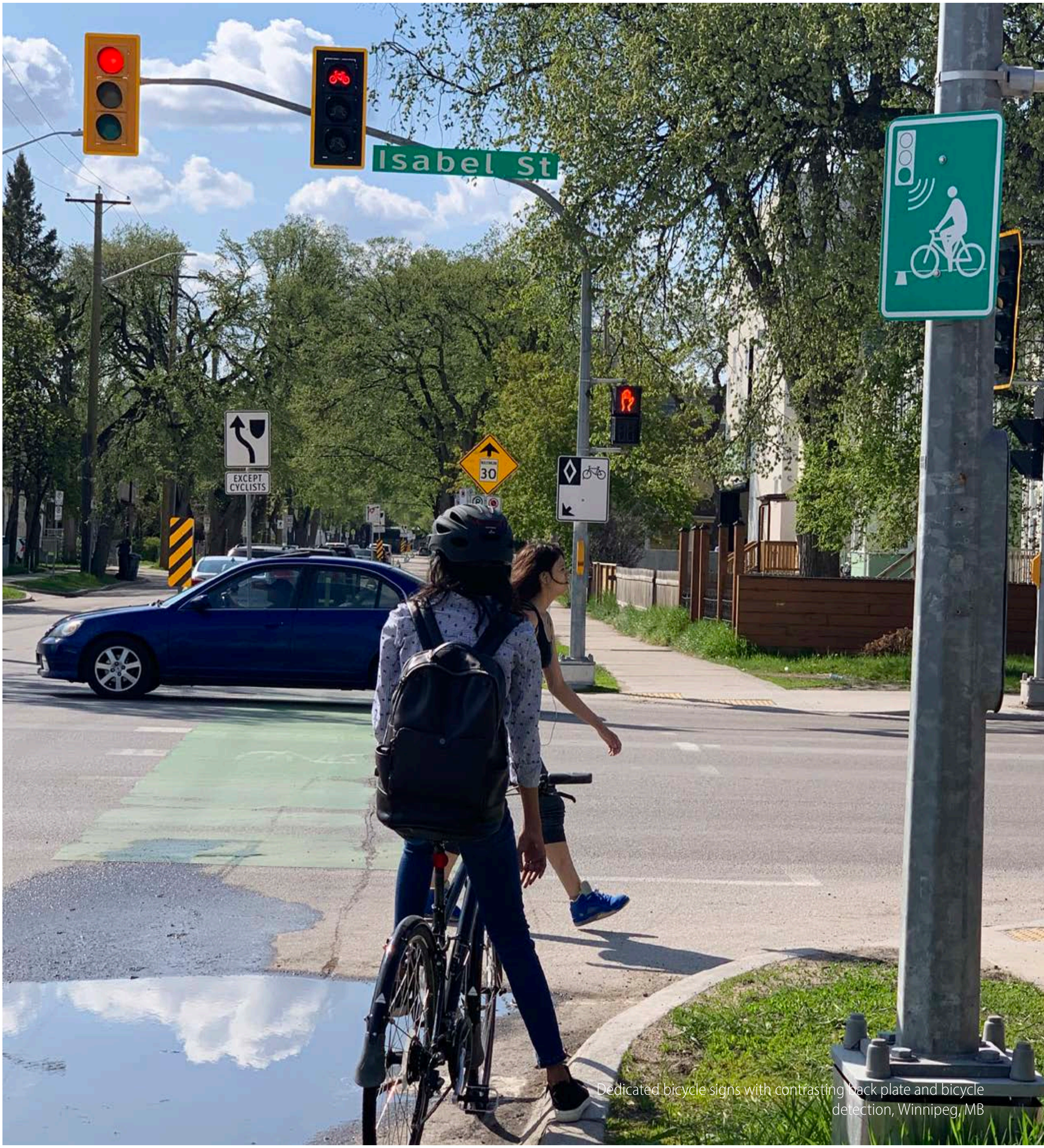
9 NACTO, National Association of City Transportation Officials. 2013. Urban Road Design Guide, New York.

Case Study

Several cities, including Calgary, Edmonton, and Portland have used small blue confirmation lights to provide confirmation to bicycle users that they have been detected at actuated approaches to traffic signals. The intent of the installation is to provide feedback to help reduce the level of stress for waiting bicycle users. Given the relatively low cost of installation, the intent is that these could be tools for creating infrastructure that promotes mobility and efficiency for people cycling. Research is limited on the effect of the confirmation devices, accompanying informational signs, and countdown timers on the behavioural and psychological effects for bicycle users. One recent study has shown positive impacts of using a blue light feedback confirmation device along with an informational sign at signalized intersections to aid bicycle detection, with a significant decrease in the number of bicycle users getting off their bicycle to use the pedestrian push button for detection. [1]

Bicycle detection light, Calgary, Alta
Source: Shea Friesen

1 Boudart, J., Liu, R., Koonce, P., and L. Okimoto. An Assessment of Cyclist Behavior at Traffic Signals with a Detector Confirmation Device. Transportation Research Record, Journal of the Transportation Research Board, No. 2520, Transportation Research Board of the National Academies, Washington D.C., 2015, pp.21-26.



Dedicated bicycle signs with contrasting back plate and bicycle detection, Winnipeg, MB

Surrey, B.C.

G.3

PEDESTRIAN CROSSINGS

The provision of safe and accessible pedestrian crossings is crucial to ensuring that people of all ages and abilities are able to navigate the active transportation network and reach their destinations. When crossing the road, pedestrians are exposed to potential conflicts with motor vehicles, bicycle users, and other road users. Geometric design elements, signals, signage, and pavement markings can all be used to prioritize pedestrians and mitigate conflicts.

A number of reference documents provide important context for pedestrian crossing design in B.C. and have been referenced throughout this chapter. These documents include the TAC *Pedestrian Crossing Control Guide*, TAC *Manual of Uniform Traffic Control Devices*, *B.C. Manual of Standard Traffic Signs & Pavement Markings*, and the *Pedestrian Crossing Control Manual for British Columbia*.

This chapter provides design guidance for on-street intersection and mid-block pedestrian crossings, introducing geometric crossing enhancements such as curb ramps, curb extensions, pedestrian refuge islands, and other elements. Off-road crossings and additional conflict areas are discussed in **Chapters G.5** and **G.6**, respectively. **Chapter B.3** provides an overview of universal access design considerations, while **Chapter B.4** provides more detail on the operational and behavioural characteristics of pedestrians, including walking speed.

CURB RAMPS

A curb ramp is a smooth, graded transition from the sidewalk to the road. Curb ramps are an essential universal design element – they are required for people using wheelchairs, power scooters, and other mobility devices, but also benefit people with strollers, baggage, and delivery carts, and they are used as a navigational tool by people with visual impairments. Curb ramp characteristics and design guidance are provided below. Additional information can be found in the MOTI *B.C. Supplement to TAC Geometric Design Guide*.

Curb Ramp Components

Curb ramps consist of several components that combine to create a universally accessible crossing, (see **Figure G-80**). These include a ramp 1, top landing area 2, bottom landing area 3, flares 4, and approach 5. The shape and positioning of each element can vary according to geometric constraints and curb ramp type. Directional score lines 6 may be included on the ramp and oriented to direct pedestrians in the correct crossing. Tactile attention indicators can also be provided for universal accessibility 7.

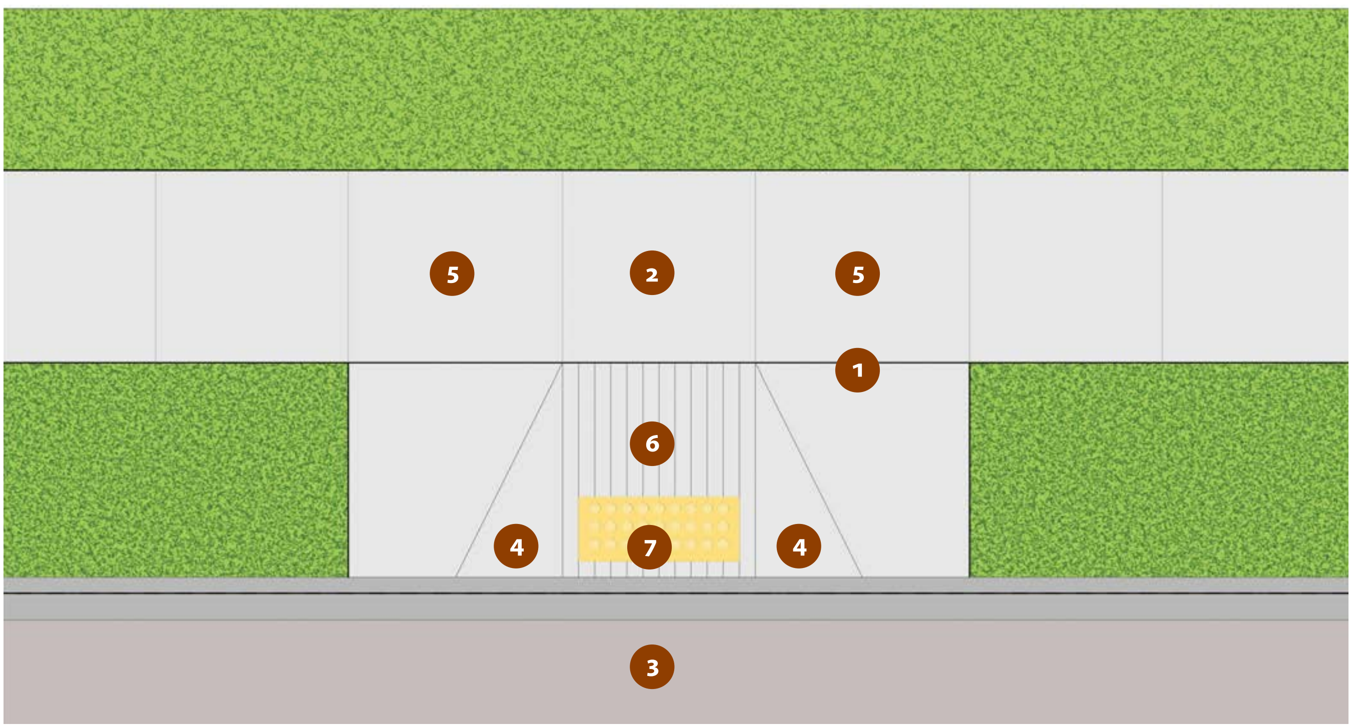


Figure G-80 // Curb Ramp Components

1 Ramp
2 Top Landing Area
3 Bottom Landing Area
4 Flares
5 Approach
6 Directional Score Lines
7 Tactile Attention Indicator

1 Ramp

The ramp is the transitional surface between the sidewalk and road. The surface of the curb ramp should be firm, stable, and slip resistant. The desired curb ramp width (exclusive of flared sides) is 1.8 metres, with a constrained limit width of 1.5 metres. The absolute minimum curb ramp width is 1.2 metres.

The maximum running slope of a curb ramp is 1:12 (8.3%). A running slope of 1:10 (10%) is acceptable in existing locations. The cross slope should be no steeper than 1:50 (2%) at intersections. At mid-block locations, the cross slope may match the road gradient.

Directional score lines may be included on the ramp and oriented to direct pedestrians in the correct crossing directions, **(**see **Chapter B.3**) for details on score lines). Additionally, in order to provide full universal access, tactile attention indicators (a type of TSWI) may be installed at the base of curb ramps to alert pedestrians that they are entering a conflict zone and to assist with wayfinding. When used, tactile attention indicators should extend the full width of the curb ramp and should start between 300 and 350 millimetres from the road face of the curb. See **Chapter B.3** for more details on tactile attention indicators. Directional score lines and tactile attention indicators may be used together to provide full universal access.

2 Top Landing Area

The top landing area is a level surface at the top of the curb ramp that provides space for manoeuvring and refuge. In constrained conditions, it may not be possible to provide a landing area. The top landing area should be as wide as the ramp portion and a minimum of 1.2 metres long. At constrained corners where the ramps land on an area where a pedestrian must change direction, a landing of at least 1.5 metres long should be provided. Larger top landing areas are preferred wherever feasible. A turning space of at least 1.35 metres by 1.35 metres should be provided, although this space can overlap with other clear spaces.

3 Bottom Landing Area

The bottom landing area is the receiving space in the road at the base of a curb ramp. While it is actually part of the crossing and not the ramp itself, the bottom landing area has important slope and drainage considerations. Counter slope is the grade change where the down slope of the curb ramp meets the up cross slope of the gutter or road. Steep counter slopes can be difficult to navigate for wheelchair users, as the counter slope may catch footrests or cause a loss in wheel traction. The maximum recommended counter slope is 1:20 (5%).

The bottom landing area should be prioritized for maintenance to ensure that the surface remains in good condition and to prevent the accumulation of debris such as gravel, leaves, and snow. Curb ramps should provide appropriate drainage to prevent water and ice from accumulating in the bottom landing area. No catch basins should be located within the bottom landing area unless they meet accessible standards (see **Chapter I3**).

4 Flares

The flares are the sloped edges that connect the ramp to the adjacent sidewalk. They should be slip resistant and have a maximum slope of 1:10 (10%). Flares provided a flexible side access to the ramp, although they may not be easily navigable for people with mobility devices users. This underlines the importance of providing an accessible top landing area.

5 Approach

The approach is the portion of the sidewalk leading up to the top landing area. The grade and slope of the approach is the same as the Pedestrian Through Zone and top landing area. 2.

Curb Ramp Placement

Curb ramp design and placement is influenced by geometric elements such as the corner radius and the width and alignment of the Pedestrian Through Zone and Furnishing Zone. Where feasible, the recommended approach is to provide **double curb ramps**, which provides a dedicated curb ramp for each individual crosswalk), as shown in **Figure G-81.** Double curb ramps help to provide full universal access by landing pedestrians directly in the crossing area and in the desired direction of travel, rather than entering the road at an angle and having to reorient themselves. This is especially important for pedestrians using mobility devices and who are visually impaired.

Wherever feasible, double curb ramps should be aligned with the Pedestrian Through Zone and centred in the crosswalk, creating a direct pedestrian path. Double curb ramps also help to reduce crowding by separating pedestrians by direction of travel. This in turn makes it easier for motorists to determine the pedestrians' desired crossing direction

A minimum of 1.2 metres of level clear space must be provided behind the ramps to allow pedestrians to bypass the curb ramps without having to enter the ramp itself. A full height curb should be provided at the corner between the two curb ramps. This prevents motor vehicle incursion into the corner. In order to form this full height curb, the two curb ramps must be separated by a minimum of 1.0 metre of full height curb, measured along the arc of the curb.

Where there is insufficient space for a double curb ramp due to larger corner radii, obstructions such as utility poles, and/or narrow Pedestrian Through Zones and Furnishing Zones, a **combined curb ramp** may be used (**Figure G-82**). Combined curb ramps still allow people using wheelchairs to enter the crosswalk along a straight trajectory, unlike a single curb ramp that is located at an angle to the road. However, combined curb ramps do not provide the benefit of separating directions of pedestrian travel, and they are at risk of motor vehicle encroachment due to the lack of full height curb.

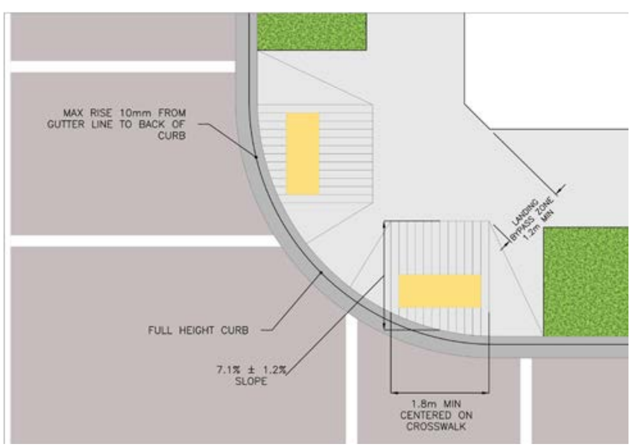


Figure G-81 // Double Curb Ramp

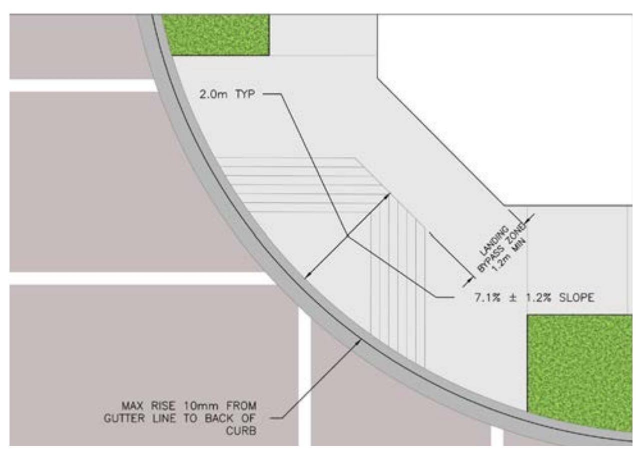


Figure G-82 // Combined Curb Ramp

INTERSECTION CROSSINGS

Unmarked Crossings

According to the B.C. MVA, at the intersection of any two roads with pedestrian facilities, all legs of the intersection are legally considered to contain crosswalks, regardless of whether or not they are marked with signage or pavement markings. Unmarked crosswalks are typically defined by connecting the Pedestrian Through Zones on either side of the road. Where there is no sidewalk, the unmarked crosswalk is measured from the edge of the road.

Marked Crossings

Providing crosswalk signage and pavement markings makes a crosswalk more visible to all road users, increasing motorist yielding behaviour and helping to guide pedestrians across the road in the safest and most direct location. All crosswalks at signalized intersections should be marked. At unsignalized intersections, a range of crosswalk markings may be considered, based on the context. The TAC *Pedestrian Crossing Control Guide* and the *Pedestrian Crossing Control Manual for British Columbia* contains warrants for when different levels of crosswalk are required, based on a number of criteria including road classification and motor vehicle speeds and volumes. As described in **Chapter G.1**, warrants should be applied alongside qualitative engineering judgement to assess the best design for each individual context.

Certain types of intersections may require crosswalk markings even if otherwise unwarranted based on road classification and motor vehicle speeds and volumes. For example, intersections with visibility constraints due to topography, road curvature, or obstructions such as buildings or road trees may require signage and markings to increase visibility. Offset and complex intersections should also be marked in order to guide pedestrians through the intersection along the most direct path. Finally, all intersections and crossings within school zones deserve special consideration.

Crosswalk Signage and Pavement Markings

The TAC *Pedestrian Crossing Control Guide,* TAC *MUTCDC, B.C. Manual of Standard Traffic Signs & Pavement Markings,* and MOTI *Pedestrian Crossing Control Manual for British Columbia* provide detailed descriptions and installation instructions for pedestrian crosswalk signage and pavement markings. These signs and pavement markings are also shown in **Appendix B**. Basic crosswalk signage includes the Pedestrian Crosswalk sign (MUTCDC RA-4; B.C. PS-003 Series), the Pedestrian Crosswalk Ahead sign (MUTCDC WC-2; B.C. PS-002 Series), the Special Crosswalk Overhead sign (MUTCDC RA-5), and the Yield Here to Pedestrians sign (not currently part of the MUTCDC).

The standard pedestrian crosswalk pavement marking is the **twin parallel line crosswalk** marking, which simply consists of two parallel while lines delineating the crossing. The twin parallel line crosswalk is suitable at intersections that are stop or signal controlled, including pedestrian signals.

Zebra crossings feature wide white parallel lines and offer enhanced visibility over the twin parallel line crosswalk. Zebra crossings should be used at mid-block crossings, school zone or school route crosswalks, and special crosswalks. They are also recommended anywhere that there are higher volumes of children, older pedestrians, or visually impaired pedestrians. According to the MOTI *Pedestrian Crossing Control Manual for British Columbia,* zebra crossings should be used for all crosswalks installed at unsignalized intersections on roadways under provincial jurisdiction. Local governments may use the twin parallel line crosswalk on roads under their jurisdiction. While zebra crossings offer enhanced visibility, consideration should be given to not overusing them as this may reduce their overall effectiveness.

Yield lines, also known as 'shark's teeth,' may also be used in advance of a marked and signed crosswalk to discourage motor vehicle incursion into the crosswalk and may be accompanied by the Yield Here to Pedestrians sign (not included in MUTCDC). Yield lines are not currently defined in the B.C. MVA and cannot be used on roadways under provincial jurisdiction. See **Chapter G.4** for more details on yield lines.

Pedestrian crossing pavement markings should be used in combination with another traffic control device, such as signage or signals. The pavement markings should use durable, skid-resistant materials and should be well maintained to ensure they remain visible.

Decorative Crosswalks

Many communities across B.C. have installed decorative crosswalk pavement markings. Decorative crosswalks can enhance the visibility of a crosswalk, can be used as branding and wayfinding along an active transportation route, and can add to the aesthetic appeal of the road. A common type of decorative crosswalk is the rainbow crosswalk, which supports the LGBTQ2S+ community while adding vibrant colour to the streetscape. Additionally, many communities have taken artistic approaches to crosswalk design that relate to local culture.

The use of decorative crosswalks is not currently covered under TAC or provincial policy. As such, careful consideration should be given to the context and design prior to installing a decorative crosswalk. Designs should include unobstructed twin parallel line crosswalk markings to ensure that they are considered a legal crosswalk. Decorative elements may be added in between the twin parallel lines but should not interfere with or obscure the standard crosswalk pavement markings.

Decorative Sidewalk, Gibsons, B.C.

Decorative Sidewalk, London, UK

School Zone Crossings

Crossings in school zones and along school routes require special attention to increase the safety of children that are travelling along the road. In addition to marking and enhancing crosswalks, motor vehicle speeds and volumes should be managed within the school zone. The TAC *School and Playground Areas: Guidelines for Application and Implementation* provides guidance for setting reduced speed school zones in both rural and urban contexts.

The TAC *Pedestrian Crossing Control Guide* and the MOTI *Pedestrian Crossing Control Manual for British Columbia* recommend that all crosswalks within a school zone be marked with a zebra crosswalk, as opposed to a standard twin parallel line crosswalk. School zones also require special signage, including the School Crosswalk sign (MUTCDC RA-3; B.C. PS-005 Series) and the School Crosswalk Ahead sign (MUTCDC WC-16; B.C. PS-004 Series) (see **Appendix B**). The In-Road School Crosswalk sign (MUTCDC RA-8) may also be placed in the middle of the road to increase visibility. It is typically used on a temporary basis during busy pick up and drop off periods.

Crosswalks within school zones may also use crossing guards, who are paid or volunteer supervisors that help children cross the road at particularly busy or hazardous crossings. The *B.C. MVA* states that all road users must obey the instructions of all authorized school crossing guards, including students acting as volunteer traffic patrol members. The MOTI *Pedestrian Crossing Control Manual for British Columbia* outlines the suite of School Crossing Programs in B.C., including the Safe Route to School Program, the School Patrol Program, and the Adult Crossing Guard Program.

Signalized Crossings

In addition to signage and pavement markings, pedestrian crosswalks may be signalized to further enhance visibility and motorist yielding behaviour. Signalization can include full signals, pedestrian and cycling activated signals, overhead pedestrian flashers, and side mount pedestrian flashers . **Chapter**

School Administrator assisting as a crossing guard in Surrey, B.C.

G2 provides an overview of each type of signalized crossing, including how these signals are activated. The TAC *Pedestrian Crossing Control Guide* and the MOTI *Pedestrian Crossing Control Manual for British Columbia* provide further details on each type of signalization.

Mid-Block Pedestrian Crossings

Mid-block crosswalks can enhance the connectivity of the pedestrian network, especially where intersections are spaced at least 100 to 200 metres apart and there are destinations on both sides of the road. They are useful where major pedestrian generators such as transit stops, parks, and businesses are located mid-block. Transportation professionals should consider pedestrian desire lines. Where a substantial amount of jaywalking is occurring, mid-block crossings may help to consolidate and formalize these crossings, improving safety for all road users.

Transportation professionals should consider a number of factors when assessing the feasibility of a mid-block crosswalk, including: road width, number of travel lanes, topography, sightlines, pedestrian volumes, motor vehicle speeds and volumes, turning conflicts, and distance to the nearest intersection. The TAC *Pedestrian Crossing Control Guide* and the MOTI *Pedestrian Crossing Control Manual for British Columbia* provide detail for conducting an engineering study that assesses the feasibility of a mid-block crossing and the type of traffic control required.

Mid-block crossings should be marked with basic crosswalk signage and pavement markings at minimum. Enhanced markings, signalization, and geometric crossing enhancements such as curb extensions and median refuge islands can be useful for increasing the visibility of mid-block crosswalks, especially since motorists may not expect mid-block crossings. These enhanced crosswalk elements are described below.

Mid-block crosswalks are often associated with off-road pathways. Refer to **Chapter G5** for design guidance on mid-block crosswalks for off-road pathways.

Mid-block Crosswalks

Offset mid-block crosswalks can be used on two-way roads with median refuge islands. The crosswalk is offset on either side of the median as shown in **Figure G-83.** A barrier, fencing, or curbs may be used to encourage compliance, guide pedestrians to the next stage of the crossing, and provide an enhanced pedestrian refuge. Offset mid-block crosswalks encourages eye contact between pedestrians and motorists, as it causes the pedestrian to turn towards oncoming traffic. The median refuge area should be at least 3.0 metres wide.

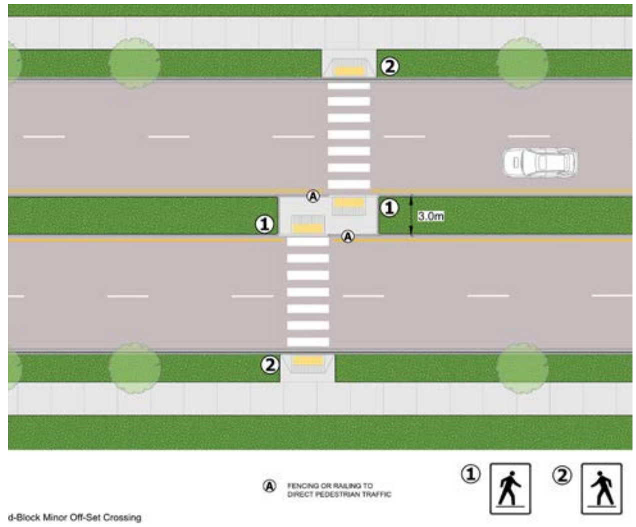


FIGURE G-83 // OFFSET MIDBLOCK CROSSING

Mid-block crosswalk in Gibsons, B.C.

Geometric Crossing Enhancements

A number of geometric design elements can be used to enhance crosswalks. In general, the approach is to provide the shortest, safest, and most accessible crossing possible. Creating safer crossings involves increasing sightlines and providing physical protection wherever possible, minimizing the amount of time that pedestrians are exposed to motor vehicle traffic. The following elements can help to achieve these objectives.

Daylighting and Advanced Stop Lines

Sightlines at intersections and mid-block crossings can be enhanced by 'daylighting' in advance of the mid-block crossing. Daylighting refers to bringing pedestrians further out into the motorists' line of vision and/or removing obstructions. This can be accomplished by installing curb extensions and removing on-street parking on both sides of the road. Advance stop lines can be used at signalized intersections to ensure that motor vehicles do not encroach into the crosswalk. At signal or stop controlled mid-block crosswalks, advance stop lines or Yield Here to Pedestrians signage can help ensure that the crossing pedestrian is visible, especially on multi-lane roads. Stop lines are only used where a control device is used. See **Chapter G5** for more guidance on daylighting at mid-block crossings.

Curb Extensions

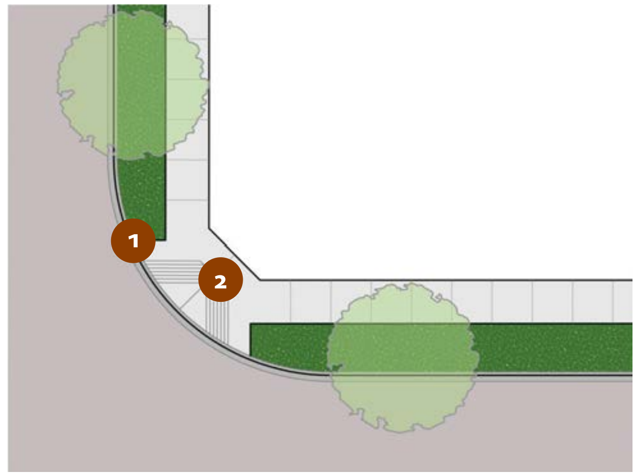
Curb extensions shorten the crossing distance, reducing the time that people are in mixed traffic conditions. They also increase visibility by bringing people waiting to cross further into the intersection, ensuring that they can be seen by motorists. Curb extensions can change the corner radii as well, as described on page G51. Finally, curb extensions create extra space at the corner that can be used for pedestrian queuing, street furniture, and landscaping.

Figure G-84 // Curb Extensions at corner

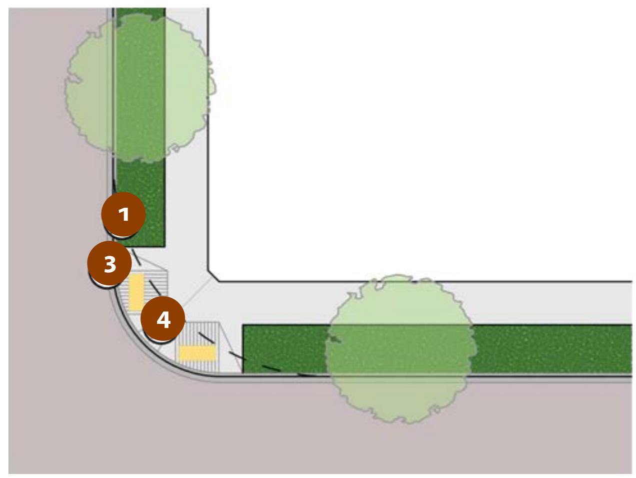
Reducing Corner Radii

As described in above and in **Chapter G.1**, corner radius has a direct impact on pedestrian visibility as well as the length and directness of a pedestrian crossing. **Figure G-85** demonstrates the impact of reduced corner radius on pedestrian positioning, curb ramp type, curb ramp alignment, and crossing distance. A smaller radius allows the application of a double curb ramp, provides increased pedestrian queuing space, and allows the curb ramp to be better aligned with the Pedestrian Through Zone. As noted in **Chapter G.1**, it is important to ensure that the design vehicle is accommodated when determining the corner radius.

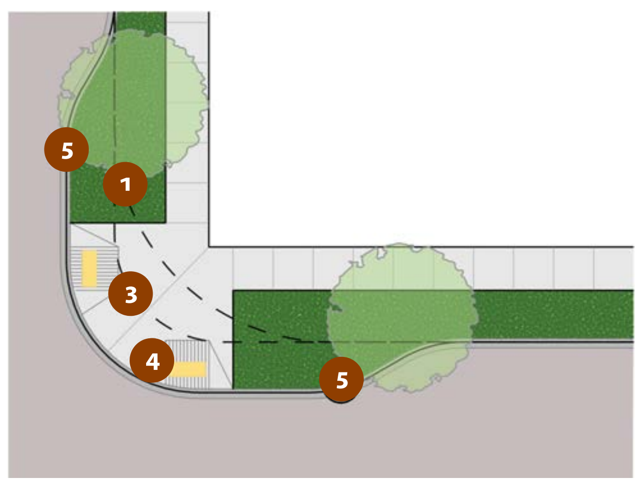
1. *Original 9 Metre Curb Radius*
2. *Combined Curb Letdown*
3. *4.5 Metre Curb Radii Reduction*
4. *Double Curb Letdowns*
5. *Curb Extensions*



1. Original Curb Radius with Combined Curb Letdown



2. Reduced Curb Radius with Double Curb Letdown



3. Reduced Curb Radius with Double Curb Letdown and Curb Extensions

FIGURE G-85 // HIERARCHY OF CROSSING ENHANCEMENTS BASED ON REDUCED CORNER RADIUS

Pedestrian Refuge Islands and Medians

Pedestrian refuge islands allow pedestrians to cross only one direction of traffic at a time and provide physical protection for waiting pedestrians. The pedestrian crossing may either be cut through a median island as shown in **Figure G-86,** or raised with curb ramps on either side of the refuge island. The refuge should have a constrained width of 2.4 metres to accommodate a range of pedestrians, bicycles, and mobility devices. The absolute minimum depth of a pedestrian refuge island is 1.8 metres. The refuge island should be at least 4.0 metres long in order to be perceived as a significant barrier by motorists. A refuge island may be cut out as part of an existing median or it may be added specifically for use by crossing pedestrians.

Pedestrian refuge islands are desirable in complex intersections with irregular crossing routes, as they break the crossing into smaller segments and allow pedestrians to rest. Pedestrian refuge islands are also recommended in areas with higher volumes of children, older pedestrians, and pedestrians with mobility challenges, such as in school zones and near healthcare facilities.

Raised Crosswalks

Raised crosswalks elevate the crossing to or close to curb level, improving pedestrian visibility and reducing motor vehicle speeds along the corridor. Raised crosswalks can also improve accessibility for people using mobility devices. Detectable edges such as tactile attention indicators can be provided at the entrance to the raised crosswalk so that visually impaired pedestrians are aware that they are entering the road. **Figure G-87** shows the dimensions of a raised crosswalk.

Raised crosswalks are applicable on local and collector roads with posted motor vehicle speeds of 50 km/h or less, as well as school zones. They can pose challenges for long vehicles, so they should typically not be used along dedicated emergency routes or within 25 metres of a bus stop serviced by articulated buses. They are not appropriate on grades over 8%, in areas with limited sight distances, curves with small turning radii, or within 75 metres of traffic signals.

Note that raised crosswalks and other forms of vertical deflection are not permitted on roadways under provincial jurisdiction.

Figure G-86 // Pedestrian Refuge Island

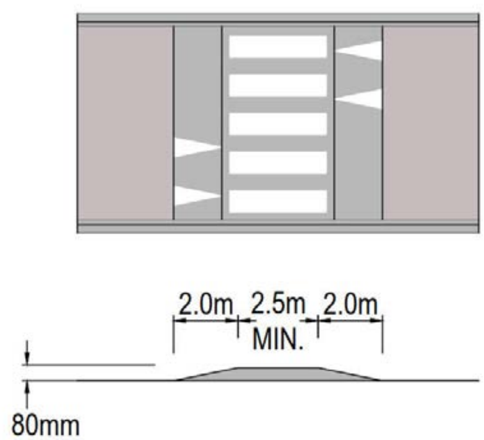


Figure G-87 // Raised Crosswalk Specs

Raised Intersections

Raised intersections apply the same principles and design as raised crosswalks, with the key difference that they are spread across an entire intersection (see **Figure G-88)**. This design gives pedestrians elevated priority and visibility throughout the intersection, while indicating to motor vehicle drivers that they have entered a different type of space where increased caution is required. As shown in **Figure G-88,** raised intersections may be constructed with alternate pavement materials to add further visual and tactile differentiation to the road.

Channelized right turn lane crossings

Channelized right turn lanes are often used at intersections along roads with high motor vehicle volumes and are used to facilitate right turn motor vehicle movements. Channelized right turn lanes can be challenging and inconvenient for pedestrians to cross due to the higher speed of the turning vehicles and the yield controlled (unsignalized) nature of the turn. Additionally, the triangular refuge island (sometimes referred to as 'pork chop island') may contain limited refuge and queuing space for pedestrians. Consideration should be made to normalizing the intersection by removing the channelized right turn lane (see **Figure G-89**). Converting the intersection into protected corners is recommended where feasible (see **Chapter G.4**).

Where removal of the channelized right turn lane is not feasible, a second option is to redesign the channel as a 'high entry angle' or 'smart channel'. The difference between a conventional channelized right turn lane and a high entry angle right turn lane. High entry angle channels increase the entry angle to the cross road and decreases the turning speed to be more consistent with a yield condition. The high entry angle reduces the motorist viewing requirement and requires less neck rotation for motorists. High entry angle approaches also make pedestrians and bicycle users more visible at the crossing. Refer to Section 700 of the MOTI *B.C. Supplement to TAC Geometric Design Guide* and Section 9.15.2 of the TAC *Geometric Design Guide for Canadian Roads* for more guidance on high entry angle approaches. Refer to **Chapter G.4** for design guidance on high entry angle crossings for both people walking and people cycling.

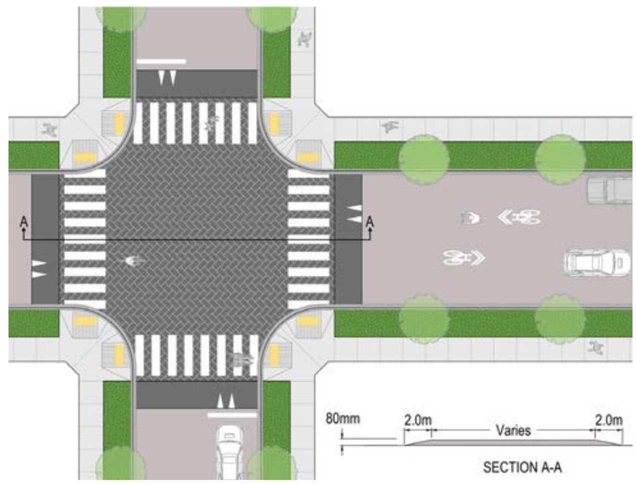


Figure G-88 // Reconfigured Channelized Intersection

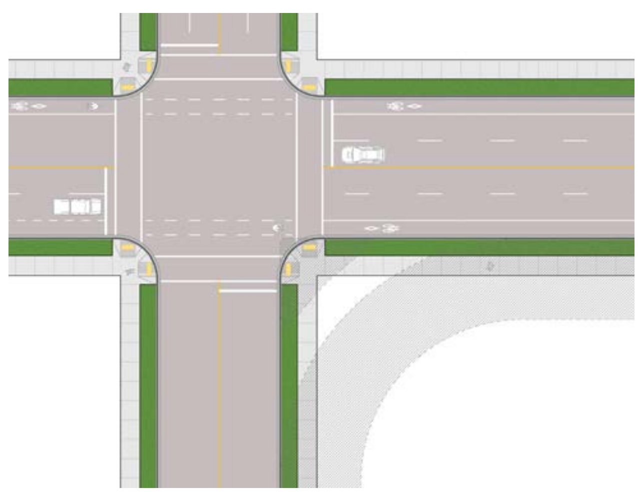
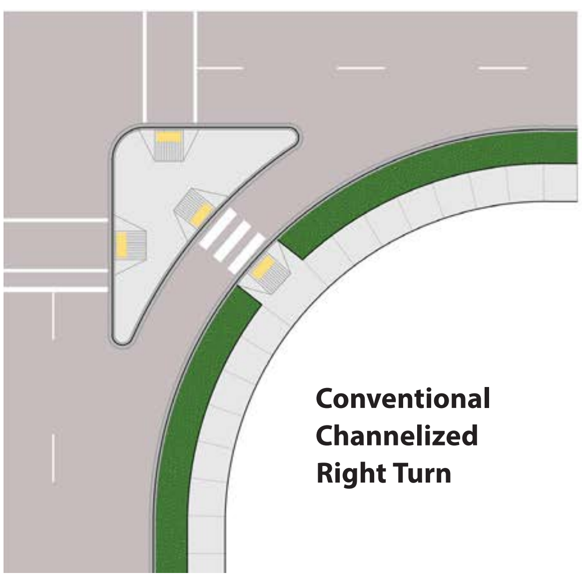


Figure G-89 // Conventional Channelized Right Turn Lane vs. High Entry Angle Right Turn Lane (Smart Channel)

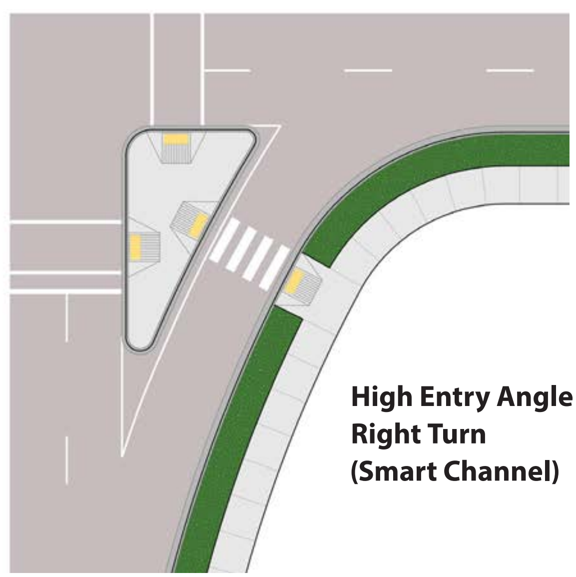
Where channelized right turn lanes cannot be removed or redesigned, there are a number of considerations concerning crosswalk placement. When installing pedestrian crossings at channelized right-turns near traffic signals, transportation professionals should consider driver workload, expectations, and sightlines. The crosswalk can be installed in one of three locations: the upstream (entering) side of the turn lane, the midpoint, or the downstream (exiting) side. The midpoint location is typically the preferred option, as described below:

- **Upstream crosswalk** locations require pedestrians to discriminate between through motor vehicles travelling straight and motor vehicles turning into the right turn lane, which can be challenging. Additionally, where there is no dedicated right turn lane in advance of the crossing, queues from vehicles yielding to pedestrians may encroach into the through travel lanes.
- **Midpoint crosswalk** locations minimize the crossing distance and are likely to coincide with the location of slowest motor vehicle speeds. This design provides more vehicle storage space than crossings at the upstream location.
- **Downstream crosswalk** locations provide the most vehicle storage capacity. However, motorists in the turn lane are more likely to be looking to their left at vehicles approaching on the major road and may not see pedestrians waiting to cross. Motor vehicles may also accelerate as they approach the downstream exit, making it less likely that they will yield to pedestrians.

Raised crosswalks may also be used at channelized islands to slow motor vehicle speeds and increase the visibility of pedestrians and cyclists at the crossing. Raised crosswalks may include yield line placement markings ('shark's teeth') on their approach. Note that neither raised crosswalks nor yield lines may be used on roadways under provincial jurisdiction. In addition, RFBs may be considered at crosswalk and cross-ride to further raise awareness of the presence of people walking and cycling. Raised crosswalks may include yield line pavement markings ('shark teeth') on their approach. Note that neither raised crosswalks or yield lines are used on MOTI facilities. In addition, RFBs may be considered at the crosswalk and cross-ride to further raise awareness of the presence of pedestrians and cyclists.

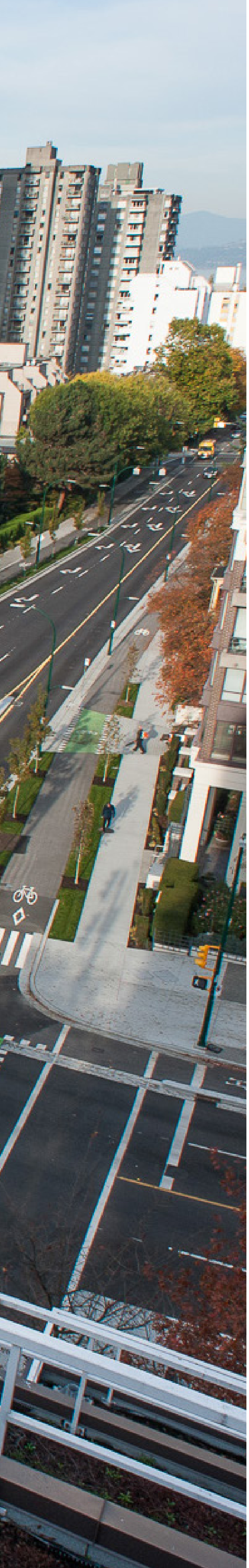


Conventional Channelized Right Turn



High Entry Angle Right Turn (Smart Channel)

Burrard and Pacific Protected Intersection, City of Vancouver, B.C.
Source: Rod Preston



G.4

ON-STREET BIKEWAY CROSSINGS

Intersection design is a critical component of overall bicycle facility design, as intersections tend to be high conflict areas along bicycle routes. Careful consideration must be taken to ensure people cycling can navigate intersections in a safe and comfortable manner. This chapter provides design guidance for intersections and for crossings with on-street bicycle facilities, including signage and pavement markings and geometric design guidance for protected intersections, dedicated major intersections, shared major intersections, minor intersections, and transitions between bicycle facility types. Off-street crossings and additional conflict areas are discussed in **Chapters G.5** and **G.6**, respectively.

SIGNAGE AND PAVEMENT MARKING CONSIDERATIONS

Signage and pavement markings can be used at intersections to help communicate right-of-way and warn all modes of conflict areas.

Signage

There are a number of signs at or approaching intersections that are important for on-street bicycle facility crossings. Relevant signage as it pertains specifically to bicycle facility design is shown in figures throughout **Section G**, and a full list of signage is provided in **Appendix B**. However, two key signs warrant introduction, as they are particularly relevant for crossings with on-street bicycle facilities and are present in a number of the designs discussed throughout this chapter.

- The **Right Turn on Traffic Signal Prohibited sign** (MUTCDC RB-17R; B.C. R-117-R Series) is used at intersections where signal priority is given to bicycle users, allowing them to complete a protected through movement without risk of collision with right turning motor vehicles. Protected signal phasing is discussed in **Chapter G.2**.
- The **Turning Vehicles Yield to Bicycles sign** (MUTCDC RB-37 with customized versions) is used where motor vehicles turning across a bicycle facility are required to yield to bicycle users. It provides through-moving bicycle users with the right-of-way over turning vehicles and is important for alerting motorists of the potential conflict. Another supplementary sign that may be used is the Turning Vehicles Yield to Bicycles and Pedestrians sign (MUTCDC RB-38; B.C. ZR-056 Series).

Cross-Ride Markings

Cross-rides, also known as elephant's feet and cross-bikes, are the bicycle equivalent of a crosswalk. They are intended to alert all road users of a bicycle crossing. Cross-rides consist of a series of white squares laid out in parallel lines across a road. They can be enhanced by adding bicycle symbols and/or applying a green surface treatment. On crossings of two-way facilities, bicycle symbol markings should indicate that there is two-way bicycle traffic by marking bicycle symbols in opposite directions in the two lanes. Placement of the bicycle symbol should be positioned in the middle of the motor vehicle travel lanes to reduce wear on the marking. **Appendix B** provides detailed pavement marking dimensions.

Cross-rides are not currently defined in the *B.C. MVA*, meaning that they have no legal status and have limited application on roadways under provincial jurisdiction. Cross-rides are only used on roadways under provincial jurisdiction where motor vehicles have a stop condition. Cross-rides that are used in combination with crosswalk markings are not currently permitted on roadways under provincial jurisdiction.

However, municipalities may enact bylaws that define cross-rides and permit them on municipal roads, as several cities across the province have done. Cross-ride markings typically do not provide legal right-of-way on their own – signage such as the Turning Vehicles Yield to Bicycles sign (MUTCDC RB-37) is also usually required. However, cross-ride markings help to reinforce the right-of-way of bicycle through movements over turning motor vehicles.

Cross-ride markings are typically used for bicycle facility crossings where bicycle users have the right-of-way over the person on the cross road. The extent of the marking will depend on site-specific conditions such as the type of traffic control for crossing motor vehicle traffic, the type of bicycle facility, and the volume of bicycle traffic. Cross-ride markings are recommended in the following circumstances:

- At bicycle crossings with appropriate signage and motorist sightlines, where motorist yielding behaviour can be expected; and
- At crossings where motor vehicle traffic is stop or signal controlled, or legally required to stop before entering the road (i.e. driveways, lanes, accesses, etc.). Yield Lines, also known as 'Shark's Teeth', may be used for approaching motor vehicles when crossing driveways and laneways to mark the edge of the bicycle facility.

Cross-ride markings should not be used:

- Where bicycle users are expected to yield priority;
- When there are not adequate decision sightlines between bicycle users and the motorists as they approach the crossing; and
- To demarcate conflict zones across high speed ramps, as the high-speed differential between bicycle users and motorists introduces a significant conflict potential where motorists do not expect to yield to people cycling.

Cross-rides may be installed parallel to the pedestrian crosswalk, or the two may be combined. A combined cross-ride and crosswalk is typically reserved for multi-use pathway crossings (see **Chapter G.5**). The combined cross-ride and crosswalk application is not permitted on roadways under provincial jurisdiction. Separate crossings for bicycles and pedestrians should be provided wherever possible. When enacting bylaws that permit cross-rides, local governments should include wording that requires people cycling, skateboarding, in-line skating, and other faster active modes to yield right-of-way to pedestrians when using a combined cross-ride and crosswalk.

Cross-ride pavement marking, Vancouver, B.C.

Cross-ride pavement marking with bicycle stencils and green coloured pavement markings. A turning Vehicles Yield to Bicycles sign is also visible, Vancouver, B.C.

Conflict Zone Markings

Conflict zone markings raise awareness and visibility of people cycling, make cycling movements more predictable, guide bicycle users and motorists through conflict zones or complex intersections, and provide clarity of right-of-way (through cycling over driveway or cross road traffic). Coloured pavement markings can be used to indicate conflict zones.

The TAC *MUTCDC* has reserved the on-street application of the colour green to be used to denote bicycle facilities. The application of green pavement marking does not legally indicate right-of-way. However, it can help to alert all road users of conflict zones and draw attention to the area.

Combined cross-ride and crosswalk on the Spirit Trail, North Vancouver, B.C.

The application of green pavement markings should be considered on a case-by-case basis. In general, green pavement markings should be reserved for the specific area where a conflict may occur, rather than being applied across an entire corridor, as overuse may reduce their effectiveness. Green pavement markings can generally be applied in the following circumstances:

- On cross-rides (see section above), especially where bicycle facilities cross major driveways and laneways, intersections with permissive left- and right-turn motor vehicle conflicts, or where there is poor compliance with turn restrictions;
- To increase the visibility of sharrow markings in areas with high bicycle traffic or significant crossing conflicts, such as merging and mixing zones. Green-backed sharrows are sometimes referred to as 'super sharrows';
- Where bicycle lanes approach an intersection away from the curb, either due to a bicycle-only turn lane or where a dedicated right turn or bus lane is located to the right of a bicycle lane; and
- In bike boxes and two-stage turn boxes.

Green pavement marking treatments are not recommended in the following circumstances:

- Along bicycle lanes approaching intersections against the curb where motor vehicles are expected to merge into the bicycle lane to turn right;
- At multi-use crossings with a combined cross-ride and crosswalk, as green should be reserved for bicycle-only applications instead of multi-use applications; and
- At bicycle crossings with no conflicts, such as where signal phasing exists and compliance is high (note that a cross-ride may still be used, but green surface treatment is not necessary).

Guideline Pavement Markings

Guideline pavement markings are used to guide bicycle users though an intersection, connecting two bicycle facilities. These are useful across complex intersections, two-stage turn boxes, and bicycle facility transitions to direct people cycling to the safest and most direct path (see **Appendix B**).

Yield Lines ('Shark's Teeth')

Yield lines, also known as 'shark's teeth', feature a line of solid white isosceles triangles pointing in the upstream direction (towards oncoming traffic). Yield lines are intended to provide a visual cue that motorists or bicycle users should yield. They may be used 6 to 15 metres in advance of a marked and signed crosswalk that crosses multiple travel lanes as a means of discouraging motorists from stopping too close to the crosswalk when yielding to pedestrians. They may also be used prior to on-street merging zones and on bicycle facilities to encourage people cycling to yield at pedestrian crosswalks.

Yield lines should not be used at crosswalk locations that are stop or signal controlled. They also should not be used in advance of crosswalks that cross an approach to or departure from a roundabout. On-street parking should be prohibited in the area between the Advance Yield to Pedestrians Line and the crosswalk.

Yield lines are not a common pavement marking in North America, so users may not readily interpret their meaning. However, the intent is that they provide 'visual friction' on the roadway that causes motorists and people cycling to intuitively take note and proceed with caution. Yield lines are not currently defined in the *B.C. MVA* and are thus not used on roadways under provincial jurisdiction.

Figure G-90 // Protected intersection Key Features

PROTECTED INTERSECTIONS

Protected intersections are intersections that use a number of enhanced design elements, to provide increased protection for people walking and cycling as shown in **Figure G-90**:

1. Corner refuge islands
2. Forward bicycle queuing areas
3. Setback of bicycle and pedestrian crossings
4. Pedestrian refuge islands
5. Bicycle-friendly signal phasing.

Protected intersections provide a high level of safety and comfort for people cycling by clearly indicating right-of-way, promoting predictable movements, reducing the distance and time during which people on bicycles are exposed to conflicts, and adding protected design elements to the intersection. These design elements result in intuitive, low-stress movements in all directions. Conflicts between right turning vehicles and through bicycle users approaching an intersection are eliminated, while conflicts at the intersection itself are mitigated by adding physical protection for bicycle users and reorienting motor vehicles to increase visibility and encourage eye contact between users. Signal phasing may be used to completely eliminate all conflicting movements (see **Chapter G.2**).

Protected intersections are the preferred intersection treatment for people of all ages and abilities.

Typical Application

Protected intersections can be applied on any road where enhanced comfort for people of all ages and abilities is desirable. Protected intersections may be suitable at both large intersections with multi-lane roads and complex signal phasing, and at smaller, simpler intersections, including stop-controlled intersections. Many existing standard intersections can be turned into protected intersections by installing protected crossing elements, although additional right-of-way may be required. A signal analysis should be conducted prior to implementing a protected intersection in order to identify any impacts on signal operations and user delay.

Protected intersections are used predominantly where protected bicycle lanes reach an intersection. Protected intersections may also be used at multi-use pathway intersections, although this is less common. Neighbourhood bikeways, shared streets, buffered bicycle lanes, and bicycle lanes may be transitioned into short protected bicycle lane segments prior to the intersection and then directed into a protected intersection (see **Figure G-90**).

Where insufficient space exists for a fully protected intersection, they may be partially implemented by adding key protected intersection elements at one or more corners, typically in the dominant direction of bicycle travel. This can be effective in constrained environments, when bicycle facilities are not located on all sides of the road, and where there is a desire to transition unprotected facilities into protected facilities and protected intersections. See the Transitions subsection below.

Protected intersections can also be implemented using interim materials, even when building a refuge and corner island may not be possible. Paint markings along with flexible delineators and modular speed humps are examples of interim materials that can be considered.

Vancouver, B.C.

Design Guidance

Figure G-91 shows a protected intersection with uni-directional protected bicycle lanes. Design elements have been numbered to correspond with the descriptions below:

- **Corner Refuge Island:**
  The corner refuge island is a physical element that defines the protected queuing space for bicycle users waiting to proceed through the intersection. A vertical curb should be used on the island to prevent motor vehicle encroachment. The transitional zone between the corner refuge island and the sidewalk should be at least 3 metres wide to allow bicycles to maneuver.

  The corner refuge island can be used to create a smaller corner radius, helping to slow the speed of turning motor vehicles. A maximum turning radius of 14 metres is recommended where permissive right turns across the through bicycle facility are permitted. To accommodate larger motor vehicles with wide turning radii, a mountable truck apron may be added as part of the corner refuge island.

In environments with a high volume of people cycling, high capacity protected intersections can be created by using a thinner corner refuge island, which maximizes the available queuing and maneuvering space. The outside of the corner refuge island remains the same, but the thinner island allows more people to wait side-by-side and depart at the same time.

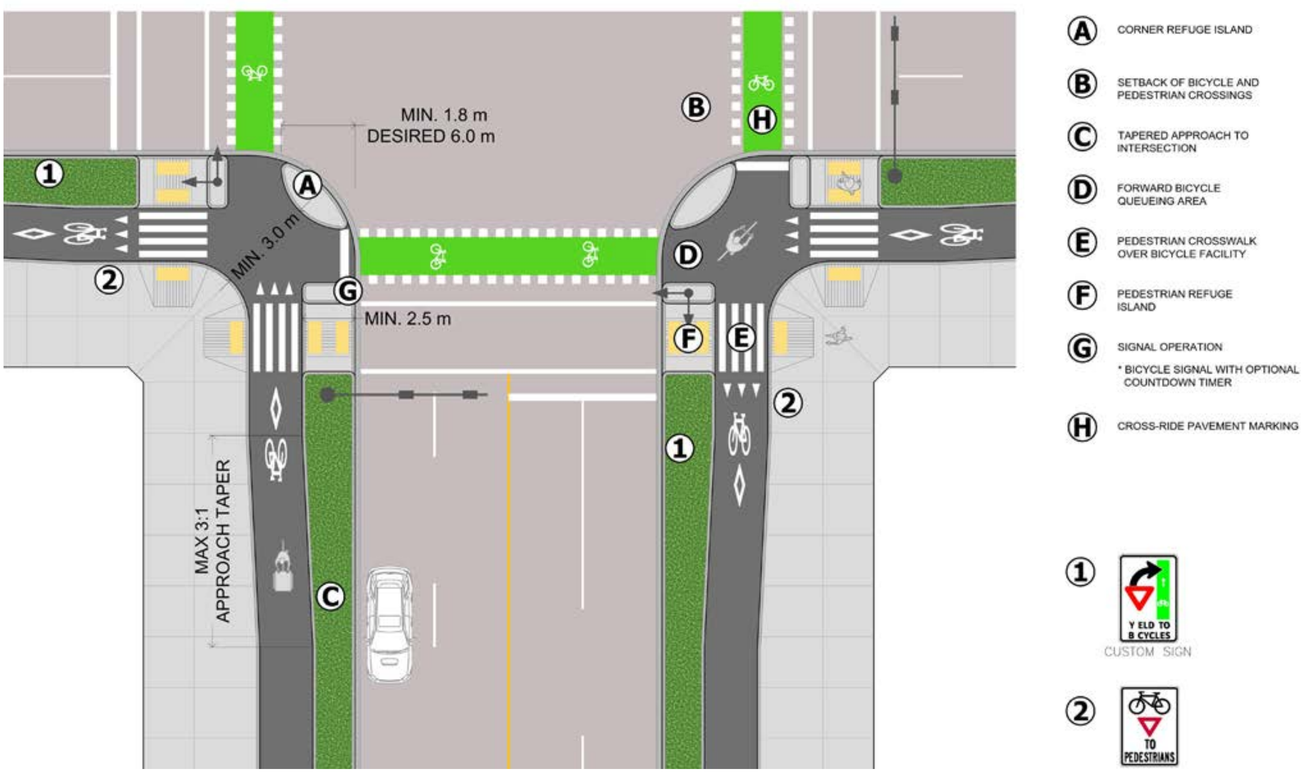


Figure G-91 // Protected Intersection with Uni-Directional Protected Bicycle Lanes

- **Setback Bicycle and Pedestrian Crossings:** Setback bicycle and pedestrian crossings create queuing space for right turning motor vehicles, which significantly improves motorist sightlines. Motor vehicles are able to turn almost 90 degrees to face people walking and cycling before crossing their paths, enabling better eye contact between users. The setback also increases the time and space that all users have to react to potential conflicts

  The recommended setback between the bicycle crossing and the motor vehicle travel lane is 6 metres, as this provides space for a single motor vehicle to queue outside of the path of through bicycle and motor vehicles. A minimum setback of 1.8 metres is required to ensure that queuing motor vehicles do not impeded through traffic.
- **Tapered Approach to Intersection:** The protected bicycle facility may be required to move away from the motor vehicle travel lane when approaching the intersection in order to align cyclists with the setback crossing and provide larger queuing areas for bicycles and motor vehicles. This alignment shift should occur gradually at a taper rate of no greater than 3:1, assuming a cycling speed of 20 km/h.
- **Forward Bicycle Queuing Area:** This is the area where people cycling wait before proceeding through the intersection. The forward bicycle queuing area shortens the crossing distance and enables people cycling to enter the intersection before motor vehicles, making them more visible to motorists. The bicycle queuing area should be 1.8 metres deep (between the road and the and the bicycle) and 1.8 metres wide for a uni-directional facility, or 3.0 metres wide for a bi-directional facility. A stop bar for bicycle users should be painted to minimize bicycle overhang into the motor vehicle travel lane.
- **Pedestrian Crosswalk over Bicycle Facility:** Bicycle users must yield to pedestrians who are crossing the bicycle facility to wait in the pedestrian refuge area. This crosswalk must be marked and a Bicycle Yield To Pedestrian sign (MUTCDC RB-39) may also need to be provided. Additional yield lines (i.e. 'shark's teeth') may be placed in advance of the crosswalk to encourage people cycling to slow down and yield to pedestrians. Tactile attention indicators should be installed on either side of the crosswalk to alert visually impaired pedestrians that they are crossing a bicycle facility.
- **Pedestrian Refuge Island:** The pedestrian refuge area provides a protected waiting area for pedestrians and shortens the crossing distance. The constrained minimum dimensions of the pedestrian refuge island are 2.5 metres deep (between the road and the bicycle lane) and 1.8 metres wide. Protected intersections can be challenging for visually impaired people to navigate. Tactile attention indicators should be installed on either side of the pedestrian refuge island to alert visually impaired people that they are crossing a bicycle facility or road.
- **Signal Operation:** Protected bicycle signal phases may be used to further reduce conflicts between people walking, cycling, and driving. **Chapter G.2** provides guidance on the placement and operation of protected bicycle signal phasing.
- **Cross-Ride Markings:** Cross-rides should be painted across the intersection to guide bicycle users and raise awareness of people cycling. Cross-ride guidance is provided earlier in this chapter, with dimensions in **Appendix B**.

People waiting in forward bicycle queuing area and pedestrian refuge island, respectively. Pacific Street/ Burrard Street intersection, Vancouver, B.C.

Maintenance Considerations

Protected intersection maintenance requirements should be considered early in the design process to ensure that there is sufficient space between vertical curb elements to facilitate road sweeping and snow removal. These requirements are similar to those of protected bicycle lanes – the same equipment should be able to clear both facilities. The radius, width, and vertical curb height of the corner refuge islands must all be considered. Smaller curbs may collect less debris and snow. Signs or vertical delineators may be installed on curbs to ensure that they are visible in winter conditions, as long as the signage or vertical delineators do not obstruct sightlines for queuing or approaching users. See **Chapter I.3** for more guidance on cycling facility maintenance.

DEDICATED MAJOR INTERSECTIONS

If protected intersections cannot be provided, dedicated bicycle facilities can be provided to direct people on bicycles through the intersection. The following subsections provide design guidance for dedicated intersection approaches and crossing points, and are organized based on the bicycle's movement, the motorist's movement, the available right-of-way, and whether there is a dedicated right-tun lane for motor vehicles.

Bicycle Through Movements with Right Turning Vehicles

Careful consideration must be given to ensure that all road users are aware of upcoming intersections and potential conflict points. One of the most common types of collisions between motor vehicles and bicycle users is the 'right hook' collision, where right turning motor vehicles hit or cut across the path of a through-moving bicycle user. A number of signage, pavement marking, and geometric design treatments can be used to improve motorists' awareness of bicycle users, clarify right-of-way, and allow people cycling to position themselves in advance of the intersection in order to reduce conflicts at the intersection.

Design treatments vary depending on the type of bicycle facility and the number and type of adjacent motor vehicle lanes. Bicycle lanes can expose people cycling to conflicts where motor vehicles must merge into or weave through the bicycle lane on the intersection approach. Protected bicycle lanes provide more security for bicycle users along the corridor, but at intersections the separation can change depending on the intersection design and transition in the facility type. Considerations for each type of facility are discussed below.

The following design recommendations apply to both painted and protected bicycle lanes at all intersection configurations:

- Cross-rides, conflict zone markings, and green pavement markings should be applied as per the guidance earlier in this chapter ;
- Sightlines at intersections and crossings should be maintained by limiting and/or restricting on-street parking and vertical barriers (see **Chapter G1**);
- At signalized intersections, bicycle signal detection should be configured to detect bicycles in the through bicycle lane (see **Chapter G.2**);
- At signalized intersections, a protected bicycle signal phase may be considered wherever feasible to mitigate the conflicts between people walking, cycling, or driving (see **Chapter G2**); and
- Where permissive left or right turns are allowed, and where motor vehicles may merge across bicycle lanes, the Turning Vehicles Yield to Bicycles sign (MUTCDC RB-37) should be used to reinforce bicycle through movement right-of-way over turning motor vehicles. The decision to implement this signage should also consider other contextual factors related to the operating environment and other signage in the area.

The subsections below provide detailed guidance on the following road layouts:

- Combined through lane and right turn motor vehicle lane;
- Dedicated right turn motor vehicle lane with continuous bicycle lane; and
- Channelized right turn lane.

These configurations are ordered based on how much right-of-way is required, from least amount of space (combined through and turn motor vehicle lane) to greatest amount of space (channelized right turn lane). Within each of these layouts, there are a hierarchy of treatments that may be considered.

Combined Through and Right Turn Motor Vehicle Lane

Figure G-92 shows a protected bicycle lane that bends-out at the intersection to improve the sightlines and provides additional yielding space for right turning motor vehicles. This design is preferred whenever the width of the Furnishing Zone provides sufficient space to shift the bicycle alignment. The protected bicycle lane can be narrowed on the approach to maximize the lateral shift away from the intersection.

Figures G-93 and **G-94** show a protected bicycle lane and painted bicycle lane, respectively, adjacent to a combined through and right turn motor vehicle lane. At signalized intersections, providing bicycle-friendly signal phasing (see **Chapter G.2**) and an advanced stop line for bicycle users is recommended. Where this is not possible, it is important to provide appropriate signage and sightlines, as outlined above and in **Chapter G.1**. At unsignalized intersections where sightlines are not achieved, a Yield or Stop sign for the bicycle users should be installed.

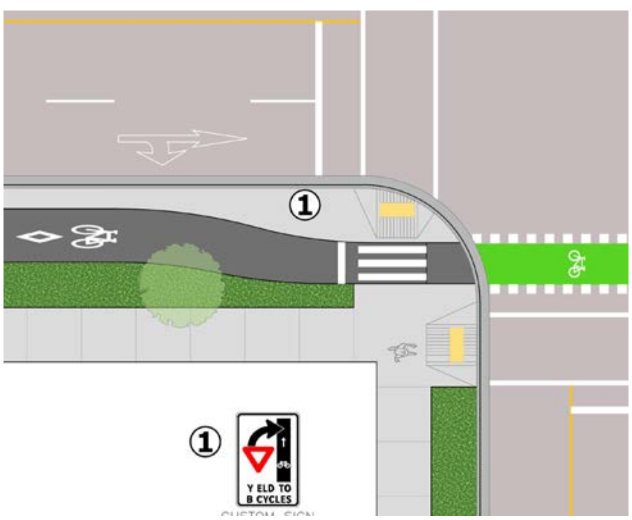


Figure G-92 // Bend-Out Protected Bicycle Lane

Figure G-93 // Protected Bicycle Lane Adjacent to Combined Right Through Turn Lane

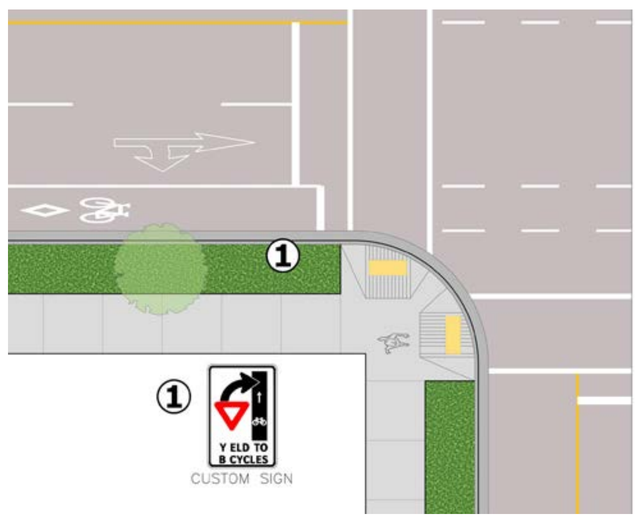


Figure G-94 // Painted Bicycle Lane Adjacent to Combined Right Through Turn Lane

Considerations should be given to eliminate motor vehicle right turns across protected bicycle lanes when the street network allows access through an alternative route. By eliminating right turning motor vehicles the physical barrier can be continued past the nearside crosswalk as seen in **Figure G-95**. This treatment can be used at one-way streets that do not accommodate traffic in that direction as well as locations where right turns are not permitted. At corners where right turns are not permitted a tighter corner radius can be used to improve the pedestrian crossing.

For bicycle lanes at unsignalized intersections, or where a protected bicycle signal phase cannot be implemented, the bicycle lane should become dashed approaching the intersection to allow motor vehicles to merge and turn right from the lane closest to the curb (see **Figure G-96**). This design will result in a higher workload for motorists and bicycle users, as it does not separate the modes in the conflict area. This configuration is the least preferred and is not considered comfortable for people of all ages and abilities.

The dashed segment of the bicycle lane should be a minimum of 18 metres in length and follow a minimum length to width ratio of 10:1. In locations with more than 4,000 vehicles per day, the dashed lane lines should be at least 30 metres in length to provide greater time and flexibility for motorists to complete the weave. See **Appendix B** for dashed bicycle lane marking dimensions.

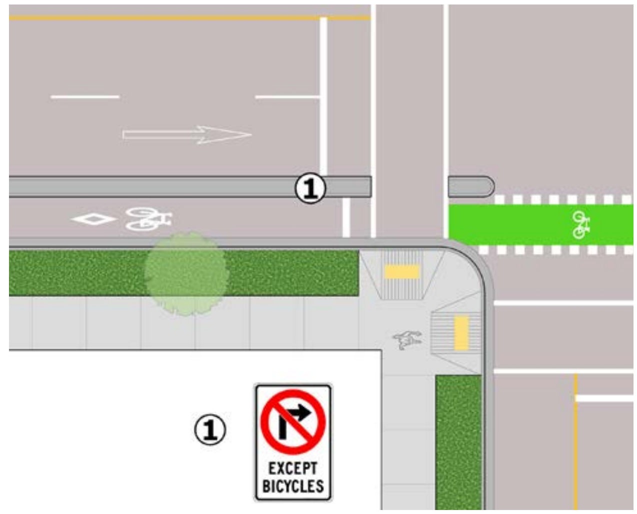


Figure G-95 // Protected Bicycle Lane, No Right Turns

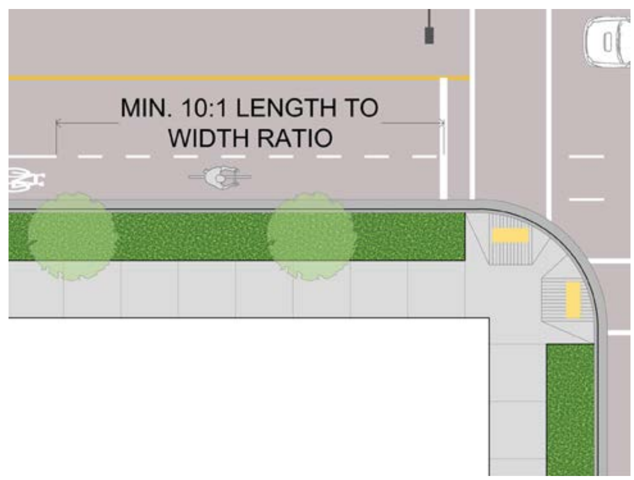


Figure G-96 // Bicycle Lane Without Right Turn Lane - Dashed Approach

Protected bicycle lane adjacent to dedicated right turn lane narrowing upon intersection approach in City of Vancouver, B.C. Custom bicycle lane narrows sign is visible (left).

Protected bicycle lane adjacent to dedicated right turn lane narrowing upon intersection approach in City of Vancouver, B.C.

Dedicated Right Turn Lane with Continuous Bicycle Lane

The presence of a dedicated right turn only motor vehicle lane implies that the right turning motor vehicle volume is high and will warrant more protection for people cycling. Motor vehicle volumes should be verified to confirm whether the right turn lane is in fact warranted before proceeding with designing the bicycle facility.

Figure G-97 shows a protected bicycle lane adjacent to a dedicated right turn lane. The protected bicycle lane should remain to the right of the dedicated right turn lane. Bicycle-friendly signal phasing may be used to mitigate conflicts between through moving bicycle users and right turning motor vehicles (see Chapter G2). Where signal phasing is not feasible, the Turning Vehicles Yield to Bicycles sign (MUTCDC RB-37) should be used.

Figure G-97 // Protected Bicycle Lane Adjacent to Dedicated Right Turn Lane

In constrained rights-of-way, the protected bicycle lane may need to narrow upon approaching the intersection. This maintains the protection for people cycling right up to the intersection and is preferred over the mixing zone approach discussed below. See **Chapter D.3** for guidance on constrained protected bicycle lane widths. The Bicycle Lane Narrows sign (CUSTOM) can be used on the intersection approach to alert people cycling of the change in facility width.

Bicycle lanes along roads with dedicated right turn lanes require a different approach than protected bicycle lanes. Bicycle lanes with green conflict zone pavement markings should be placed to the left of any dedicated right turn lane and to the right of any left turn lanes at intersections.

Figure G-98 shows a constrained protected bicycle lane next to a dedicated right turn lane. This design transitions the on-street protected bicycle lane to a constrained raised bicycle lane to maintain some physical separation between the bicycle lane and the right turning vehicles. The bicycle lane should be dashed approaching the intersection to allow motor vehicles to weave across the bicycle lane into the dedicated right turn lane.

Figures G-99 shows a continuous bicycle lane with dedicated turn lane for motor vehicles and on-street motor vehicle parking. Right turn only lanes should be designed to ensure adequate motor vehicle storage so that motor vehicles are not stopping in the bicycle lane. These lanes should not be longer than necessary, as having moving motor vehicles on both sides can be uncomfortable for people cycling.

The dashed segment of the bicycle lane should be a minimum of 18 metres in length and follow a minimum 10:1 length to width ratio. In locations with more than 4,000 vehicles per day, the dashed lane lines should be at least 30 metres in length to provide greater time and flexibility for motorists to complete the weave. The width of a dashed bicycle transition lane and through bicycle lane should match the width of the bicycle lane on the approach (see **Chapter D.4**). Dashed lane line transition areas for through bicycle lanes should not be used on roads with double right turn lanes. Double right turn lanes are extremely difficult for bicycle users to negotiate. An alternative off-street bicycle pathway with perpendicular crossing should be considered.

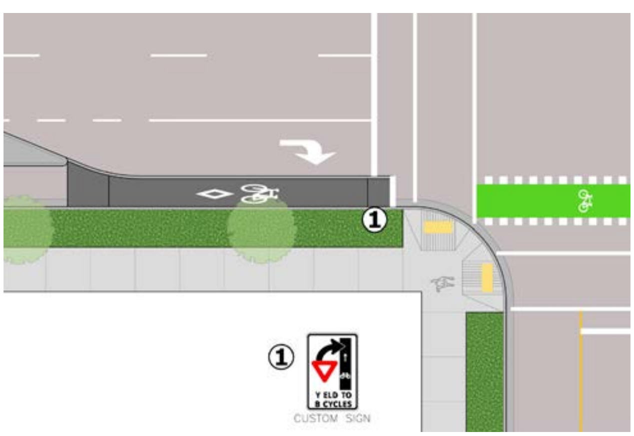


Figure G-98 // Constrained Protected Bicycle Lane Adjacent to Right Turn Bay

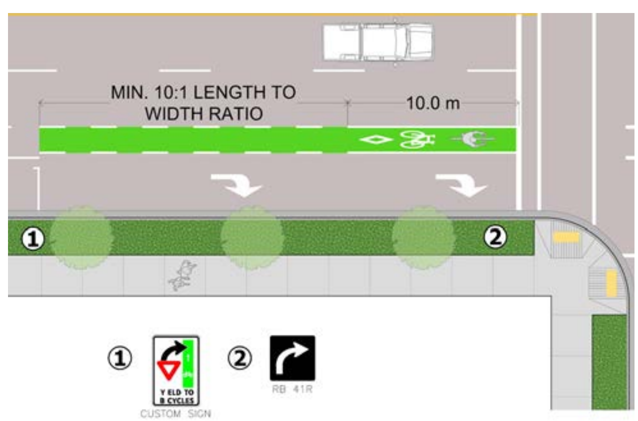


Figure G-99 // Continuous Bicycle Lane with Dedicated Turn Lane

Green conflict zone pavement markings should be used in the bicycle lane to bring awareness to the conflict area. Additionally, the bicycle symbol and diamond markings should be used to denote the reserved bicycle lanes and can be supplemented with directional arrows. However, bicycle symbols and diamond markings should not be used through transition areas. The Turning Vehicles Yield to Bicycles sign (*MUTCDC* RB-37) should be used on the intersection approach where motor vehicles will be merging across the bicycle lane, but is not required at the intersection because of the dedicated right-tun lane.

When a through motor vehicle travel lane drops into a right turn only lane, it is recommended that the through bicycle lane remain to the right of the travel lane, and that the bicycle lane transition to a protected facility or off-street pathway in advance of the intersection. In conjunction with this, a protected bicycle signal phase may be considered to minimize the conflict with the right turning motor vehicle volume.

Channelized Right Turn Lane

As described in **Chapter G.3**, channelized right turn lanes can be found at intersections along roads with high motor vehicle volumes and are used to facilitate right turn motor vehicle movements. They can be challenging and inconvenient for people walking and cycling to cross due to the higher speed of the turning vehicles and the yield controlled (unsignalized) nature of the turn. Additionally, the triangular refuge island may contain limited refuge and queuing space for people walking and cycling.

Design guidance for bicycle facilities in this context is dependent on the right turning motor vehicle volume and speed, sightlines, and whether or not the intersection can be redesigned. Consideration should be made to normalizing the intersection by removing the channelized right turn lane (see **Chapter G.3**). Converting the intersection into protected corners is recommended where feasible (see protected intersection section above).

It may not be possible to remove channelized turn lanes due to roadway geometry, traffic operations, costs, and other considerations. Where removal is not feasible, a second option is to transition the bicycle lane off-street in advance of the intersection **(**see **Figure G-100**). This option minimizes the amount of exposure bicycle users have to motor vehicle traffic. In this configuration, people walking and cycling cross onto the right turn island and then have to cross the road again. This application should only be applied where adequate sightlines are achieved for all road users, and in lower speed applications where motorists would be expected to yield to people walking and cycling.

Along with transitioning the bicycle facility, the channelized island may be geometrically adjusted to reduce motor vehicle speeds. Redesigning the channelized island as a 'high entry angle' or 'smart channel' increases the entry angle to the cross road and decreases the turning speed to be more consistent with a yield condition. See **Chapter G.3** for further details on the benefits of the high entry angle design.

Cross-ride pavement markings may be considered to increase motorist awareness of people cycling and their anticipated path of travel approaching the intersection. The Pedestrian and Bicycle Crossing Ahead sign (WC-46R) and Right Turning Vehicles Yield to Pedestrians and Bicycles sign (MUTCDC RB-38) can be installed to bring additional awareness to motorists (see **Appendix B**). A Stop sign should also be provided for bicycle users to ensure they only proceed through the channelized right turn after stopping and proceeding only when safe to do so.

As mentioned in **Chapter G.3**, raised crosswalks may also be used at channelized islands to slow motor vehicle speeds and increase the visibility of people walking and cycling at the crossing. Raised crosswalks also provide smoother transitions for pathway users, which may result in higher approach and crossing

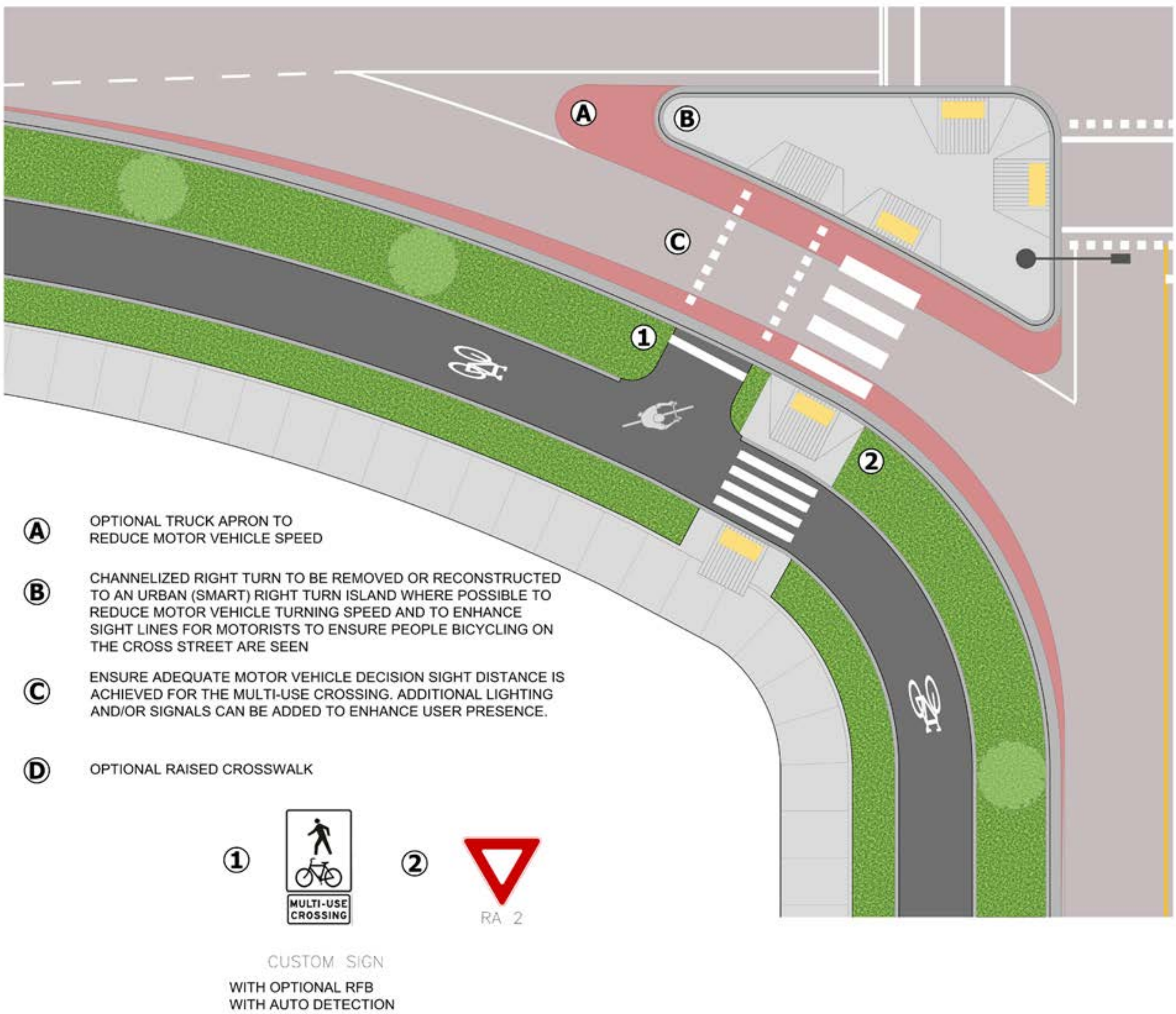


Figure G-100 // Protected Bicycle Lane Crossing at Channelized Right Turn Island

speeds of bicycle users. Raised crosswalks may include yield line pavement markings ('shark's teeth') on their approach. Note that raised crosswalks and other forms of vertical deflection are not permitted on roadways under provincial jurisdiction.

Where channelized right turn lanes cannot be removed or redesigned, a third option is to carry the bicycle lane straight through to the intersection, similar to the dedicated right turn lane configuration discussed above. **Figure G-101** shows an example of this configuration. This option is less desirable from a safety standpoint because it creates a long conflict area where motorists and bicycle users are mixing. However, it has the benefit of providing the most direct alignment for bicycle users through the intersection.

Coloured conflict zone pavement markings should be applied through the bicycle lane conflict area. At the right turn island, the bicycle lane can be denoted with white solid lane lines, the bicycle symbol, and a diamond marking. To provide a more protected facility, a physical barrier may be installed between the bicycle lane and the motor vehicle lane.

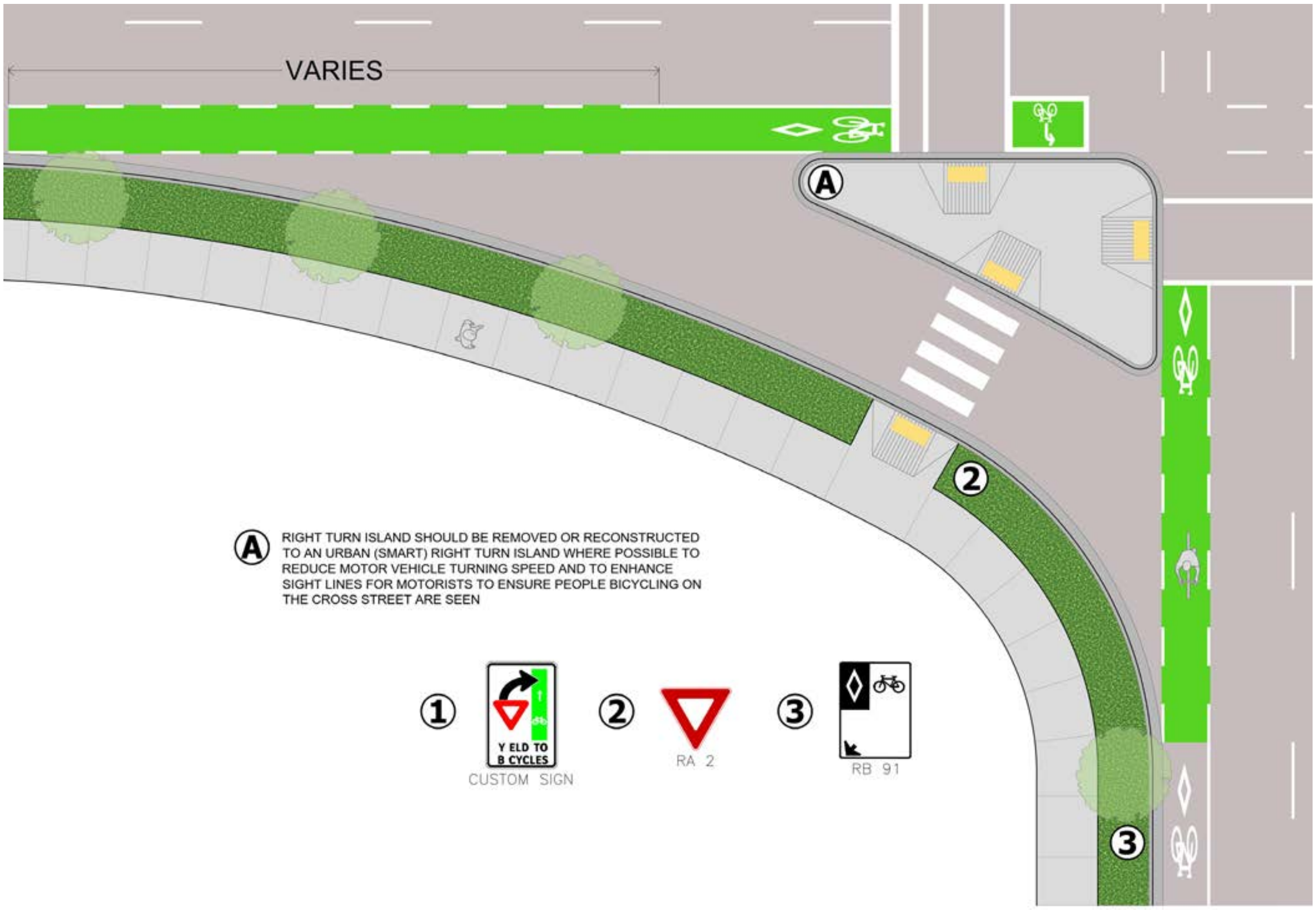


Figure G-101 // Bicycle Lane With Channelized Right Turn Island - Through Bicycle Lane Option

Bicycle Left Turning Movements

Completing a left turn movement can be challenging for people cycling, as it can expose them to conflicts with motor vehicles travelling in multiple directions. There are a number of left turn options for bicycle users, each with varying levels of directness and exposure to potential conflicts. People cycling may choose different left turn options depending on the number of travel lanes and motor vehicle speeds and volumes.

A person's approach to left turns may also differ based on comfort levels. For example, in the absence of dedicated bicycle facilities, a confident bicycle user may choose to take the lane and make a vehicular left turn, whereas less confident bicycle users often do a two-stage left turn, crossing one direction of motor vehicle traffic at a time. There are a number of design solutions to help make left turns more comfortable for people of all ages and abilities.

Bicycle Left Turn Lane

On bicycle facilities with low motor vehicle speeds and volumes, there are likely sufficient gaps in motor vehicle traffic to allow people cycling to merge to the left and make a left turn either from a combined through and turning lane or a dedicated left turn lane if one exists. A dedicated bicycle left turn lane adjacent to the motor vehicle left turn lane may be provided, as shown in **Figure G-102.**

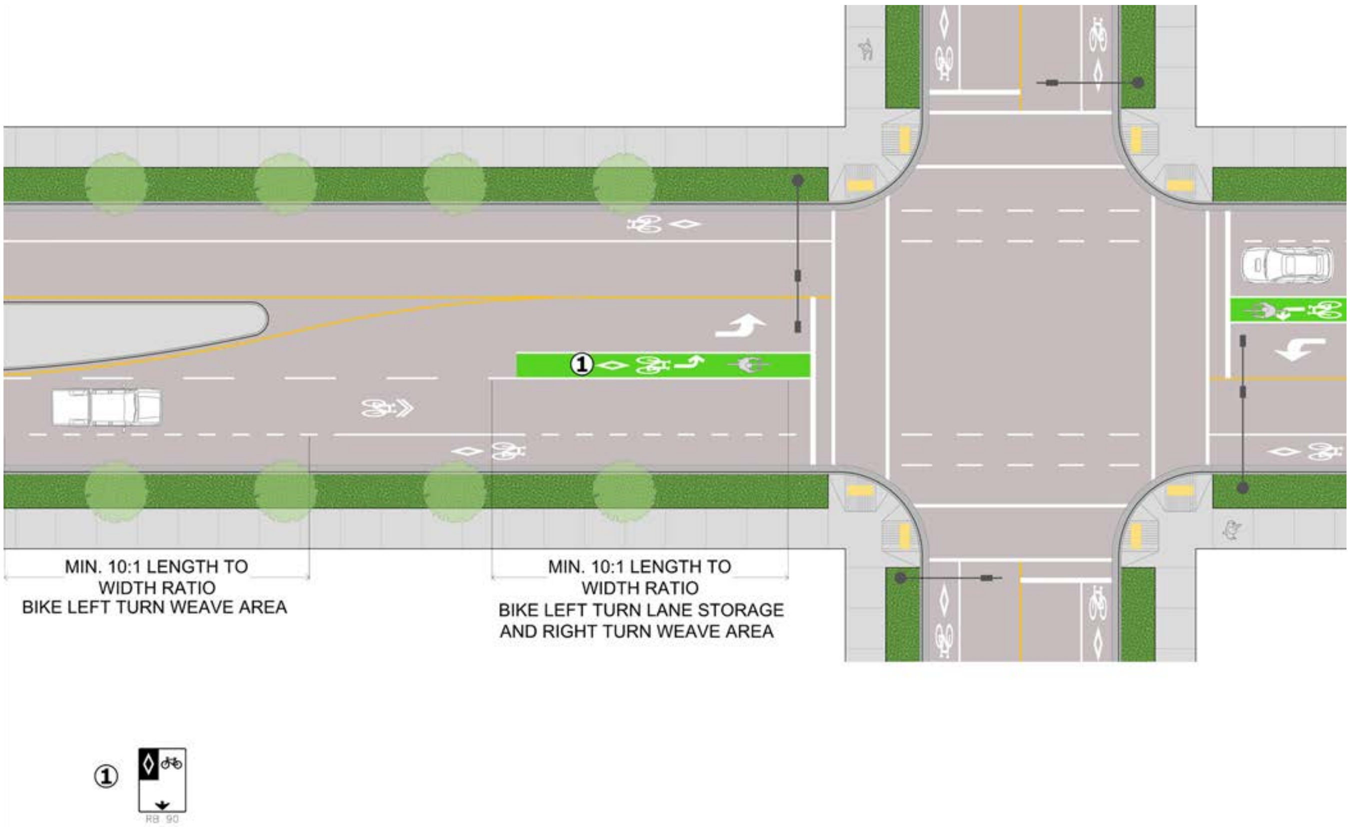


FIGURE G-102 // PAINTED BICYCLE LEFT TURN LANE

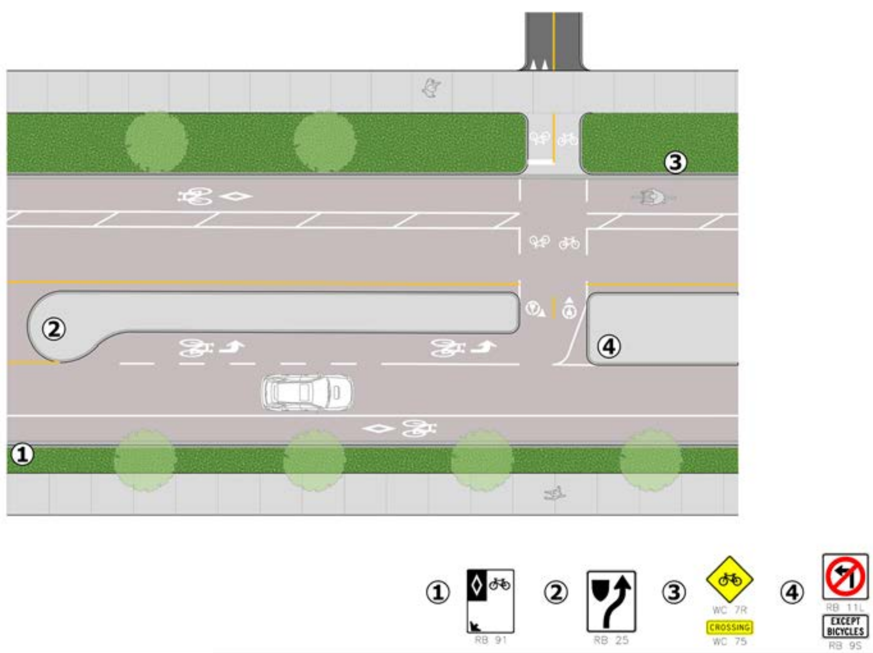


FIGURE G-103 // PROTECTED BICYCLE LEFT TURN LANE

This treatment should not be implemented on roads with multiple motor vehicle through lanes per direction of travel. Dedicated bicycle left turn lanes are not considered an all ages and abilities facility, as they require people cycling to weave across traffic and wait between two motor vehicle travel lanes when traffic is stopped.

Protected bicycle left turn lanes can provide people cycling with a safer crossing facility with less exposure to motor vehicle traffic (**Figure G-103**). These are only appropriate on neighbourhood bikeways, on low volume two-lane roads where the weaving maneuver is shorter, or where there is a T-intersection.

Bike Boxes

A bike box is a designated area located at the front of motor vehicle lanes at signalized intersections where people cycling can wait for a green signal phase (see **Figure G-104**). Bike boxes help to position bicycle users ahead of waiting motor vehicles, increasing their visibility and allowing people cycling to enter the intersection ahead of motor vehicles. This added visibility means that bike boxes can be beneficial in preventing 'right-hook' conflicts at the start of the green signal phase.

Motor vehicles cannot stop within the bike box when waiting at a light but may pass through it when the light turns green. This means that bike boxes are only effective when the people cycling arrive at the intersection during the red signal. Bike boxes facilitate left turn movements by allowing bicycle users to safely move into the correct lane during the red signal phase. This only applies when the bike box extends across the entire travel lane(s) for that direction of travel. Bicycle users approaching a green signal phase and looking to turn left need to either perform a vehicular left turn or wait for a red signal phase before moving into the bike box.

Bike boxes can be installed in the following locations:

- In built-up areas with high cycling volumes and a relatively small speed differential between motor vehicles and bicycles;
- At signalized intersections with high volumes of left turning bicycle movements or where through bicycle users are anticipated to be waiting for a green indication;
- Where right turns on red are, or can be, prohibited; or
- Where the right turning motor vehicles and through bicycle users are separated prior to the intersection (i.e. channelized right turn, or via access ramp), as the right turning motor vehicle traffic will not be in conflict with bicycle users stopped in the bike box.

Design considerations for bike boxes include the following:

- The bike box should be at least 2.75 metres deep, with depths commonly ranging from 2.75 to 5.0 metres. The minimum width of a bike box is equal to the combined width of the motor vehicle lane and the adjacent bicycle facility.
- Bike box design should consider non-standard bicycle lengths and operating characteristics. Longer bicycles may need a larger refuge area and may require additional manoeuvring space to enter the bike box.
- Green surface treatment and a bicycle symbol should be applied to the bike box to demarcate it as dedicated bicycle facility. It is recommended that a solid green surface treatment is applied in the bicycle lane for a minimum of 15 metres in advance of the bike box.
- A 600-millimetre-wide stop line for motor vehicles should be provided in advance of the bike box, supplemented by a Stop Line sign (MUTCDC RC-4; B.C. R-025 Series) with supplemental Except Bicycles tab (MUTCDC RB-9S; B.C. R-009 Tabs). The motor vehicle stop line may be set back by up to 2 metres to limit motor vehicle encroachment into the bike box.

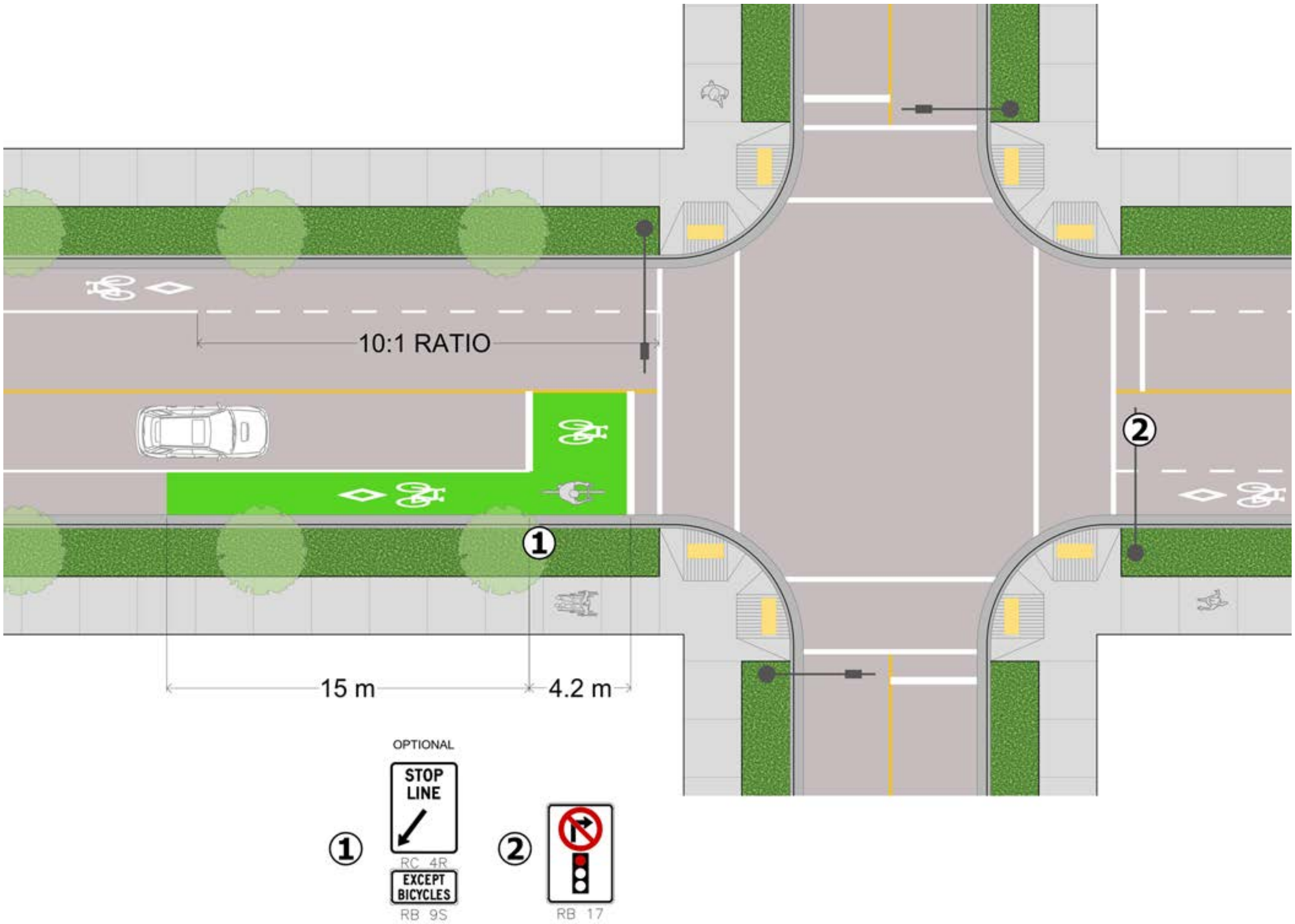


Figure G-104 // Bike Box

Optional 'Wait Here' pavement markings may be installed in areas of low compliance.

- A 600-millimetre-wide stop line should also be provided at the front of the bike box to prevent encroachment of bicycles into crosswalks. The bike box may be set back from the crosswalk to further limit bicycle encroachment.
- For actuated signals, bicycle detection should be provided with bicycle loop detectors in the bike box.
- Right Turn on Red Traffic Signal Prohibited signs (MUTCDC RB-17R; B.C. R-117-R Series) should be installed to ensure that motorists do not encroach into the bike box during the red signal phase.
- The Turning Vehicles Yield to Bicycles sign (MUTCDC RB-37) is recommended to clarify that bicycle users in the bike box have right-of-way.
- Educational signage directed at bicycle users may be required to communicate where bicycles should stop.

Two-Stage Turn Boxes

A two-stage turn is when a person cycling crosses one direction of traffic at a time. A two-stage turn box provides a designated waiting area outside of the travel lanes on the adjacent road, giving people cycling a waiting area to complete a two-stage left turn. The left turning bicycle users proceed straight to the waiting area on a green signal phase and then turn across the intersection when the crossing traffic gets a green signal phase. **Figures G-105** and **106** show two-stage turn box applications with protected and painted bicycle lanes, respectively.

Two-stage turn boxes improve safety and comfort by reducing the turning conflicts between vehicles and bicycles, and prevent conflicts resulting from bicycles queuing in the bicycle lane or on the sidewalk. This configuration typically results in increased delay for people cycling, as they must receive two separate green signal indications or wait for a safe gap at an unsignalized intersection.

Two-stage turn boxes are applicable in a number of circumstances, including:

Figure G-105 // Protected Bicycle Lane with Two-Stage Left Turn Box

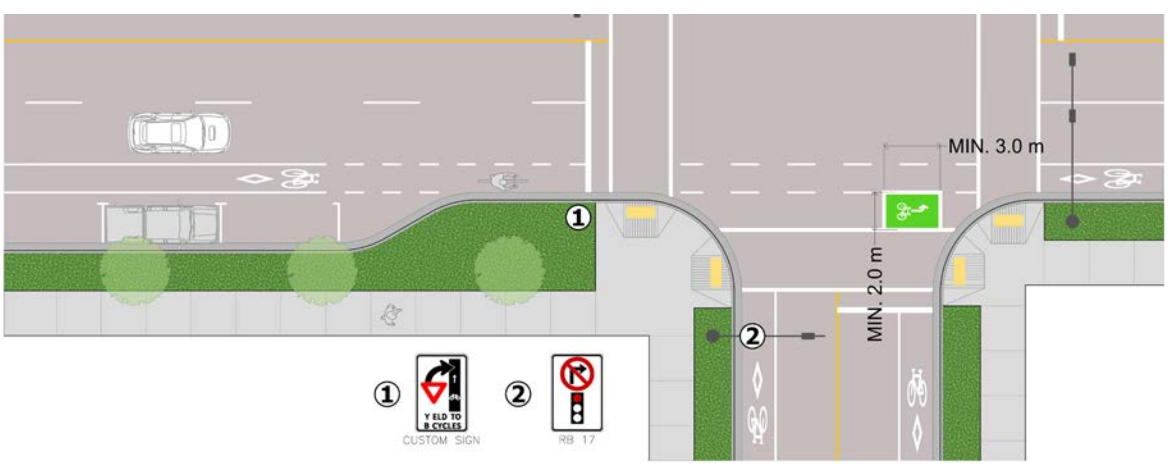


Figure G-106 // Painted Bicycle Lane with Two-Stage Left Turn Box

- At signalized intersections where there are few gaps in traffic;
- At multi-lane signalized intersections;
- Where the right turning motor vehicle traffic on the cross road is low and where right turns on red can be prohibited, or where there is a right turn lane on the cross road that can be separated from the bike box space;
- At locations where the person riding a bicycle needs to turn left from a right-side bicycle facility or right from a left-side bicycle facility;
- At mid-block crossings, to orient people cycling properly for safe crossings; and
- Where protected bicycle lanes are continued up to an intersection, but a protected intersection is not provided.

Two-stage turn boxes may also be applied at unsignalized intersections to simplify turns from a bicycle lane to another facility type, such as neighbourhood bikeways. However, challenges can occur when applying two-stage turn boxes at unsignalized intersections, as the turn box cannot be protected. As a result, motor vehicles on side roads may encroach on the turn box while waiting for a gap in traffic.

Design considerations for two-stage turn boxes include the following:

- The preferred dimensions for two-stage turn boxes are 2 metres by 3 metres, with a constrained minimum width of 1 metres.
- Two-stage turn box design should consider non-standard bicycle lengths and operating characteristics. Longer bicycles may need a larger refuge area and may require additional manoeuvring space to enter the two-stage turn box.
- Green surface treatment and a bicycle symbol should be applied to the bike box to demarcate it as a dedicated bicycle facility.
- A turn arrow should be included to clearly indicate bicycle positioning and direction.
- Right Turn on Red Traffic Signal Prohibited signs (MUTCDC RB-17R; B.C. R-117-R Series) should be installed to ensure that motorists do not encroach into the two-stage turn box during the red signal phase.
- Educational or wayfinding signage directed at bicycle users may be required to show bicycles the ideal travel path to complete their left turn, as this facility may not be intuitive.
- Guideline pavement markings may also be used to indicate the bicycle travel path.
- Placement of the two-stage turn box must be carefully considered. In order to enhance the visibility of bicycle users, the two-stage turn box should be positioned laterally in the cross road and aligned with the direction of travel of motor vehicles approaching the intersection from behind. The two-stage turn box must also be located in a protected area – typically, they are placed in line with an on-street parking lane or between a bicycle lane and a crosswalk.

In cases where a constrained geometry or right-of-way prevents placing the two-stage turn box in a protected area, the pedestrian crosswalk may be adjusted or realigned to enable space for the two-stage turn box. Alternatively, a two-stage turn box placed behind the pedestrian crossing can serve the same purpose (see **Figure G-107).** However, this configuration should only be considered if pedestrian volumes are low, as it requires people cycling to yield to pedestrians then weave across the crosswalk to enter the two-stage turnbox.

FIGURE G-107 // TWO-STAGE LEFT TURN BOX BEHIND CROSSWALK

Two-Stage Protected Left Turn

Bicycle left turns at T-intersections can be facilitated by redirecting the bicycle users to a waiting area behind the curb line on the right side of a road, often referred to as a jughandle. Jughandles position bicycle users to face the cross-road traffic. Designs vary depending on a number of factors, including available space, bicycle volumes, and the road's design speed. **Figure G-108** shows one example of a jughandle-style left turn. A more gradual transition to the side is more comfortable for people cycling and can provide a larger queuing area, but this requires more space than is typically available in existing environments.

Jughandles create a fourth leg to the intersection and require traffic control complementary to the other approaches. The T-intersection approach is typically a minor cross-road and would likely be stop controlled. In more developed areas where there are few gaps in traffic, traffic signals may be required in the jughandle waiting area. In these cases, bicycle signal detection should be installed in the jughandle.

At signalized intersections, conflict zone markings can be used for the conflict area with the through bicycles and the left turning motorists. Supplementary signage and pavement markings, including a bicycle symbol, directional arrows, and green pavement markings can be installed on the jughandle to indicate the space is reserved for turning bicycles.

Bicycle Right Turning Movements

At signalized intersections with a demand for right turning bicycle movements,, a free-flowing bicycle right turn can be designed to improve operations. This can be developed using a protected corner. Before the intersection, people cycling can be guided past the signal and connected to a facility on the cross road. A bicycle right turn lane with no stop bar can be provided, with directional arrow pavement markings. Signage can be used that indicates that people cycling are permitted to turn right.

Free-flowing bicycle right turns require additional right-of-way and have potential conflicts with

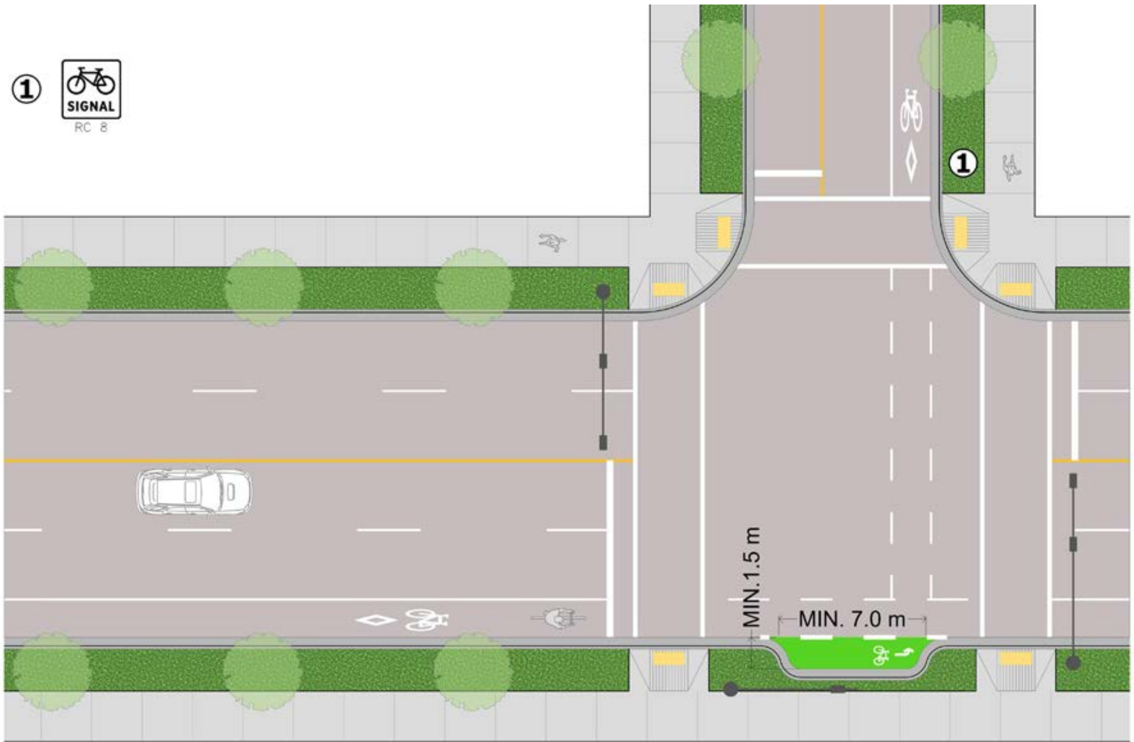


Figure G-108 // Jughandle-Style Left Turn

pedestrians. The right-of-way must be clearly defined for crossing pedestrian and cycling facilities. More details on protected intersections are provided below.

CONSIDERATIONS FOR BI-DIRECTIONAL BICYCLE FACILITIES

Bi-directional protected bicycle facilities require special consideration at intersections, including the following:

- A directional dividing line should be painted on the bi-directional protected bicycle lane at the approaches to the intersection for a minimum of 5 metres;
- Bicycle symbols, and the reserved diamond should be marked on the entrance of the bicycle facility for each direction;
- Bicycle signals with protected bicycle signal phasing should be considered where possible. Where permissive turns are allowed, Turning Vehicles Yield to Bicycles signs(MUTCDC RB-37) should be installed both approaching the intersection and at the intersection;
- The Contraflow Bicycle Lane Crossing sign (MUTCDC WC-43) may also be installed for the approaching cross-road traffic to alert motorists to the presence of the bi-directional bicycle facility. This is especially important on one-way motor vehicle roads.
- Protected intersections where a bi-directional protected bicycle lane intersects with a uni- or bi-directional protected bicycle lane may see a larger relative amount of cycling traffic. These protected intersections require additional bicycle queuing and manoeuvring space to ensure that bicycle through movements are not impeded. The forward bicycle queuing area should be at least 3.0 metres wide. It is recommended that right turns on red be prohibited and short signal phases are used, allowing the bicycle queuing areas to empty more frequently.

Shared Major Intersections (Mixing Zones)

Where dedicated space is not available for a separate facilities for people cycling and turning motor vehicles, shared intersections (also known as mixing zones) may be considered. However, it should be noted that shared intersections do not address conflicts between people cycling and turning motor vehicles and are not comfortable for people of all ages and abilities. As such, these treatments should only be considered after exploring options to provided dedicated facilities as noted in the previous sections.

Dedicated Right Turn Lane with Mixing Zone

Where a dedicated right turn lane is provided but there is insufficient space to maintain the bicycle facility up to the intersection, a mixing zone may be considered. This configuration is not suitable for people of all ages and abilities – where feasible, a dedicated cycling facility should be maintained up to and through the intersection. Mixing zones are suitable where there are relatively low turning motor vehicle volumes. Mixing zones can be considered if right turning motor vehicle volumes are less than 100 vehicles during the peak hour. **Figures G-109** and **G-110** provide guidance on the transition from protected or bicycle lane to a mixing zone before the intersection. Green-back 'super sharrows' can be applied to further enhance the shared lane.

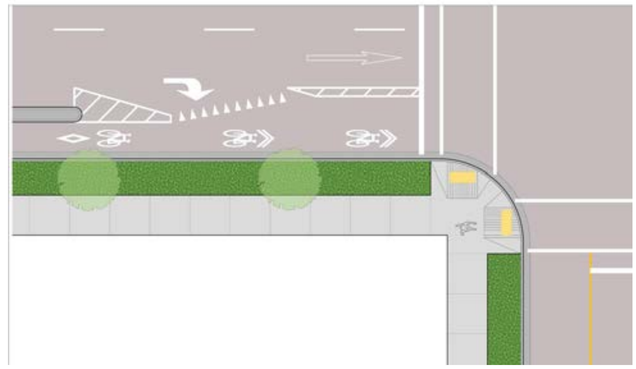


Figure G-109 // Discontinuous Protected Bicycle Lane with Mixing Zone

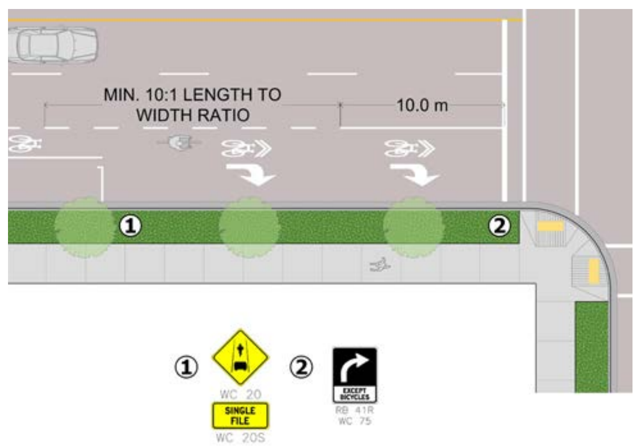


Figure G-110 // Discontinuous Painted Bicycle Lane with Mixing Zone

Minor Intersections

At minor intersections, laneways, and driveway crossings, people cycling can be assigned priority over motor vehicles as described below.

Minor Road Crossings

Treatments for minor road crossings are dependent on the intersection geometry, sightlines, and motor vehicle speeds and volumes. Transportation professionals should aim to reduce or minimize bicycle delay by limiting the number of stop signs along a bicycle route. This means that wherever, possible, bicycle through movements along bicycle facilities should have priority over local cross roads. However, a Yield or Stop sign should not be installed on the higher motor vehicle volume road unless justified by an engineering study (refer to the MUTCDC for details on the application of Yield and Stop signs).

Design professionals should consider the following when deciding which road should yield or stop where two roads with relatively equal motor vehicle volumes and/or characteristics intersect:

- Control the direction that conflicts the most with established bicycle crossings, pedestrian crossing activity, or school walking routes; and
- Control the direction that has obscured vision, dips, or bumps that already require drivers to use lower operating speeds.

Traffic calming and diversion measures such as neighbourhood traffic circles, curb extensions, and median diverters should be used in coordination with the above approaches to prevent neighbourhood bikeways from becoming attractive shortcuts for motorists (see **Chapter D2**). Where traffic calming and diversion measures are used, transportation professionals should ensure that municipal operations departments, emergency services, and transit agencies are involved in the design process to ensure winter maintenance considerations and to minimize impacts on other emergency services and transit. At road crossings, sharrow pavement markings can be used on the approach and can be carried across the intersection to enhance awareness of bicycle crossings. On higher volume roads, green-backed 'super sharrows' can further enhance the visibility of the sharrow and crossing. Additional wayfinding pavement marking symbols with directional arrows may be used where the bicycle route changes directions (see **Chapter D2**).

Laneway and Driveway Crossings

Bicycle facilities have greater potential for conflict where there are many laneway and driveway crossings along the corridor. The number of laneway and driveway crossings should be considered in the network planning and bicycle facility selection processes. Where laneway and driveway crossings exist, design considerations are necessary to mitigate potential conflicts.

Sufficient sightlines for both bicycle users and motorists must be provided. This may necessitate removing obstructions and restricting on-street parking on either side of the laneway or driveway. For high-use laneways and driveways, such as commercial and employment accesses, conflict zone markings can be used to enhance the visibility of the crossings. Signage can also be used to alert motorists both entering and exiting the laneway or driveway of the conflict. However, transportation professionals should use caution when installing signage to ensure to not result in reduced effectiveness of existing signage.

Where possible, bicycle facilities should maintain a consistent elevation through the laneway or driveway crossings. This is applicable to sidewalk level and intermediate level protected bicycle lanes. In this case, the sidewalk and bicycle facilities would remain at a consistent elevation with the laneway or driveway ramping down to road level once past the bicycle facility.

TRANSITIONS

Transitioning between different bicycle facility types requires special consideration to ensure a safe and intuitive transition for people cycling. It is important to maintain sightlines and clearly communicate right-of-way to all road users. Maintenance is particularly important in transition areas to ensure signage and pavement markings are visible and that surface conditions are safe. Minimum grades through transition areas should be confirmed to ensure no ponding or icing will be present during wet and winter conditions.

Transition designs will vary depending on site-specific conditions. For example, in some cases the available right-of-way along a corridor can vary, and the lane configuration can change to meet the demand of the motor vehicle traffic patterns on approaches to more major intersections. Design considerations for specific facility types are provided below. Each transition can also be considered in the opposite direction (i.e. vice versa).

Figure G-111 shows the signage and pavement markings required for transitioning between a bicycle lane and a neighbourhood bikeway Guideline pavement markings should be used to guide bicycle users through the intersection in the correct position in order to line up with the receiving facility. When transitioning to a bicycle lane, a dashed bicycle lane should be included for 25 metres prior to the intersection, with a Reserved Bicycle Lane sign (MUTCDC RB-90, RB-91) installed. A Reserved Bicycle Lane Ahead sign (MUTCDC WB-10) should be used to alert road users of the transition.

When transitioning to a neighbourhood bikeway the bicycle lane should carry through to the far side of the intersection and should transition from solid to dashed, with Reserved Bicycle Lane Ends sign (MUTCDC RB-92) installed. On the neighbourhood bikeway, sharrow pavement markings can be used guide bicycle users' lateral position on the road, shifting them into or out of the bicycle lane. The Shared Use Lane Single File sign (MUTCDC WC-20) may be used to alert road users of the transition.

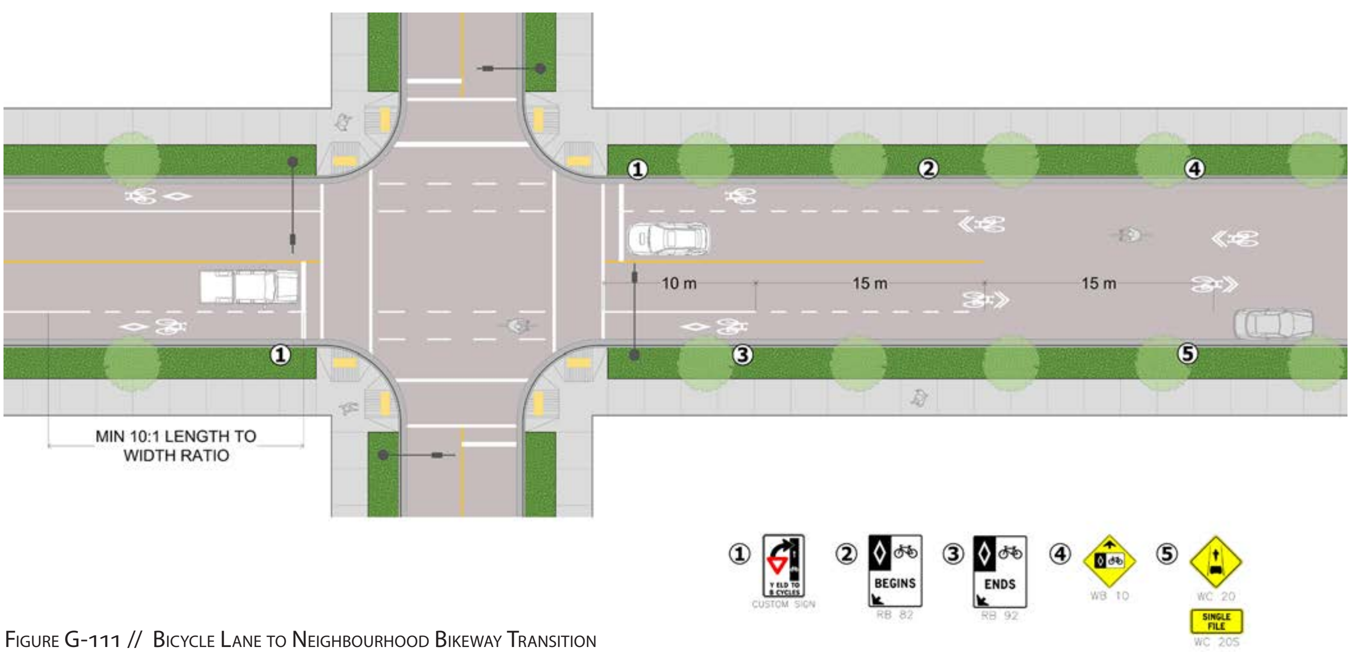


FIGURE G-111 // BICYCLE LANE TO NEIGHBOURHOOD BIKEWAY TRANSITION

Bicycle Lane

Transitioning to bicycle facilities with physical protection in higher conflict areas can improve safety and comfort for cyclists. **Figure G-112** shows the transition to a protected bicycle lane. Transitions to protected facilities should include Object Marker signage (MUTCDC WA-36; B.C. W-054-D Series) to identify the introduction of upcoming physical barriers for cyclists and drivers.

Transitions should cause minimal shift in travel for cyclists, with a maximum recommended taper of 3:1. The taper design should consider off-tracking for longer bicycle and bicycles with trailers. This transition bends cyclists away from the intersection – see **Chapter G5** for more details on bend out transitions. A straight segment of protected bicycle lane that is at least 5.0 metres long should be included prior to the intersection to ensure that cyclists are properly aligned for the crossing. Cross-ride markings should be included as per the guidance earlier in this Chapter.

When transitioning to a lower order bicycle facility, protection for cyclists and facility type should be carried through the intersection and then transition into a lower order bicycle facility on the other side in order to lessen the workload for all road users.

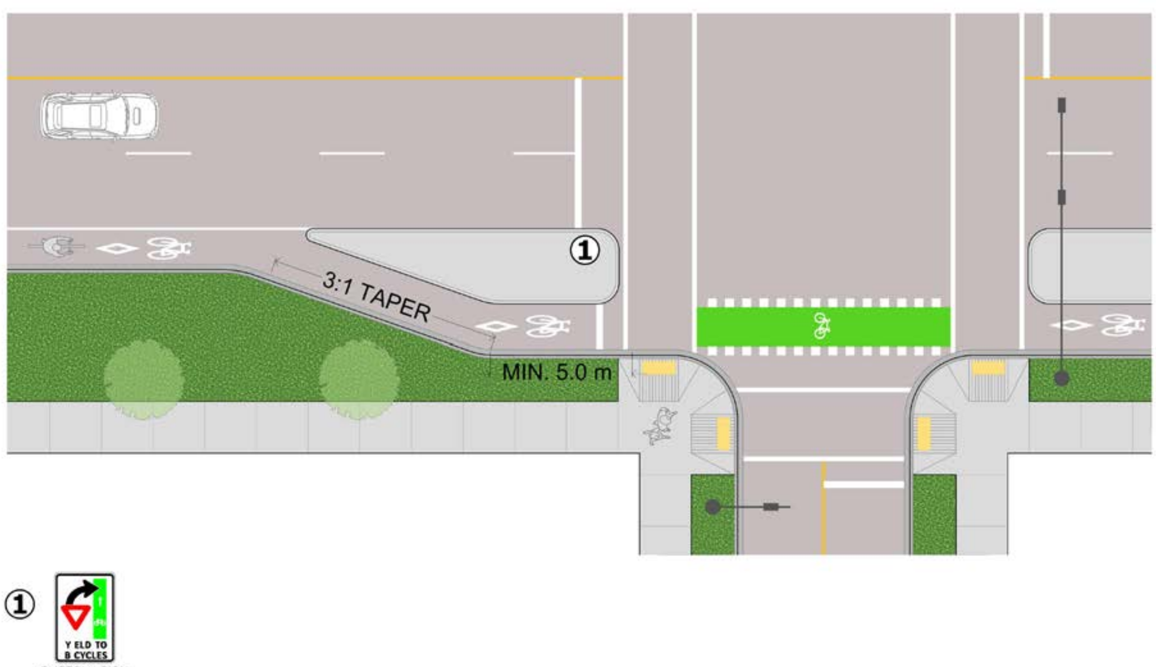


Figure G-112 // Painted Bicycle Lane to Protected Bicycle Lane Transition

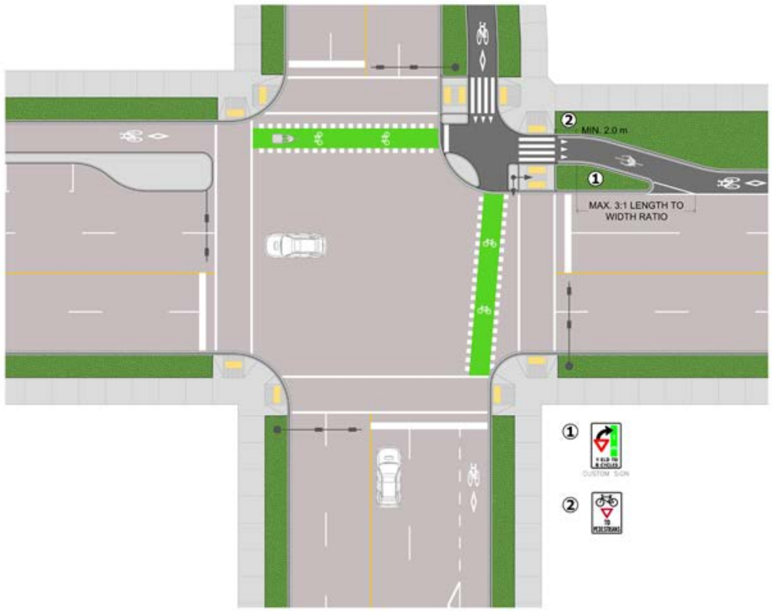


Figure G-113 // Bicycle Lane Transitioning to Protected Corner

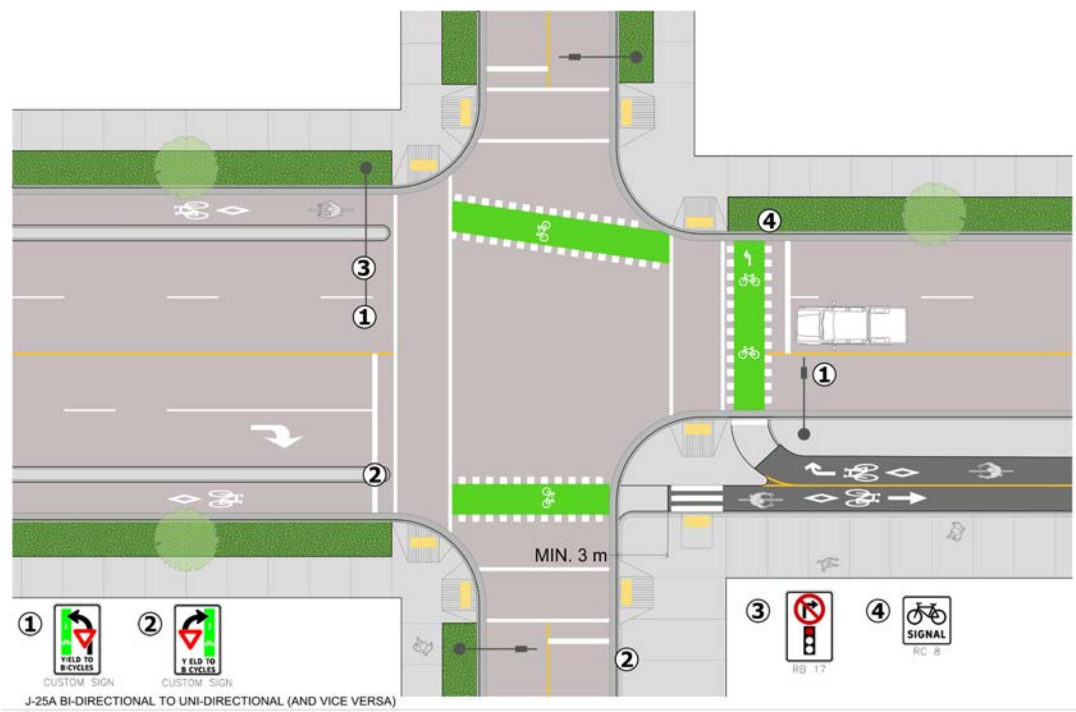


Figure G-114 // Bi-Directional to Uni-directional Protected Bicycle Lane

Unprotected Bicycle Facility to Protected Intersection

Neighbourhood bikeways and buffered bicycle lanes may be transitioned into short protected bicycle lane segments prior to the intersection and then directed into a protected intersection (see **Figure G-113**). This treatment can be used where the bicycle corridor intersects with a major road with higher volumes and turning conflicts. Where feasible, protected intersection elements should be provided on both sides of the intersection. Once the bicycle user has crossed through the intersection, the protected facility can then transition back to an unprotected facility if desired.

Bi-Directional to Uni-Directional Protected Bicycle Lane

Figure G-114 illustrates the transition between a bi-directional protected bicycle lane and a uni-directional bicycle lane. Transitioning between bi-directional and uni-directional facilities requires clear pavement markings and signage for the transition areas to ensure that contraflow bicycle users do not go the wrong-way down the uni-directional protected bicycle lane. Bicycle symbols with directional arrows provide visual guidance for bicycle users transitioning between the two facilities. Bicycle route and/or directional signage should also be installed at the intersection to indicate the shift in cycling facility.

Bike boxes, two-stage turn boxes, and/or protected corners can be installed to help transition between facilities by providing a protected space for bicycles to stop during a two-stage turning maneuver. Bicycle traffic signals should be provided, and protected bicycle signal phasing should be implemented (see **Chapter G2**). Near side bicycle signals may be appropriate for some facilities. Higher-level conflict zone markings should be used to provide enhanced visual guidance to all intersection users.

Free-flowing bicycle right turn movement
Vancouver, B.C.

Arbutus Greenway, Vancouver, B.C.
Source: Dylan Passmore

G.5

OFF-STREET PATHWAY CROSSINGS

An off-street pathway crossing is where an off-street bicycle facility such as a multi-use pathway or bicycle pathway crosses a road, driveway, or laneway. Crossings provide a potential conflict between people cycling, walking, and using other mobility devices and motor vehicles, and as such, require careful design considerations. These conflict points also tend to be locations where a higher number of collisions occur. Off-street pathway crossings can be located at intersections or mid-block locations, and may be at-grade or grade separated. This chapter provides design guidance for crossings of multi-use pathways and bicycle pathways.

TRAFFIC CONTROLS

Roadway Facing Controls

As noted in previous chapters, the TAC *Pedestrian Crossing Control Guide* and MOTI *B.C. Pedestrian Crossing Control Guide* provide guidance on when various types of crossings are warranted at intersections. When an off-street pathway is crossing a roadway that is currently uncontrolled, a warrant should be conducted to determine the appropriate intersection control required. Some jurisdictions may also have their own guidance and warrant process to determine the crossing control that is warranted. A summary of specific roadway facing controls is provided in **Chapter G.2**.

Off-street Pathway Facing Controls

Signage and pavement markings are the primary means of communicating to off-street pathway users when they must yield or stop before proceeding through an unsignalized or minor intersection or before crossing at a mid-block location. The off-street pathway controls required will depend on which user has the right-of-way: the motor vehicle driver on the roadway, or the pathway user. At unsignalized or minor intersections and mid-block crossings, where pathways volumes are greater than motor vehicle volumes, priority should be provided to pathway users. This involves giving the right-of-way to pathway users by requiring motorists on the roadway to stop. This also ensures consistency along the length of the entire off-street pathway facility at all unsignalized intersections. However, certain situations may require yield or stop control for pathway users, including:

- When appropriate sightlines can not be achieved between motorists and people cycling. Additional signage for bicycle users to yield or stop and watch for turning motorists should be installed. The presence of stop or yield signs on the pathway does not limit people walking from entering the crosswalk in an appropriate manner. More information about sight distance can be found in **Chapter G.1**.
- At locations where a pathway intersects with a road that has a designated bicycle facility.

DESIGN GUIDANCE

Bend-in Versus Bend-Out Crossings

When designing intersection approaches for on-street bicycle facilities and off-street pathways, there are two options for designing the alignment of the facility as it approaches an intersection to improve sightlines and visibility:. Bend-In Crossings:

1. Bend-In Crossings: Bending the facility towards the parallel road;
2. Bend-Out Crossings: Bending the facility away from the parallel road.

The taper ratio of the alignment shift for either option, should be between 3:1 and 10:1, with a 10 to 15 metre tangent. Each of these approaches are described below. Generally, the bend-out design is recommended as it can provide more benefits, but it requires more space than bending the pathway towards the road. The benefits and drawbacks of each treatment are discussed below.

Bend-In Crossings

Bend-in crossing designs allow for improved sightlines for motorists on the parallel roadway as they approach the intersection to see bicycle users as the facility is brought closer to the road. This design also requires less space and generally does not require any change to the width of the right-of-way. As the crossing is brought closer to the parallel roadway, there is an intuitive sharing of traffic signals (when present) between users. As the crossing location is closer to the parallel roadway, the stop line on the side road is also brought closer to the intersection, allowing for improved efficiency and throughput for motor vehicles.

The drawbacks of the bend-in crossing include a reduction in user queuing spaces at the intersection. As the crossing is close to the intersection, there is little room for turning vehicles from the parallel road to stop before entering the crossing. This situation may be compounded by the creation of a blind spot that does not allow turning motorists stopped at the stop line on the parallel roadway to see bicycles approaching from behind. Design considerations to alleviate this conflict may include separate signal phasing of movements and/or signage for motorists to yield to bicycles.

Bend-Out Crossings

Bend-out crossing designs are generally recommended as they provide more space and time for motorists to react as they turn from the parallel road onto the side road. This additional queuing space allows motorists from the parallel road to orient their motor vehicles perpendicular to the bicycle facility before crossing it, facilitating two-way sightlines between bicycle users and motorists. The queuing space is also located outside of the through traffic path on the parallel road, improving vehicle throughput. Design considerations include ensuring clear sightlines for turning motor vehicles to the setback bicycle facility

Bend-out crossing designs also allow for more room at the intersection to provide queuing space for pedestrians between the pathway and curb ramp when crossing the parallel road. Where there are high volumes of pedestrians crossing the parallel road, this design is preferred. The additional room at the intersection may also allow for bicycle box placement to facilitate bicycle turning movements onto the perpendicular road from the pathway.

The drawbacks of bend-out designs include the additional space required at the intersection. In constrained rights-of-way, this design may not fit. There may be reduced sight lines for motorists approaching the intersection on the perpendicular road, as the stop bar is set back. It may also cause some motorists to queue onto the crosswalk as they advance towards the intersection for better sight lines. At signalized intersections, this may be alleviated by restricting right turn movements on red.

Speed Reducing Elements at Crossings

When off-street pathways intersect roads at unsignalized crossings, several design options may be considered to slow motor vehicle traffic, as well as people cycling, to ensure that all users are aware of the crossing. Approaches to reduce speeds for both roads and pathways are discussed below.

Road Approach

Narrowing of the road through the introduction of geometric design elements such as median islands and/or curb extensions can slow motor vehicle traffic prior to approaching pathway crossing. Median islands provide an additional benefit to pathway users as a refuge while crossing the road. Median islands are desirable on roads with multiple motor vehicle lanes in each direction and/or higher speed roads. Median islands should be a minimum of 3.0 metres wide in order to provide adequate protection for all types of bicycles (such as bicycles with trailer), and should include curb ramps or cut-throughs with tactile warning strips.

Curb extensions reduce the distance for pathway users to cross as well as provide enhanced visibility of people walking and cycling waiting to cross. Curb extensions are particularly valuable on roads with high volumes of on-street parking that may limit motorist sightlines of the pathway. Design considerations with curb extensions may include whether there are any on-street bicycle facilities or existing bicycle use of the project into the Bicycle Through Zone, pushing bicycles into adjacent motor vehicle lanes.

Median islands and curb extensions can provide opportunities for enhanced landscaping, including rainwater management as well as snow storage.

However, landscaping elements, public art, and vegetation should be placed and managed so that sightlines are maintained. Median islands and curb extensions can also be used for snow storage in the winter, provided sightlines are maintained and the pathway remains clear. Additional visual cues such as signage may also be installed on median islands and curb extensions to alert motorists and maintenance staff of the curb locations in winter conditions.

In addition to median islands and curb extensions, a raised crossings may be used. Raised crossings increase crossing visibility and yielding behaviour with the use of vertical deflections on the roadway. Raised crossings are most appropriate in areas with high volumes of pathway users, such as near parks, schools, and other major destinations. Raised crossings should be used where the posted speeds are 30 km/h or less. The use of raised crossings should include consideration for snow clearing.

Pathway Approach

Geometric design may be used to reduce user speed on bicycle pathways and multi-use pathways as they approach crossings. This can include adding horizontal and vertical curvature to the pathway or an uphill grade in advance of the crossing.

Additional speed-reducing elements that can be applied to the pathway approach include textural surface contrast, transverse paint lines, yield markings, and warning signage along the pathway.

Separating Users

Intersections can also be a location for conflicts between various pathway users. There are a wide range of users and existing facility types approaching intersections, including separated pedestrian and cycling facilities and multi-use facilities that need to be considered when designing intersections. Separating people walking from people cycling at intersections is the best practice at all crossings regardless of the pathway configuration of the approach. At locations where a multi-use facility approaches an intersection, there are conditions were a multi-use crossing is preferred, such as at locations with low volumes of pathway users and challenging geometry that restricts sightlines of both pathway and roadway users.

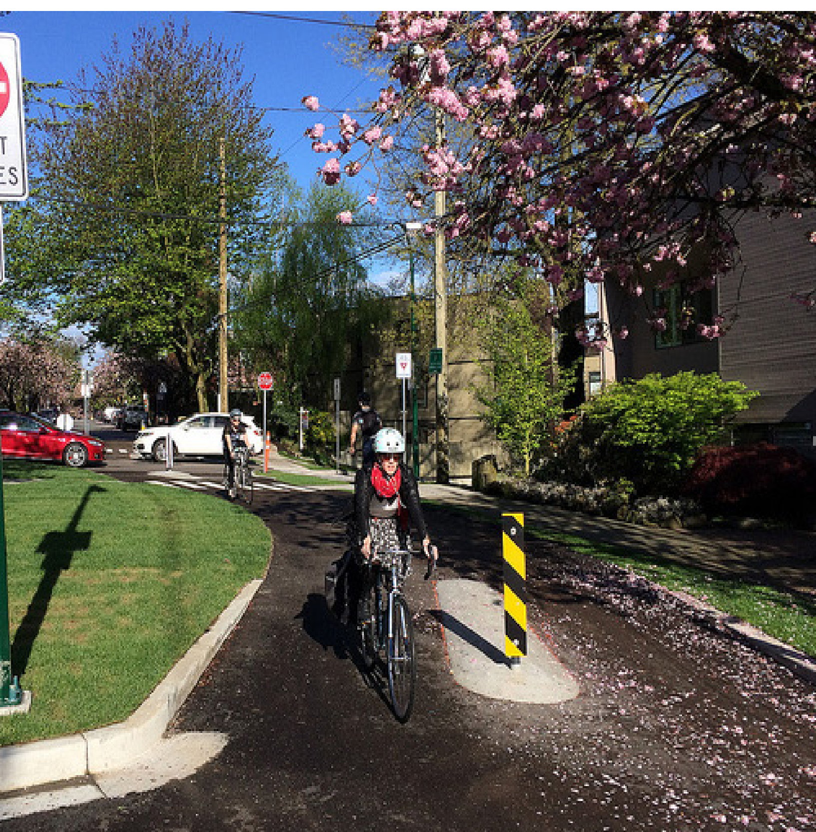
Speed reducing transverse pavement markings for bicycle pathway, North Vancouver, B.C.

Access Restrictions

Access restrictions for off-street pathways have often historically occurred through the installation of access control devices such as bollards, maze gates (offset gates), flexible delineators, raised medians, and/or signage to restrict access by motor vehicles to the pathway. As noted in **Chapter D.1**. It is recommended to avoid the use of rigid bollards, maze gates, or other solid impediments in the pathway at points of entry unless there is a demonstrated history of motor vehicle encroachment, and/or a collision history.

The use of rigid bollards or maze gates for bicycle speed control is also not appropriate, as its slowing effect is by creation of a potential safety hazard to the bicycle users. Bollards and other obstructions placed within the operating space of a bicycle facility create a confined operating space for all pathway users, increasing the likelihood of conflicts and collisions. Speed control of bicycle users is better obtained through geometric controls. Where physical elements are required, flexible bollards should be considered instead.


Bollard with Painted Diamond




Centre Medians

The physical design of the pathway point of entry should clearly indicate that it is not intended as a motor vehicle access. One method of restricting motor vehicle entry is the use of a centre island that splits the point of entry into two pathways separated by low landscaping and/or signage. The low landscaping allows maintenance and emergency vehicles to straddle the island to access the pathway when needed. The pathway-side approach to the island should include solid lane markings leading to and around the island to guide pathway users around the centre island. The width of the pathway on either side of the island should be no more than 1.8 metres to emphasize the non-motorized use of the pathway, but no less than 1.2 metres. The pathway entry design also needs to consider winter maintenance and snow clearing equipment.

MAJOR INTERSECTIONS

This section provides guidance on the treatment of off-street pathway crossings at major intersections, which are typically signalized.

At major intersections, design treatments such as dedicated phasing, pavement markings, and signage are required to provide safe and comfortable crossings for all pathway users. These treatments highlight the pathway user's presence and inform motorists that the crossing is not only for people walking, but for all forms of active transportation.

At signalized intersections with high volumes of turning motor vehicles or with complex intersection geometry, it is recommended that a separate signal phase is provided to allow pathway users to cross the intersection separate from turning motor vehicles (see **Chapter G2**). At larger intersections where there are channelized turn lanes, where feasible, it is recommended that channelized right turn lanes be removed from all major intersections and replaced with dedicated or shared right turn lanes.

Multi-use pathway crossings through a signalized intersections are shown for both **bend-in designs** (see **Figure G-115** for multi-use crossing and **Figure G-116** for separated bicycle and pedestrian crossing) and **bend-out designs** (See **Figure G-117** for multi-use crossing and **Figure G-118** for separated bicycle and pedestrian crossing).

For both bend-in and bend-out designs, the corner radii should be reduced to as small as possible for the design vehicle and circumstance (see **Chapter G.1**). Both designs must ensure adequate sightlines are provided for pathway users. Sightline obstructions can include trees, guideway columns, signals, and utility poles.

For bend-in designs, intuitive sharing of existing traffic signals at signalized intersections can be achieved. For bend-out designs, the pathway crossing should be set back a minimum of 6 metres to provide space for one vehicle to stop in advance of the crossing. This provides additional reaction time to motorists turning across the path.

Bending pathways away from the parallel roadway is generally recommended as it yields more benefits; however, bending the pathway towards the roadway tends to require less space. Both bend-in and bend-out intersections can be configured with separated or combined crossings for pedestrians and cyclists. Separated crossings are preferred, when space permits, and should include separated ramps or contrasting pavement for people walking and people cycling.

MINOR INTERSECTION, LANEWAY, AND DRIVEWAY CROSSINGS

Minor intersections are locations where off-street pathways intersect minor roadways with lower traffic volumes. Typically, these intersections are controlled by stop signs on at least two of the four legs, with a preference to stop control the roadway that crosses the pathway, which then assigns the right-of-way to the off-street pathway user. As these intersections are typically unsignalized, they often rely on both motorists and pathways users to yield the right-of-way depending on the context of the intersection.

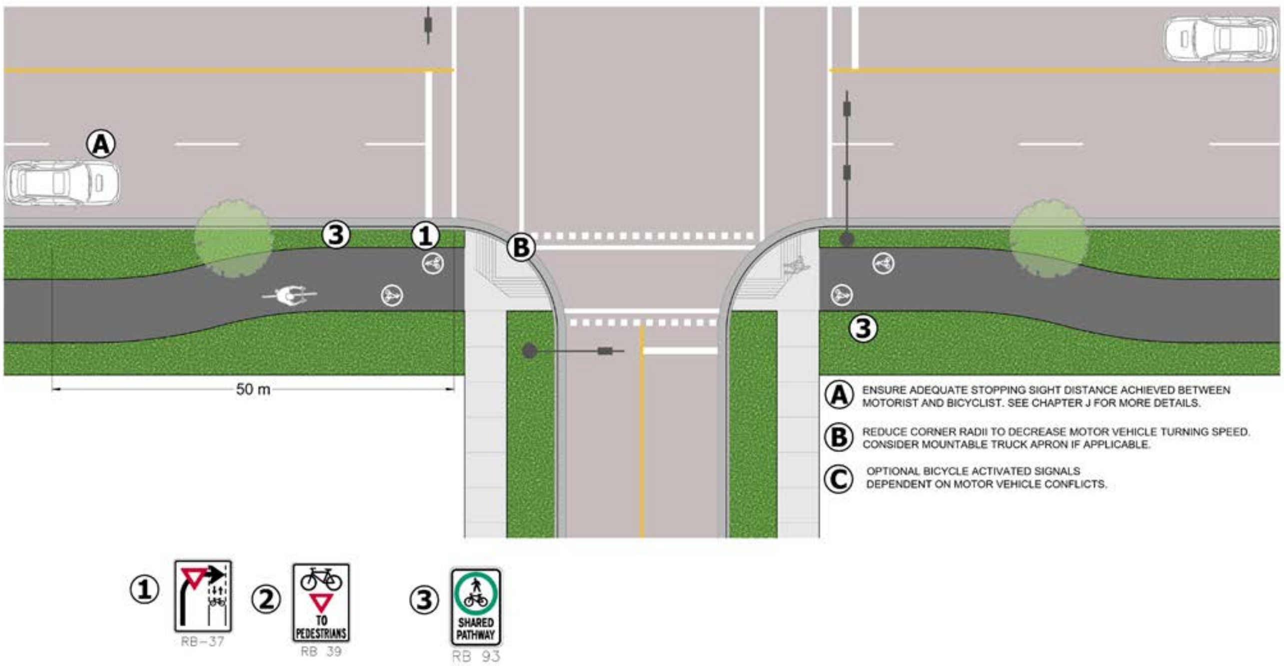


Figure G-115 // Multi-Use Bend-In Crossing

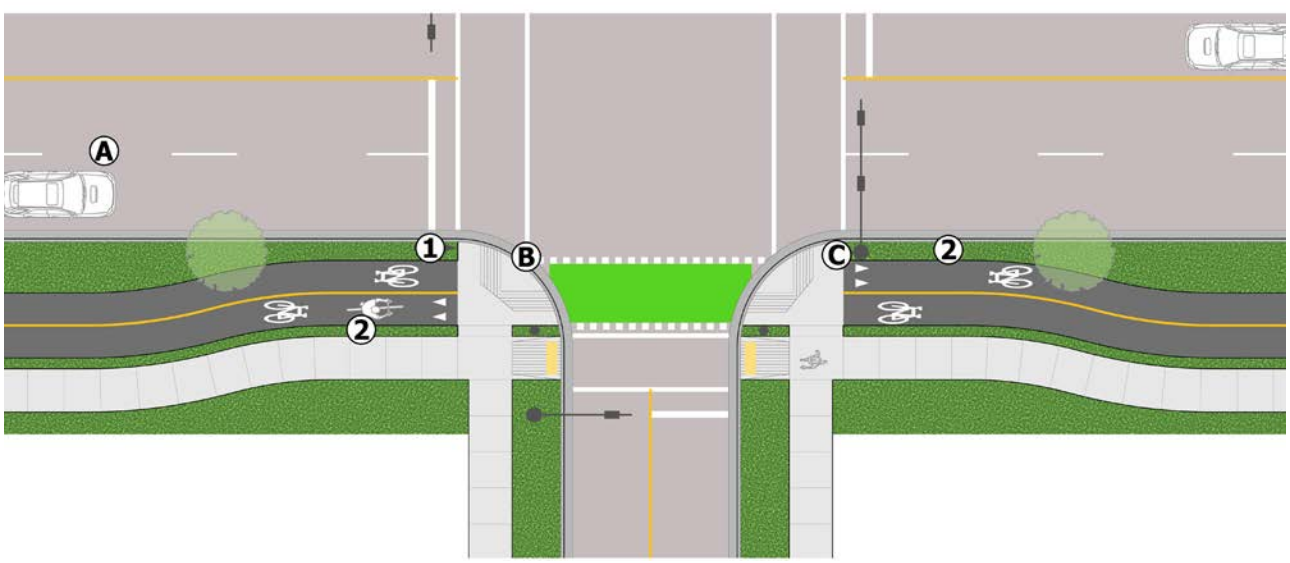


Figure G-116 // Separated Bicycle and Pedestrian Bend-In Crossing

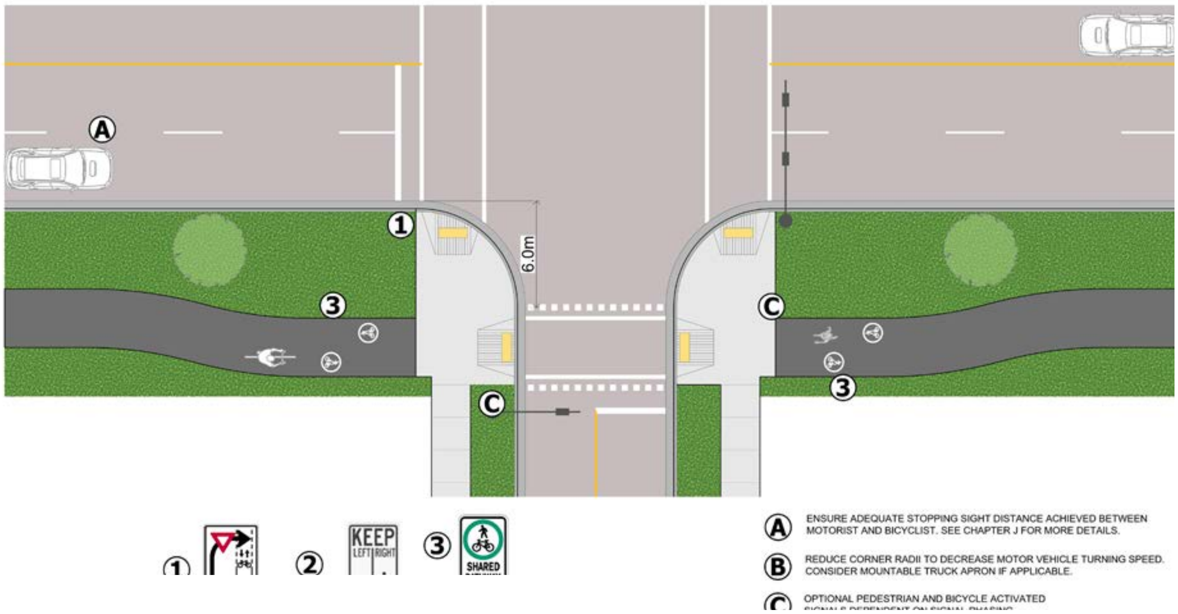


Figure G-117 // Multi-Use Bend-Out Crossing

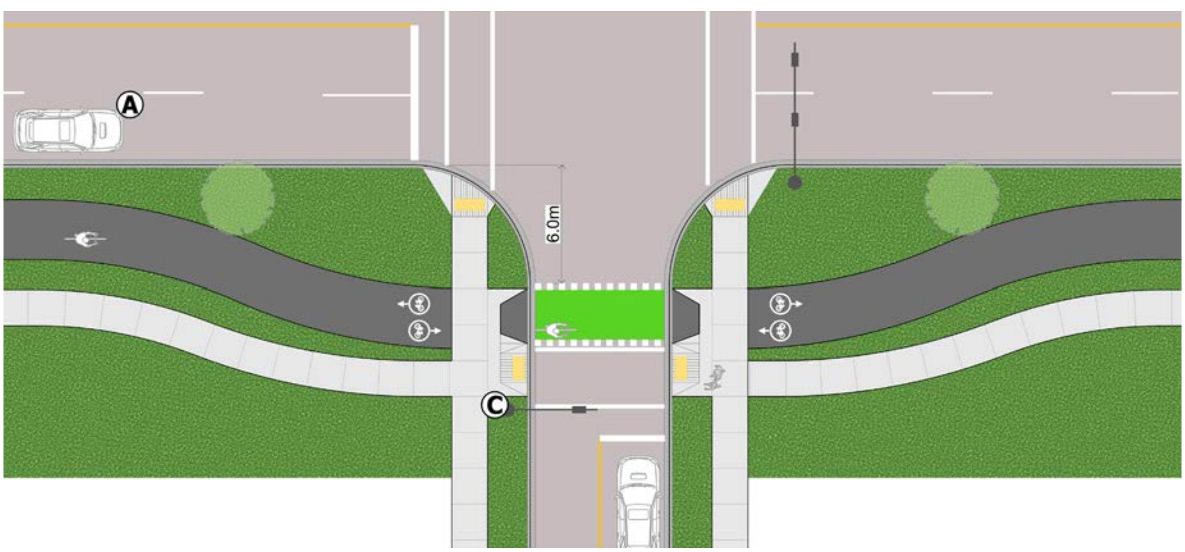


Figure G-118 // Separated Bicycle and Pedestrian Bend-Out Crossing

At unsignalized intersections, pathway users may be given right-of-way through stop control for the side road. Where this is the case, no intersection controls are required for the pathway user, although signage, pavement markings, and geometric design may be used to alert pathway users of the upcoming intersection. Other types of roadway facing controls that can be installed at minor intersections include RRFBs or special crosswalks (see **Chapter G2**).

Laneways and driveways are locations where motor vehicles cross off-street pathways to access local access roadways or parking lots.

In both of these locations, motorists might not be expecting pathway users, which highlights the importance of design features to highlight and/or control the conflict point. Additionally, considerations should be made at minor intersections and driveways to restrict certain movements to improve the safety and comfort of the pathway users.

Consistent use of traffic control for pathway users and motorists is essential to ensure pathway users safety and compliance. Pathway user compliance at intersections with pathway stop control and should only be used when geometric or sightline issues increase the risk of a conflict.

Minor Intersection Crossings

Figure G-119 illustrates an example of a multi-use pathway crossing a minor, unsignalized road. **Figure G-120** illustrates an example of where people walking and cycling are separated throughout the crossing through the use of a separate crosswalk and cross-ride pavement markings. Separated crosswalks and cross-rides are preferred when space is available.

These examples include reduced corner radii (preferably 5 metres) that helps to slow motor vehicle turning speeds. The pathway bends out, away from the parallel roadway. A minimum of 6 metres of space should be provided between the face of the curb and the start of the crosswalk and cross-ride to provide stacking space for turning motor vehicles so that they are out of the through traffic path when waiting for people crossing.

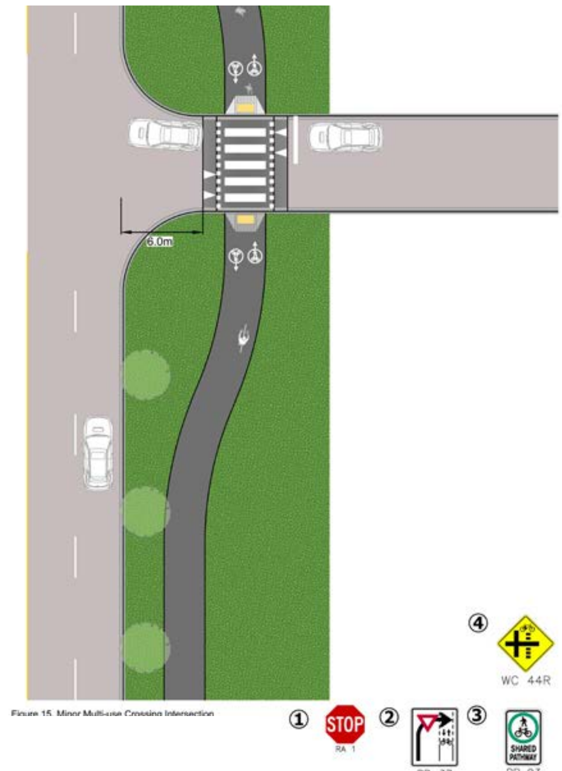


Figure G-119 // Multi-Use Crossing of A Minor Street

Figure G-120 // Separated Crossing of A Minor Street

Where sightlines are not achieved between motorists and off-street pathway users, signage for pathway users to yield or stop and watch for turning motorists should be installed. Stop signs should be installed on the pathway and oriented to indicate to pathway users riding bicycles that they must stop before proceeding across the crossing. The presence of stop signs on the pathway does not limit people walking from entering the crosswalk in an appropriate manner, nor does it relieve motorists of the responsibility to yield to people in the crosswalk. An additional measure to bring awareness of the crossing to motorists is to install enhanced crossing treatments such RRFBs or special crosswalks (see **Chapter G.2**).

Raised crosswalks or fully raised intersections are the preferred design treatments at unsignalized intersections and driveways to help define right-of-way, slow approaching vehicles, and create a comfortable level crossing for pathway users. Raised crosswalks increase crossing visibility and yielding behaviour with vertical deflection. Raised crosswalks are most appropriate in areas with high volumes of pathway users, such as near parks, schools, transit stations and other major destinations.

Raised intersections are full intersections that are constructed at a higher elevation than the adjacent approach roads. The purpose of a raised intersection is to reduce motor vehicle speeds and reduce conflicts, as they often are provided in conjunction with a stop control on one or both intersecting roads. A raised intersection should be raised by the same amount as any adjacent raised sidewalks (typically 80 millimetres). When raised crossings or intersections are not possible, pathway users are crossing at road grade, . In such cases, separate ramps for people walking and cycling are preferred contrasting pavement can also be used to define the space for constrained locations.

Laneways and Driveway Crossings

Off-street pathways have potential for conflicts where there are many laneway and driveway crossings present. The number of laneway and driveway crossings should be considered in the network planning and facility selection processes. Where laneway and driveway crossings exist, design considerations are necessary to mitigate potential conflicts. Speed reduction considerations for pathway users, as discussed above, may be considered.

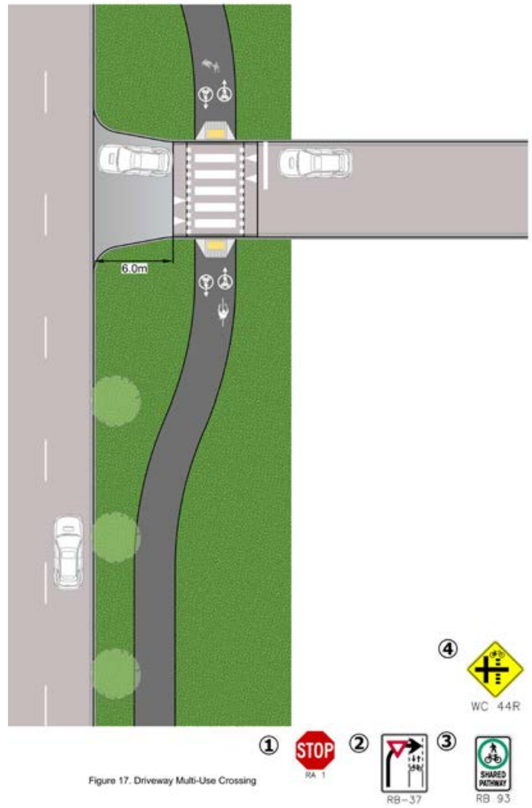


Figure G-121 // Multi-Use Crossing of a Driveway

Figure G-121 Illustrates an example of a multi-use pathway crosswalks a driveway. Similar to minor intersections, raised crossings are preferred. This ensures that pathway users have priority, as this provides continuity of pathway material across the laneway or driveway to highlight to motorists that they are crossing a pathway.

Motorists entering the roadway from driveways, laneways, and accesses are legally required to stop prior to entering the roadway. However, additional traffic control signage can be installed to reinforce this in locations where motorists encroachment on the sidewalk and/or pathway is an issue. For high-use laneways and driveways (such as commercial or employment access), enhanced cross-ride markings or different surface treatment such as textured or coloured concrete can be applied to increase visibility of crossing areas. Signage may also be provided to alert motorists both entering and exiting the laneway or driveway to the presence of people walking and on bicycles and the direction(s) they are approaching from.

Traffic Control and Signage

This section provides guidance on pathways crossing side roads depending on the type traffic control signage for of intersection traffic control.

Signalized crossings

- Install Bicycle Trail Crossing Side Road sign (MUTCDC WC-44) on the major street for both directions of the road in advance of the intersection.
- Install Turning Vehicles Yield to Bicycle signs (MUTCDC RB-37) for the motor vehicle left and right turn movement on the major street at the intersection
- Additional measures to reduce conflict can include adding a protected signal phase to the intersection crossing, adding a leading bicycle/walk phase, or adding a restricted right/left turn phase. These measures will eliminate many potential conflicts between users.

Unsignalized crossings

- Install appropriate Pedestrian and/or Bicycle Crossing Ahead sign (MUTCDC WC-46; B.C. W-129-2 Series) on the cross road approach in advance of the crossing.
- Install Bicycle Trail Crossing Side Road sign (MUTCDC WC-44) on the major street for both directions of the road in advance of the intersection. The Bicycle Trail Crossing Side Road sign (MUTCDC WC-44) and complementary Trail Crossing tab sign (MUTCDC WC-44T) is used to indicate that a bicycle pathway runs parallel and in close proximity to the cross road.
- Install Turning Vehicles Yield to Bicycle signs (MUTCDC RB-37) for the motor vehicle left and right turn movement on the major street at the intersection.
- An additional measure to bring awareness of the crossing to motorists, is to install RRFBs.
- Where sightlines are not achieved between motorists and people riding bicycles, additional signage for bicycle users to yield and/or stop and watch for turning motorists should be installed. Stop or yield signs may include a supplementary tab indicating 'cyclists only' and should be installed on the pathway and oriented to indicate to people cycling that they must stop/yield before proceeding across the crossing. The presence of stop or yield signs on the pathway does not limit people walking from entering the crosswalk in an appropriate manner, nor does it relieve motorists of the responsibility to yield to people in the cross-ride.

Pavement Markings

Pavement markings for pathways crossing side roads help provide guidance to delineate spaces for all modes, guide the travel path, raise awareness of potential conflict points, and indicate who has right-of-way Cross-ride pavement markings along with crosswalks should be installed at pathway crossings (see **Chapter G.1**).

MID-BLOCK CROSSINGS

This section provides guidance on the treatment of off-streets pathways at mid-block crossings. Mid-block crossings are not at intersections and need to be designed appropriately to consider motorists' expectations to yield to users at the crossing, or they can create a safety issue.

Typically, mid-block crossings are preferred when the nearest intersection is more than 75 metres from an existing crossing location. When an intersection is less than 75 metres from an existing crossing location, design professionals should consider rerouting the pathway crossing to the nearest intersection.

Mid-block crossings are not desirable on multi-lane roads, as motor vehicle shadowing can obscure sight lines to people crossing.

Pathway Alignment

At mid-block crossings, the off-street pathway should be as close to perpendicular as possible to the road that is being crossed. The pathways on each end of the crossing should be aligned with one another. Therefore, pathway alignments may need to shift before crossing the road. Additionally, as noted previously, prior to crossing the road, the pathway alignment should be adjusted geometrically to slow the pathway users' approach speeds to the crossing.

Adequate Sightlines of Cyclists and Motorists

Mid-block crossings should be installed only where adequate sight distance for both motorists and pathway users is available. **Figure G-122** and **Table G-33** show the calculation required for determining the appropriate sightlines required for mid-block crossings and resulting values for some road widths and speeds. For any widths or speeds not shown in **Table G-33,** the formula shown in the figure may be used to calculate the required sight distance. Sightlines can be enhanced by 'daylighting' in advance of the mid-block crossing, which refers to improving sightlines of the crossing by removing obstructions and/or bringing pathway users further out into the motorists' line of vision. This can be accomplished by installing a curb extension, bringing pathway users out into the view of motorists, and/or by removing on-street parking on both sides of the road in advance of the crossing. The extent of parking removal will be dependent on the design speed of the pathway and the road, and the location and width of the crossing. An additional advantage of curb extensions is that they shorten the crossing distance while creating a break in on-street parking that impedes motorists from driving down the parking lane.

TABLE G-35 // MINIMUM SIGHT DISTANCE FOR MULTI-USE PATHWAY CROSSING

Source: TAC Geometric Design Guide for Canadian Roads, Chapter 5, Section 5.6.3.2, Table 5.6.1

MINIMUM SIGHT DISTANCE (D) TO APPROACHING VEHICLE (M)				
Width of Street - W (m)	Street Design Speed (km/h)			
	50	60	70	80
7.0	130	150	180	200
10.5	170	200	230	270
14.0	210	250	290	330
17.5	250	300	350	400
21.0	290	350	410	460

Unsignalized Mid-Block Crossings

Figure G-122 shows an example of an unsignalized mid-block multi-use pathway crossing at a minor road where pathway users are prioritized and have the right-of-way. In this example, motor vehicle traffic is stop controlled.

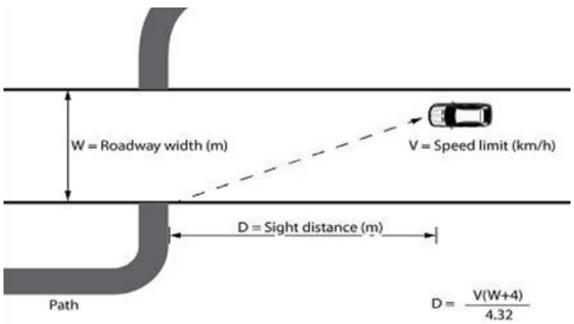


Figure G-122 // Minimum Sight Distance for Mid-Block Crossing

Source: TAC Geometric Design Guide for Canadian Roads, Chapter 5, Section 5.6.3.2, Figure 5.6.12

Stop lines should be set back 6 to 15 metres from the mid-block crossing either on the roadway when pathway users have right-of-way, or in advance of the road when motorists have the right-of-way. Along minor roads, another measure to bring awareness of the crossing to motorists is to install enhanced crossing treatments such as RRFBs (see **Chapter G.2**).

The example in **Figure G-123** also shows the use of curb extensions to narrow the crossing. An alternate treatment to narrow the crossing is to install a raised median island to provide refuge for crossing pathway users. Median islands should have a desired width of 3 metres (minimum 1.5 metres) while leaving a minimum travel lane width of 3.5 metres on either side of the island.

There may be some locations where yield or stop control may be used to control the movements of pathway users:

- Where sightlines are not achieved between motorists and people riding bicycles, additional signage for cyclists to yield or stop and watch for turning motorists should be installed. The presence of stop or yield signs on the pathway does not limit people walking from entering the crosswalk in an appropriate manner.
- At locations where a pathway intersects with a roadway that has a designated bicycle facility yield or stop control for pathway users can be installed.

Signalized Mid-Block Crossings

Where mid-block crossings cross higher volume roads and/or multi-lane roads, traffic signalization may be warranted. **Figure G-124** shows an example of a signalized mid-block multi-use pathway crossing at a major road. At signalized mid-block crossings, pedestrian and bicycle signals should be provided for pathway users. This example shows separate crosswalk and cross-ride pavement markings.

Signage

Signage on the road leading up to a mid-block crossing depends on the type of pathway user that will be crossing.

- The Pedestrian and Bicycle Crossing Ahead sign (MUTCDC WC-46; B.C. W-129-2 Series) indicates that the motorist is approaching a multi-use pathway crossing.
- For multi-use pathways, crossings must include the Shared Pathway sign (MUTCDC RB-93) on the pathway leading up to the mid-block crossing.
- For a bicycle-only off-street pathway with no crosswalk, the Bicycle Crossing Ahead sign (MUTCDC WC-7; B.C. W-129-1 Series) and supplementary Crossing tab sign (MUTCDC WC-7S; B.C. W-129 Tab) should be used.
- For separate bicycle pathways, crossings must include the Pathway Organization sign (MUTCDC RB-94) on the pathway leading up to the mid-block crossing, instructing users to stay either left or right when crossing.

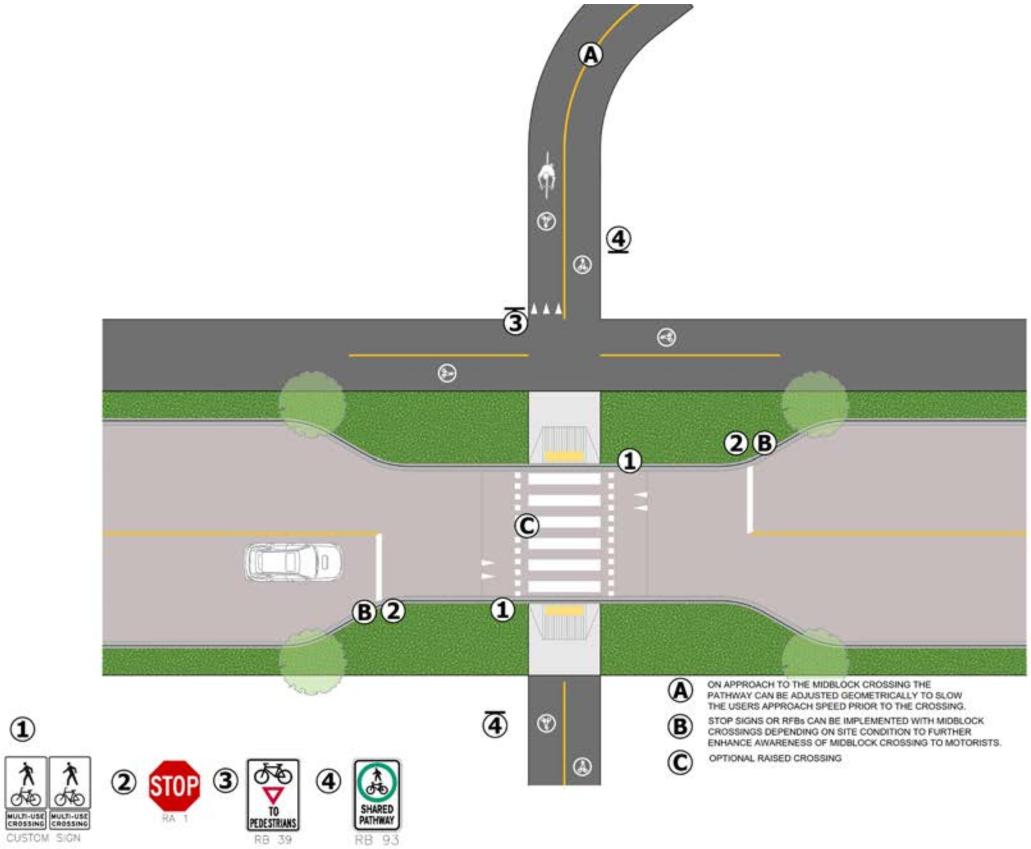


Figure G-123 // Mid-Block Crossing with Curb Extensions

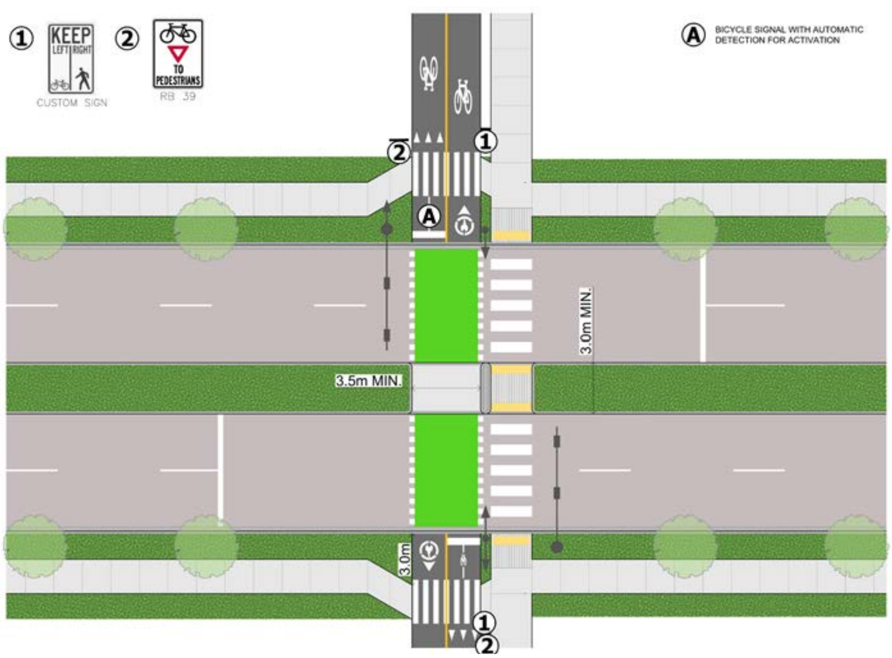


Figure G-124 // Signalied Mid-Block Separated Crossing

- Bicycle Yield to Pedestrian signs (MUTCDC RB-39) should be placed in advance of where a bicycle pathway crosses a pedestrian facility.
- Advanced warning signs with flashers installed on the road facing motor vehicles may be appropriate to increase awareness of people at major crossings or crossings with marginal sight distance. If these measures are insufficient, the crossing should be signal controlled.
- For all ages and abilities facilities, the motor vehicle traffic should be stop controlled when the pathway is crossing minor roads and signalized when crossing major roads.

Pavement Markings

Pavement markings at mid-block intersections are important design elements that increase awareness of the crossing point for approaching motorists, further enabling them to react to potential conflicts. The MOTI *Manual of Standard Traffic Signs & Pavement Markings* provides guidance on signage and pavement markings. The following are recommended pavement markings at mid-block pathway crossings.

- Where clear sightlines exist for motorists to see approaching people riding bicycles on the pathway, cross-rides should be used at the mid-block crossings. Cross-rides alert road users to the presence and right-of-way of crossing persons cycling and walking. For multi-use pathways, a combined crosswalk and cross-ride should be used (see **Figure G-125).** Zebra style crosswalks are recommended to enhance the visibility of the crossing. It should be noted that cannot be implemented on roadways under provincial jurisdiction. On roadways under provincial jurisdiction, cross-ride markings can only be implemented where pathway users have a stop control.
- Combined crosswalk and cross-ride markings,
- For off-street pathways with separate pedestrian and bicycle pathways, the cross-ride and crosswalk should be separated (see **Figure G-126).** Zebra style crosswalks are recommended to enhance the visibility of the crossing.
- Yield lines or markings may be placed in advance of the crossing, either on the road or on the pathways, to indicate to users who has priority at these crossings, and should be accompanied by a yield sign.
- Stop lines should be set back 6 to 15 metres from the mid-block crossing either on the road when pathway users have right-of-way, or in advance of the road when motorists have right-of-way. Stop lines should only be used when signalized or stop sign controlled.

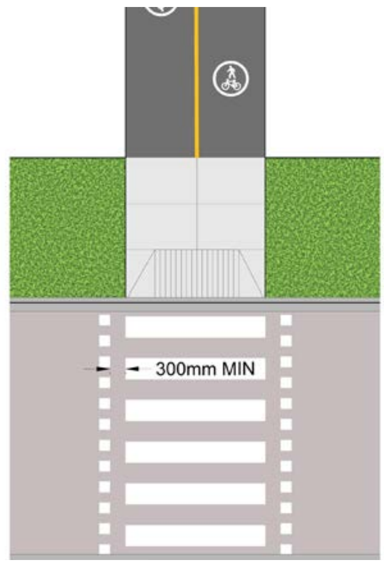


Figure G-125 // Combined Crossing Pavement Markings

Figure G-126 // Separated Crossing Pavement Markings

Salton Road Pedestrian and Bicycle Bridge, Abbotsford, B.C.

Source: City of Abbotsford

G.6

ADDITIONAL CROSSINGS + CONFLICT AREAS

This chapter covers additional crossings and conflict areas that are relevant to pedestrian facilities, bicycle facilities, and off-road pathways. This includes cut-through pathways, rail crossings, and grade separated crossings.

CUT-THROUGH PATHWAYS

Cut-through pathways run between two properties to connect two segments of a pedestrian facility, bicycle route, or off-road pathway that are separated by development or open space. They are typically paved or a hard surface. Cut-through pathways make neighbourhoods more walkable and bikeable by shortening distances and providing important connections to destinations. They are especially useful where there are long blocks or in suburban developments with non-grid layouts. Cut-through pathways can be an important tool to prioritize active transportation by making destinations more direct for people walking and cycling than they are for motorists.

Cut-through pathways are intended for active transportation use only. They have often historically been designed with access restriction devices such as maze gates and bollards. However, maze gates and bollards can make them difficult for people cycling to use, particularly for a wide range of types of bicycles. To ensure cut-through pathways are accessible for people of all ages and abilities, maze gates and bollards are not recommended unless there is a demonstrated history of motor vehicle encroachment, and/or a collision history (see **Chapter G.5**). Pedestrians are typically the primary users of cut-through pathways; however, cut-through pathways can provide valuable cycling connections as well, so bicycle access should be considered. As such, cut-through pathways should be designed consistent with design guidance for off-road pathways (see **Chapter E.3**). Appropriate wayfinding signage and pavement markings should be used to help guide users (see **Chapter H.3**).

Cut-through pathways require that adequate horizontal clearances and widths are provided for all users (see **Chapter C.2**). Cut-through pathway entrances should be well lit with adequate sightlines. Pedestrian scale lighting may be considered for longer pathway sections to ensure adequate lighting of the facility and intersections, while considering the impact to adjacent properties. Straight pathways where both entrances are visible at all times are preferred from a Crime Prevention Through Environmental Design (CPTED) perspective and can help to discourage undesirable activities within the cut-through.

Year-round maintenance is important to ensure that cut-through pathways are functional in all seasons. They may collect debris, garbage, and snow, making them less desirable for active transportation users. Cut-through pathways should have appropriate drainage for the longitudinal grades and the cross-sectional grades. Installation of a concrete swale or gutter can help direct drainage. See **Chapter I.3** for more details regarding maintenance.

Chapter G.5 provides guidance on the end treatment considerations when intersecting a road or laneway.

RAIL CROSSINGS

Rail crossings are particularly relevant for bicycle facilities. If bicycle facilities are desired in the same corridor as rail lines, careful consideration and caution must be taken to ensure adequate separation between the rail line and the bicycle facility. Refer to Transport Canada's *Grade Crossing Regulations and Grade Crossing Standards* for detailed design guidance on rail crossings. Additional design guidance can be found in Section 8.8 of the TAC ***Bikeway Traffic Control Guidelines*** and the MOTI *B.C. Supplement to TAC*. A summary of important design considerations is provided below.

The crossing design should ensure that people cycling are given adequate advance warning of the rail crossing. Adequate sightlines along the tracks should be provided, and appropriate warning systems should be installed. If warning systems with gate arms are used, the gate arms should span the bicycle facility as well as the road. Where rail tracks run parallel to a bicycle lane, two-stage turn boxes should be used to facilitate left turns from the bicycle facility.

Where rail tracks run parallel to a pathway and perpendicular to the road, traffic signals can be installed in combination with the warning systems. Bicycle and pedestrian signal activation may be installed with the traffic signals. Gate arms should be installed on the side of the pathway adjacent to the railway to deter pathway users from crossing the tracks when the warning systems are activated.

The rail tracks themselves can also present a hazard to people cycling, as bicycle wheels can get caught in or alongside the track. Freight rail tracks have higher risks of bicycle wheels getting caught than streetcar tracks which are typically more flush with the road and have a narrower flange. To prevent this issue, rail crossings should be perpendicular (at right angle) to the tracks (see **Figure G-127**) Where tracks cannot be crossed at right angles, widening the road or adding a curve at the rail crossing approach can allow bicycle users to achieve a better crossing, enabling them to maneuver without interfering with motor vehicle traffic. See section 5.6.9 of the TAC *Geometric Design Guide for Canadian Roads* for more details.

Flangeway gaps and track height should be designed to minimize variation in surface grade to allow for a smoother surface. This is critical for pedestrian rail crossings as well. Installation of barriers to slow people cycling and walking at the crossings is not recommended as these may be more hazardous to users manoeuvring around the barriers while trying to cross.

GRADE SEPARATED CROSSINGS

Grade separated crossings improve safety and allow for the uninterrupted flow of active transportation users and motorists or trains. However, grade separation requires additional space, makes active transportation facilities less direct, and can require significantly higher construction and maintenance costs. At-grade crossings are preferred where feasible. A traffic flow and safety assessment of an at-grade crossing should be completed as part of the consideration for whether or not to construct a grade separated crossing, taking into account the expected volume of active transportation users and the potential delay for active transportation users if crossing at-grade.

Generally, grade separated crossings should only be considered over rail lines, natural features, and roads with high motor vehicles volumes or speeds (70 km/h or greater) where at-grade crossings cannot be achieved safely and comfortably. Such locations include high speed on/off ramps, interchanges, highways, and locations with other geographic barriers. Grade separated crossings can be used where high volumes of people walking and cycling exist or are planned (such as at a crossing for a regionally significant pathway).

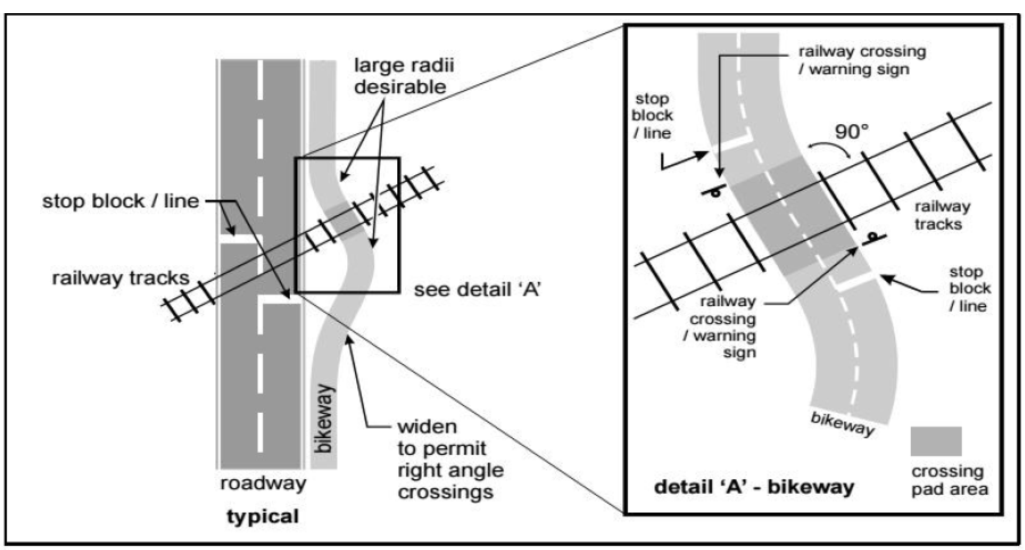


Figure G-127 // Bicycle Facility Crossing of Railway

Source: TAC Geometric Design Guide for Canadian Roads, Figure 5.6.19

Design Guidance

Grade separated crossings should be accessible for people of all ages and abilities whenever possible. In order to provide full universal access, accessible ramps and/or elevators should be provided. Ramps should be designed so that they are not too steep for wheelchair users or a deterrent for people on bicycles, with enough space at curves to allow people cycling to maneuver. Refer to **Chapters C.2** and **D.1** for guidance regarding accessible grades for people walking and people cycling.

In situations where large grade differences exist and stairs are unavoidable, bicycle channels should be installed on stairs. Guidance for bicycle channels is provided below. Entrances and exits to grade separated crossings should be clearly visible and accessible, and they should connect to existing at-grade transportation facilities.

In order to encourage use of the grade separated pathway, the crossing distance should be minimized. If the existing (but undesired) at-grade crossing distance is significantly shorter, the grade separated crossing may be used less often. For grade separated crossings where bicycle users are expected, longitudinal grades of less than 4% are recommended, with a maximum grade of 6%. Grades of 6 to 8% can be considered for short sections. Grade breaks of flat sections (less than 3%) should be provided every 100 metres for steep sections. Where pedestrians are expected, level resting spots should be provided even more frequently: where the longitudinal grade is greater than 4%, a flat landing area should also be provided every 50 metres.

The width of the grade separated crossing should remain consistent, other than at entrances and exits where additional widths can better facilitate movements between different users. Minimum lateral clearance to obstacles should be provided, including 0.2 metres to obstructions that are 100 millimetres to 750 millimetres high, and 0.5 metres to obstructions that are greater than 750 millimetres high. The minimum radii for the pathway need to factor in stopping sight distance, superelevation, bicycle speed, turning radii for larger bicycles (i.e. cargo, tandem, trailers), and coefficient of friction.

There are two types of grade separated crossings – bridges and overpasses, and underpasses. Each have different costs and unique design considerations.

Bridges + Overpasses

Bridges, including pedestrian and cycling overpasses, are most applicable where the topography allows for a structure that has little grade change for active transportation users, such as when the road is lower than the pathway. Bridges have a greater visual impact on the landscape but can be designed as an architectural feature. They can include multi-modal bridge structures or dedicated active transportation overpasses.

Protective railings should be installed on the outside of the bridge in all instances where an active transportation facility is located on the outside of the road. Protected railings of at least 1.4 metres should be provided on the outside of the bridge.

Barriers and railings should also be considered on the motor vehicle side when there is a vertical difference between the bicycle facility and the road of greater than 0.20 metres, where the active transportation facility does not have the desirable width, or when the motor vehicle speed is greater than 60 km/h. Protective barriers and railings should be a minimum of 600 millimetres tall, with a desired height of 1.4 metres, and should meet applicable barrier design standards for bridge structures. See *section 7.6.4* of the TAC *Geometric Design Guide for Canadian Roads* for more detailed design guidance.

The active transportation portion of an overpass should have a desired width of 5.0 metres and a constrained limit width of 3.5 metres to accommodate two-way travel with lateral clearance. On multi-modal bridges, bicycle facilities should typically be situated between the pedestrian facility and the motor vehicle travel lanes. Bicycle and pedestrian facilities should be provided on both sides of bridges where possible. Facilities that require active transportation users to shift from one side of the road to the other in order to use the bridge are unlikely to be embraced.

Continuity of the facility is important – wherever feasible, the same bicycle facility type should be continued across the bridge. In constrained locations, it may be necessary to transition to a shared use facility across the bridge. This may be viable depending on the motor vehicle speed and volume, but this design is not appropriate for all ages and abilities. If a shared facility is required, additional pavement markings and advanced warning signs for all road users should be used to indicate the upcoming shared lane. Additional Advanced Warning of Bicycle on Bridge sign (MUTCDC WC-49) can be installed on the approaches to the bridge for additional awareness. The shared lane should only be considered as an interim measure until a more appropriate and dedicated facility can be designed and developed for all users.

If the existing width of the bridge is insufficient to accommodate active transportation facilities, modifications to the structure may be required. Structural modifications are costly and will require specific analysis to determine their feasibility. Where accommodating active transportation users on an existing bridge is not feasible, alternative routes should be considered and wayfinding should be provided for active transportation users.

Underpasses

Perceived safety is an important consideration for design and use of underpasses or tunnels, as they can be dark, confined spaces that are less visible to passersby if not well designed. Underpasses provide shelter from the elements, but this shelter may also lead to loitering. Underpasses are most suitable when the design allows for an open and accessible crossing that is well lit 24 hours a day, to allow a feeling of safety and security for users. Lighting should also be provided outside of the underpass entrances at night so that the contrast between the interior of the underpass and the exterior does not cause visibility challenges. Refer to **Chapter H4** for more lighting design guidance.

Underpass design may not be appropriate in areas where there is high groundwater, as drainage can be an issue. Snow clearance is another challenge, as regular maintenance is required to ensure that underpasses remain functional in all seasons.

The constrained limit width for underpasses that accommodate two-way active transportation travel with lateral clearance is 3.5 metres, with a desired width of 5.0 metres. If the underpass is longer than 20 metres, consideration should be given to increasing the facility width to improve sightlines and allow for more passing opportunities.

The minimum vertical clearance of an underpass or tunnel is 2.5 metres, with a desirable clearance of 3.5 metres. This allows for small services motor vehicles and equestrians to use the underpass. The clearance is measured from the surface of the active transportation facility to the underside of the structure.

Where an underpass is also used for motor vehicle traffic, both walking and cycling facilities should be separated from the motor vehicle travel lane. The underpass should also be well lit, and additional Advanced Warning of Bicycle in Tunnel sign (MUTCDC WC-48) can be installed on the approaches to the tunnel for additional awareness.

RAMPS AND STAIRCASES

Pedestrian Ramps

Accessible pedestrian ramps allow people using mobility devices, pushing strollers, or rolling any type of bag or device to safely and comfortably access grade separated facilities and crossings. In order to provide full universal access, pedestrian ramps should have a maximum longitudinal grade of 1:12 (8.3%) and a maximum cross slope of 1:50 (2%). Longitudinal grades between 1:20 (5%) and 1:15 (6.7%) are recommended. Handrails are required on both sides of all accessible pedestrian ramps.

Ramps should have a desired width of at least1 .8 metres wide with a minimum width of at least 1.5 metres between any obstruction or handrail. Where space is required for two wheelchairs to pass, ramps of at least 1.8 metres should be provided. Level landing spots at least 1.5 metres long should be provided at the top of each ramp and anywhere that the ramp changes direction. Landings of 1.8 metres are recommended, as this accommodates most manual wheelchairs and certain electric wheelchairs. Landings of 2.25 metres will accommodate most types of wheelchair and mobility scooter.

Detailed guidance regarding exterior ramps is provided in CSA Standard B651-18: *Accessible Design for the Built Environment*.

Bicycle Ramps

Bicycle ramps enable bicycle users to transition between bicycle facilities that are at different grades without dismounting. They are commonly used between on-street and off-road facilities and when connecting to overpasses. Smooth transitions on and off the ramp should be provided. Grade changes greater than 13% should be avoided when transitioning between the ramp and the road or gutter. This considers a maximum ramp slope of 8% and a maximum counter cross slope of 5% in the gutter and/ or road. The preference is to have a ramp that has a portion flush with the pavement and curb and gutter. However, a flush ramp needs to take into consideration a line of drainage to follow and a detectable edge for pedestrians with visual challenges.

Bicycle ramps at an intersection should be constructed at 90 degrees to the road and should function as an extension of the bicycle facility. When transitioning between off-road and on-street facilities, ramps should be constructed at an angle of 30 degrees or less to the curb line along the corridor. Custom ramps that accommodate both people cycling and people walking can be used for multi-use crossings. The top of the ramp widths should be as wide as the combined crossing.

Ramps should have a maximum longitudinal grade of 1:12 (8.3%) and a maximum cross slope of 1:50 (2%). Similar to a pedestrian curb ramp, flares should be provided to avoid abrupt grade changes and tripping hazards (see **Chapter G.3**). Bicycle ramps should be located downhill from catch basins or drainage inlets where possible in order to reduce the risk of water pooling and ice buildup.

Stairways

Stairways are not universally accessible, as they are inaccessible for people using wheelchairs, pushing strollers, and using other mobility devices. However, where at-grade crossings and pedestrian ramps are not feasible, stairways are effective in traversing significant vertical distances in a limited horizontal distance, making them a space-efficient means of accessing grade separated facilities.

Staircase components include a flight of stairs, handrails, and landings. There are a number of design considerations for making stairs accessible to the largest possible percentage of the population. These include stairway width, stair rise and run, handrails, and the provision of landing areas. Detailed guidance regarding staircases is provided in CSA Standard B651-18: *Accessible Design for the Built Environment* and section 6.5.2.2 of the TAC *Geometric Design Guide for Canadian Communities*.

Bicycle Channels and Stroller Push Ramps

Bicycle channels and stroller push ramps can be provided along stairways to make them accessible for strollers and dismounted bicycle users. Stroller push ramps require two flat ramps with stairs between them, allowing the stroller pusher to walk between the ramps. Dismounted bicycle users may also use these ramps. Alternatively, bicycle channels can be provided along the edge of a stairway. These ramps are inaccessible to stroller users.

Bicycle channels allow for transitioning between facilities, accessing services, and bicycle access at intersections where there is a large vertical grade difference and grades do not allow for development of a gradual approach or ramps. Bicycle channels should be provided on both sides of the stairs, to facilitate up and down movement. Channels can be concrete, metal, or wood. Maintenance of the channels is important during all seasons to ensure clearing of any debris or snow build-up.

Placement of channels should be away from handrails or have handrails set closer to the wall to prevent handlebars from hitting the rail. In general, providing channels on all stairs allows for better accessibility for people cycling. The top of the channel should be flush with the top of the steps. For weather-controlled environments with high cycling demand, a bicycle escalator could also be considered, but would need to be evaluated for feasibility.

Section 6.5.2.2 of the TAC Geometric Design Guide for Canadian Roads provides further design guidance for both bicycle channels and stroller push ramps.

Bicycle channel on stairway leading to bicycle parking facility, University of Victoria, Victoria, B.C.