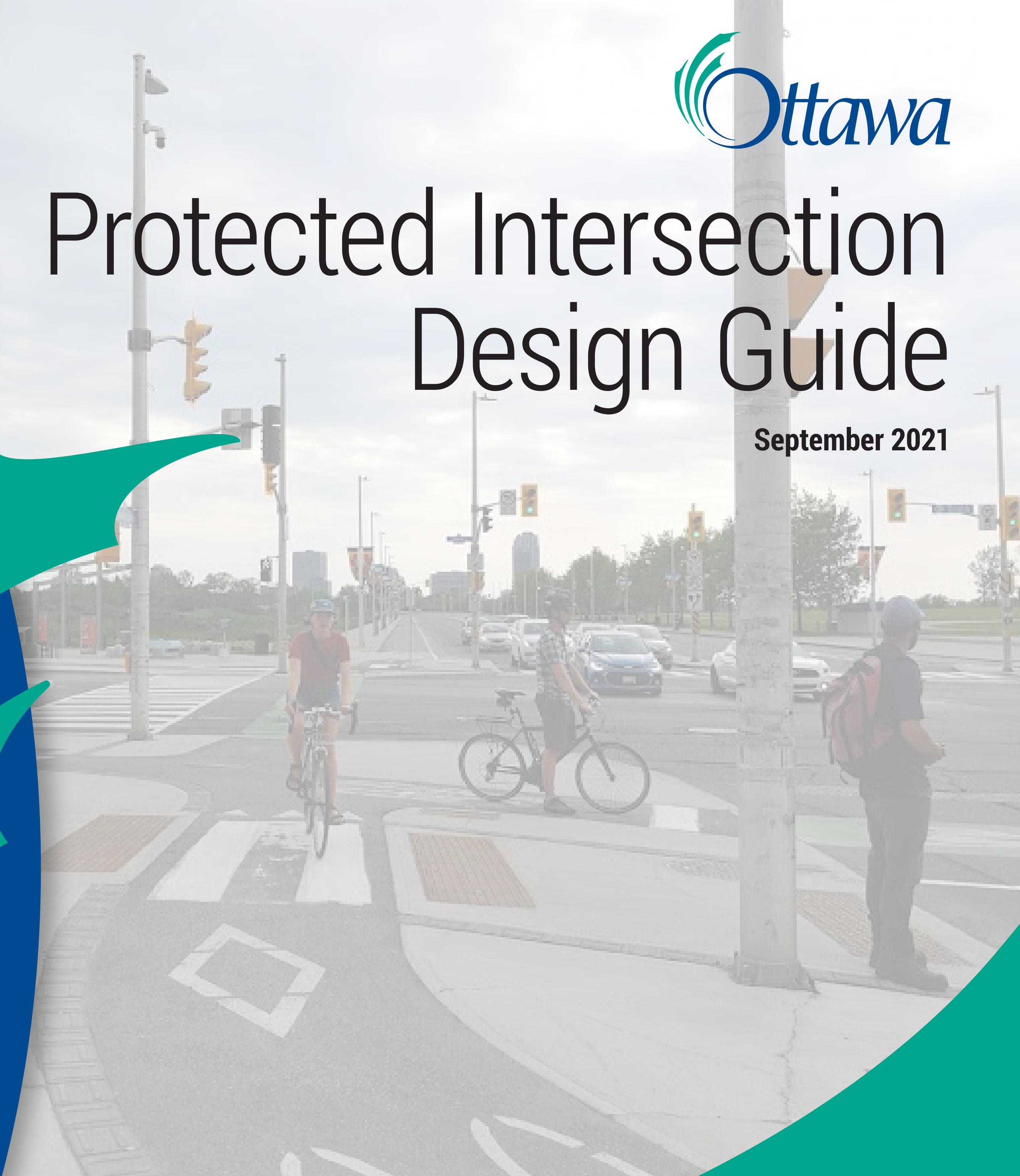
# Protected Intersection Design Guide

**September 2021**



# Acknowledgement


This document was created by the City of Ottawa Transportation Services Department and Alta Planning + Design, Canada Inc.

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**Final Version - September 20, 2021**

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# INTRODUCTION

# 1.1. Purpose of the Guide

Design of cycling facilities, including protected intersections, is rapidly evolving. The concept of protected intersections has been implemented throughout North America, including Ottawa, since 2015. However, there is not yet a consistent approach to their design. The purpose of this Guide is to provide guidance on the design of protected intersections within the City of Ottawa. The Guide will include considerations when designing, and will set out the conditions necessary for, protected intersections. The Guide applies to signalized and unsignalized protected intersections.

This Guide was developed based on a thorough review of best practices from other guidance documents, observations of specific behaviours at key locations in Ottawa and elsewhere, and through detailed discussions with peer municipalities. Findings from an on-site workshop were used to inform the recommendations on delineation between the cycling facility and sidewalk.

This Guide is a living document and will be updated as the City monitors and evaluates various corner design types and characteristics.

# 1.2. Protected Intersection Elements

A protected intersection is designed to make it safer for vulnerable road users, which includes people on bicycles and pedestrians, in the approach to and when crossing an intersection. This is achieved by shortening crossing distances, reducing exposure, increasing visibility, and improving yielding behaviour by motor vehicle drivers. Although a protected intersection consists of several interacting design elements, the most important are:

- Crossride setback, or the lateral offset from the motor vehicle lane to the bicycle crossride, which enables better sightlines and allows more time for drivers to stop for pedestrians and people on bicycles
- Forward stop bar, which places people on bicycles who are waiting further ahead than motor vehicles, improving visibility of people on bicycles and reducing potential for conflicts at the start of the signal phase
- Corner safety island, which separates and protects the bicycle and pedestrian space from the roadway at the corner
- Integrated accessibility features to facilitate safe crossing by vulnerable road users

The elements of a protected intersection are shown on Figure 1.1 Corners that do not include all of the elements listed above may still be a viable design solution based on the localized site constraints and context; however, they are not included in this Guide. There are other elements that can be present at protected intersections but that are not required, such as bicycle signals. Bicycle signals are traffic signals specifically for people on bicycles, and which may be on a separate phase than some motor vehicle traffic.

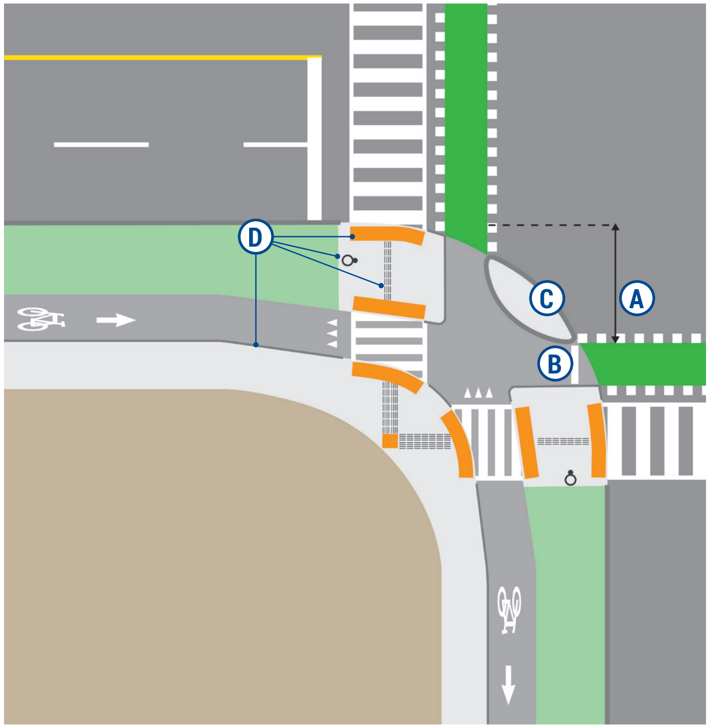


*Figure 1.1. Elements of a protected intersection*

**Design Features**

- (A) Crossride setback
- (B) Forward stop bar
- (C) Corner safety island
- (D) Accessibility features

# 1.3. Protected Corners

An intersection is made up of more than one corner, and depending on the context, each corner may or may not include all of the elements listed above. For this reason, this Guide will take a practical approach to the design of protected intersections, focussing on many of the design scenarios that may be inherent to individual protected corners. The terms “protected intersection” and “protected corner” will be used throughout this Guide depending on whether the situation is discussing the entire intersection in general or specific corners.

# 1.4. Policy Context

There are several regulatory, policy, and guideline documents that allow, promote, and guide the provision of protected intersections in the City of Ottawa. These include:

**National and Provincial Documents:**

- Ontario Human Rights Code, 1990 (OHRC)
- Highway Traffic Act, RSO 1990 (HTA)
- Accessibility for Ontarians with Disabilities Act, 2005 (AODA)
- Integrated Accessibility Standards, O.Reg. 191/11 (IASR)
- Transportation Association of Canada (TAC) Geometric Design Guide (2017)
- Ontario Traffic Manual (OTM) Book 18: Cycling Facilities (2014) and update (2021)
- OTM Book 12: Traffic Signals (2012)
- OTM Book 12A: Bicycle Traffic Signals (2018)
- CNIB Clearing Our Path

**City of Ottawa Documents:**

- Transportation Master Plan (2013)
- Cycling Plan (2013)
- Multi-Modal Level of Service (MMLOS) Guidelines (2015)
- Accessibility Design Standards (COADS) (2015)
- Complete Streets Framework (2015)
- Pedestrian and Cycling Design Toolbox (2019)
- Bus Stops and "Off-Road" Cycling Facilities Interaction Zone Design Guidelines (Draft, 2020)
- Pedestrian and Cyclist Protected Intersection Traffic Signal Detail (2018)
- Protected Intersection Plan (Draft Concept Plan, 2018)
- Designing Neighbourhood Collector Streets (2019)

This Guide is intended to align with current legislation, regulations, and high-level policies, and may build on the guidance included in the guideline documents above. Although detailed guidance does exist for the design of protected intersections, such as in the 2021 update of OTM Book 18, additional details specific to the Ottawa context and experience is desirable.

# 1.5. How to Use this Guide

The protected corner design process is iterative, and trade-offs between priorities for a given context will need to be considered. The designer should always refer to the Guiding Principles when considering trade-offs

This Guide provides a framework for developing designs for protected intersections. It provides detailed direction for designers through the design process of an intersection with one or more protected corners. The design process described is iterative, accounting for trade-offs between modes and right-of-way constraints, and is applicable to a wide variety of contexts present in the City of Ottawa.

This Guide uses the design domain concept, which sets out a range of acceptable values for each design element for the designer to consider in the design process. The guidance will include a target value for each element, which is the value that the designer should attempt to achieve. Detailed explanations and considerations are provided for each element that the designer should understand. The guidance may also include a minimum value for constrained situations, which the designer should use only where site-specific context does not allow the target to be met and provided the designer uses good engineering judgement. In some cases, guidance on when a larger value may be considered is also included, such as where there is a high volume of pedestrians. In all cases, designers should provide a thorough justification for their design choices and provide a record of their own design process.

The Guide is organized into the following chapters:

- **Chapter 2** provides an overview of the Guiding Principles that will inform priorities for designing protected intersections
- **Chapter 3** determines the design requirements and constraints, including identification of existing and planned context, constraints, and the corner radius
- **Chapter 4** sets out the process for determining the type of protected corner to be used on each corner of an intersection, based on the Guiding Principles in Chapter 2, and the design requirements and constraints from Chapter 3
- **Chapter 5** describes the functional design elements that are present at protected corners, explaining the intent, target dimensions, and considerations for each element
- **Chapter 6** describes the detailed design elements, including materials and construction
- **Chapter 7** includes discussion of signal and lane arrangement measures that can assist in achieving the benefits of protected intersections

Protected corner elements that have specific guidance have been "**bolded**" when referenced elsewhere in the Guide for ease of reference.

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# GUIDING PRINCIPLES

> Further definitions, direction, and rationale for many of these guiding principles are provided within subsequent sections of this Guide or within the background policy documents listed in Section 1.4. For example, Section 5.1 contains a more nuanced discussion and definition of "straight path of travel" for pedestrians including guidance on the application of acceptable sidewalk taper angles, where necessary

The high-level principles form the foundation of decision-making during planning and design stages outlined in this Guide. The principles do not detail solutions or design directions but rather what the designs should achieve for a successful protected intersection. All principles should be adhered to during the design.

1. **Design for Universal Accessibility**
    - Consider all users and their different needs
    - Provide a straight, clear path of travel for pedestrians
    - Provide tactile and colour contrasted detectable facilities for people who are blind or have low vision
    - Design for navigability for all users

2. **Increase Safety for Vulnerable Road Users and Reduce Conflicts Between Users**
    - Maximize visibility and sightlines
    - Reduce the speed of conflicting movements
    - Reduce opportunities for conflicts based on typical collision types and users
    - Clearly communicate user expectations, reinforce road user laws, and establish who has the right-of-way through clear and legible design
    - Minimize pedestrian exposure to traffic at motor vehicle roadway crossings
    - Provide appropriate illumination and clear lines of sight between users

3. **Provide Comfort and Convenience for Vulnerable Road Users**
    - Provide sufficient space for pedestrians in the corner
    - Cater to desire lines and provide intuitive, direct paths of travel for pedestrians
    - Provide intuitive path of travel for people on bicycles, with sufficient maneuvering and queueing space for a range of bicycles and users
    - Minimize delay for all Vulnerable Road Users
    - Provide relatively flat grades and smooth, consistent surfaces

4. **Design in Accordance with Context**
    - Use Multimodal Level of Service (MMLOS) targets to guide road user level of service priorities, and make trade-offs accordingly
    - Consider planned function and users
    - Accommodate function of intersecting streets, such as truck routes, bus routes, or arterial roads
    - Design within the available or planned right-of-way

5. **Design for the Full Life Cycle**
    - Accommodate drainage and avoid pooling of water
    - Accommodate snow storage and ease of snow clearing
    - Design for durability and reduced life cycle cost

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# FUNCTIONAL PLANNING

*This section will discuss establishing the design requirements and constraints that will need to be taken into account in the design of a protected intersection and each of its corners. This includes identification of existing and planned context, constraints, and the corner radius, all of which affect the selection of the type of protected corner and the design.*

## 3.1. Existing and Planned Context

The intersection must be planned in light of the existing context and planned function of the transportation network. The corner design should tie in to both existing and planned facilities for all modes. Where any street is included in the cycling network as shown in the Active Transportation Plan, the specific type of facility that is intended to be implemented on the affected streets should be discussed with the Transportation Planning Service before initiating the design. The type of cycling facilities in place or planned will determine the type of protected corner that will be used. Specific guidance on transitions to mid-block cycling facilities is included in **Section 5.5 Transitions**.

The MMLOS Guidelines set out the level of service for each mode depending on the policy context. Although it is expected that pedestrians and people on bicycles will be prioritized at all protected intersections, the MMLOS may indicate whether another mode is of higher priority. For example, if an intersection is within a Transit Priority Corridor, the target for transit level of service will be higher, and thus trade-offs between modes will need to consider the impact on transit in addition to pedestrians and people on bicycles.

The design should take into consideration the existing number and configuration of motor vehicle lanes. The designer should explore opportunities to narrow or reduce the number of lanes or modify the configuration where appropriate in order to provide a desirable protected corner design.

The road classification (i.e., arterial, major collector, collector, local) and presence of a truck or OC Transpo route are also important in the planning of a protected intersection. These aspects may be relevant for the following **Minimum Viable Corner Radius** section.

The existing or planned adjacent land use context should be considered in the design of the protected intersection. The land use context impacts the volume of pedestrians, people on bicycles, and general traffic that will use the intersection. Streets with land use designations such as Mainstreet, Hub, or Minor Corridor may have special public realm requirements that will need to be integrated into the street design.

# 3.2. Identification of Constraints

Except in ideal situations, constraints will be present around which the intersection will need to be designed. Constraints should be identified at the beginning of the design process. Constraints may include:

- Existing right-of-way width and available property, including presence of buildings or structures
- Skew of intersection
- Major above or below ground utilities, such as hydro poles and stormwater infrastructure
- Vehicular volumes, including volume of turning movements
- The requirement to accommodate traffic signal infrastructure including poles, displays, and pedestrian and cycling detection/actuation equipment
- Truck, emergency vehicle, or bus turning movements and heavy vehicle percentage
- Grading

There may be retrofit situations where it is desirable to retain some or all of the existing curbs, which will also present a constraint on the corner design.

# 3.3. Minimum Viable Corner Radius

The City's Traffic Operations Branch (Signal Design and Traffic Engineering Sections) should be consulted when determining the acceptable lane encroachments, which may be impacted by existing or planned signal phasing

There is a strong relationship between the physical corner radius and the performance of a protected corner.

**A small radius:**

- Encourages slower motorist turning speeds and creates sharper turning angles at the point of conflict
- Consumes less space in the roadway, creating more compact intersection and maximizing the effective area within the boulevard for pedestrian and bicycle facilities
- May lead to large vehicles sweeping across the corner safety island and possibly areas where pedestrians or people on bicycles are queuing if the turning path of the large vehicle is not accommodated in the design

**A large radius:**

- Simplifies the accommodation of large design and control vehicles
- Will encourage faster turning speeds by the majority of vehicles and a creates a shallower turning angle such that turning motorists are less able to make eye contact with people on bicycles
- May increase crossing times for pedestrians and people on bicycles by lengthening crossing distance
- Increases the size of the intersection by occupying a substantially larger area at the corner and may render a protected corner infeasible. For example, for corner radii above 10.0 m, it becomes more difficult to meet the target widths for elements of protected corners. Figure 3.1 demonstrates the space that is "lost" when a larger radius is used

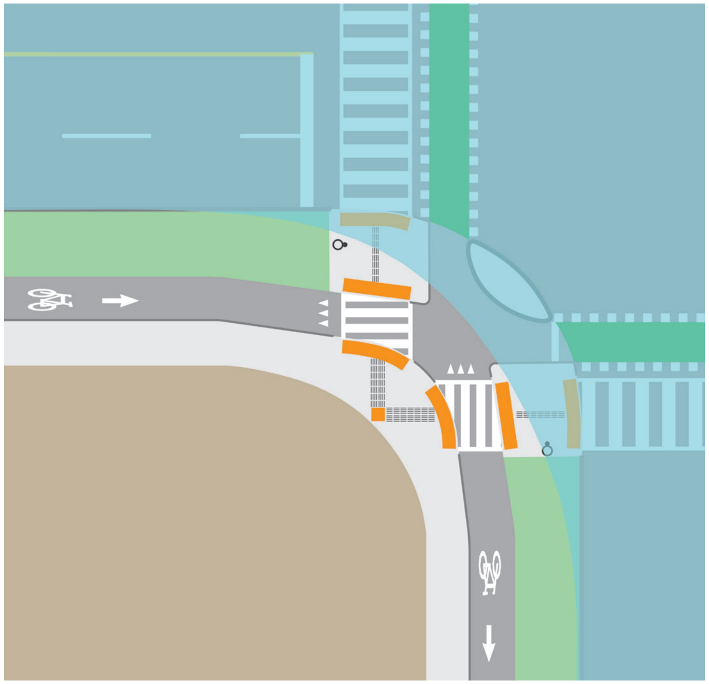

*Figure 3.1. Large radius curve to accommodate large vehicle turning overlaid on a protected corner with a 10.0 m radius*

The optimal corner radius is determined as a function of:

- **The design vehicle:** the largest vehicle expected to make the turn frequently, which may be a bus, medium single unit truck (MSU), or heavy single unit truck (HSU)
- **The control vehicle:** the largest vehicle expected to make the turn on an infrequent basis. A more non-standard turning path is typically permitted for the control vehicle
- **The allowable turning parameters:** these are the parameters used to simulate a turn and should be representative of how drivers perform in the field. Parameters that may result in smaller corner radii include:
    - Allowing slower or even crawl-speed turns
    - Allowing design and/or control vehicles to use multiple receiving lanes
    - Allowing design and/or control vehicles to straddle two inbound lanes or to turn from the lane adjacent to the right turn lane (except where a **fully protected** or **overlap right turn phase** is present)
    - Allowing oversteer across the centreline of the receiving roadway (except where a protected right turn phase is concurrent with a perpendicular left turn phase), which could be used in combination with a setback stop bar of 3.0 - 5.0 m
    - Designing hardscape to be encroached on unless vertical infrastructure is present (e.g., signal or hydro poles)

The design and control vehicles are determined by a combination of policy (e.g., truck routes) and observed turning movement counts. Turning counts should distinguish very large heavy vehicles (i.e., larger than HSU) from other heavy vehicles to ensure an accurate understanding of the largest vehicle that uses the intersection. A compound curve may achieve more space in the corner for bicycles and pedestrians while still allowing the turning movements of the design vehicle.

The minimum viable corner radius should be determined early in the process. Radii of 5.0 - 8.0 m are ideal for protected corners. Radii of between 8.0 - 12.0 m can be accommodated in some contexts, while radii above 12.0 m lead to significant constraints in the design of a protected corner.

**Corner aprons** (also known as truck aprons) may be used to create a smaller effective radius for managed vehicles where a large radius is needed to accommodate large design and control vehicles. A managed vehicle is the most common vehicle to use the corner, which is typically a passenger vehicle. The effective radius is the actual radius of a vehicle's turning path, which may differ from the curb radius. It should be noted that provision of a corner apron does not alter the curbline and thus does not increase the amount of space for a protected corner. This highlights the importance of achieving a small curb radius at the beginning of the process in order to maximize the amount of space in the corner for bicycles and pedestrians.

The City of Ottawa does not currently have guidelines for determining corner radii. The above information is not exhaustive and other resources should be cited by designers when determining corner radii. The **City of Toronto's Curb Radii Guideline (2017)** is a leading example of a formal policy established to create consistency in determining appropriate corner radii.

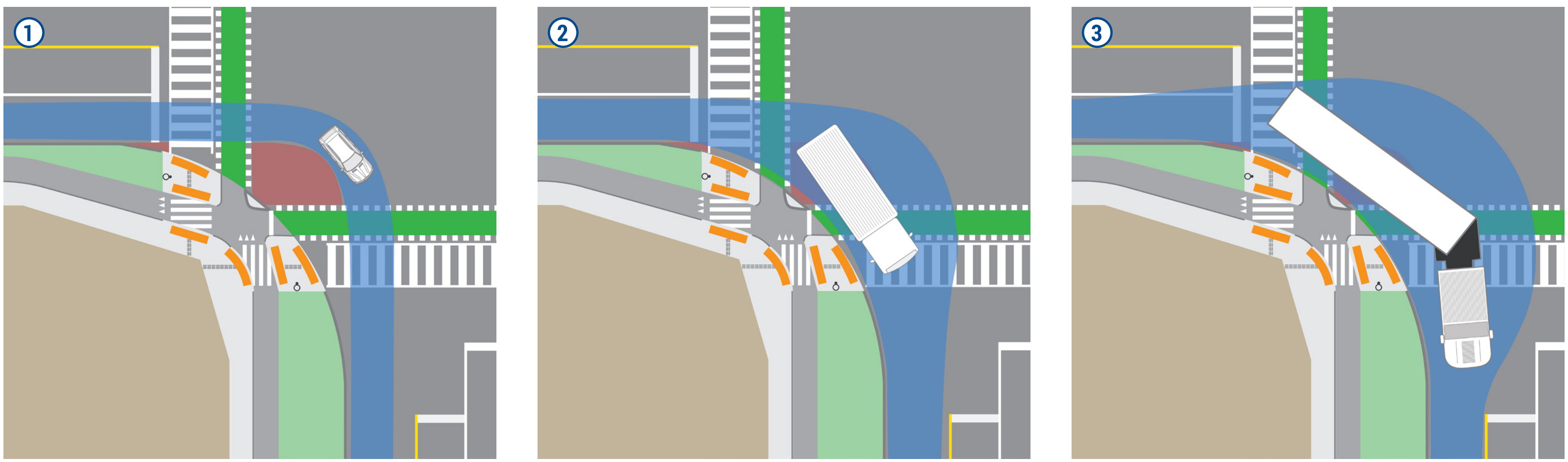


*Figure 3.2. Standard protected corner with large radius and corner apron showing 1. Managed vehicle, 2. Design vehicle, and 3. Control vehicle turning paths*

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# PROTECTED CORNER SELECTION

*After the existing and planned context is assessed, constraints identified, and corner radius is determined, the designer can then select the type of protected corner that is most appropriate for this context. This is an iterative process, as the designer may revisit certain assumptions where constraints or design challenges prevent the preferred protected intersection type from proceeding.*

# 4.1. Types of Protected Corners

*A protected intersection consists of one or more protected corners. Each corner can be assessed individually.*

## Standard Protected Corner

The standard protected corner includes all of the desired elements of a protected intersection. Pedestrian refuges are provided to reduce the overall signalized crossing distance, and a forward stop bar is provided for people on bicycles proceeding straight through or turning left.

### Characteristics

- People on bicycles yield to pedestrians where there is a pedestrian crossing of the cycle track

### Additional Considerations

- Provides the most capacity for movements of people on bicycles
- Minimizes pedestrian exposure distance enabling shorter crossing interval requirements and reduced overall signal cycle lengths reducing delay for all users

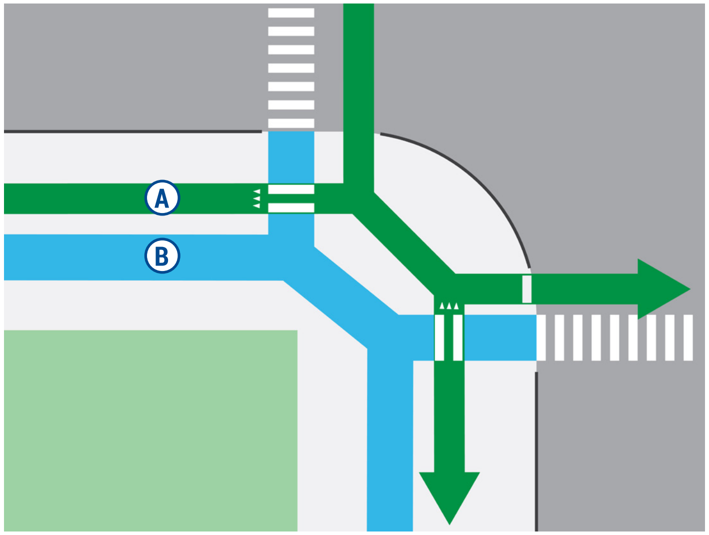



*Figure 4.1. Standard protected corner*

**Design Features**

(A) Cycling path

(B) Pedestrian path

## One-Stage Protected Corner

Where the boulevard area on the approach and/or through the corner is more constrained, the one-stage protected corner may be more applicable. A one-stage corner may also be preferrable in order to provide a straight path of travel for pedestrians or in locations with a high volume of pedestrians. Pedestrians cross the roadway and bicycle facilities in a single signalized crossing, and people on bicycles going through or right, stop before the pedestrian crossing. Only people on bicycles completing two-stage left turns stop using the forward stop bar.

### Characteristics

- Cycle track lowers to street level in advance of the pedestrian crossing, with a raised median between the cycle track and vehicle lanes. If incoming bike facility is already at street-level then grade remains the same
- Pedestrians cross cycle track and roadway in a single signalized crossing
- Through-bound and right-turning people on bicycles stop before the pedestrian crossing
- People on bicycles completing two-stage left turns stop at the forward stop bar

### Additional Considerations

- Generally, offers less capacity for cycling movements compared to standard protected corners and may not provide as smooth of a path of travel
- One-stage protected corners may be challenging to design where there are bidirectional cycling facilities

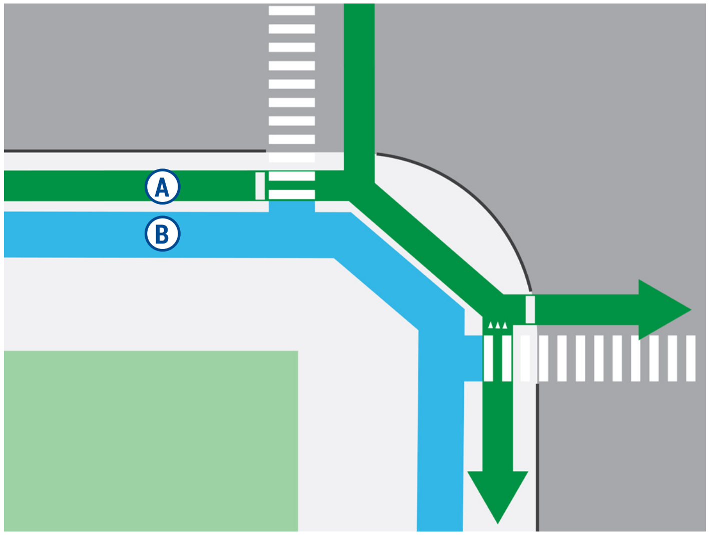



*Figure 4.2. One-stage protected corner*

Design Features

Ⓐ Cycling path

Ⓑ Pedestrian path

## Hybrid Protected Corner

Depending on the space available on each leg of the intersection, it may be advantageous to mix the standard and one-stage protected corners. In this case, a pedestrian refuge is provided for one of the crossings, while the other crossing is a single stage.

### Characteristics

- Depending on orientation, the **bicycle queuing area** may be beside the **pedestrian refuge** or beside the **corner safety island**

### Additional Considerations

- When the one-stage crossing is across the minor street, intersection operations will likely not be impacted, as the pedestrian crossing interval likely will not be the determining factor in the main street green time

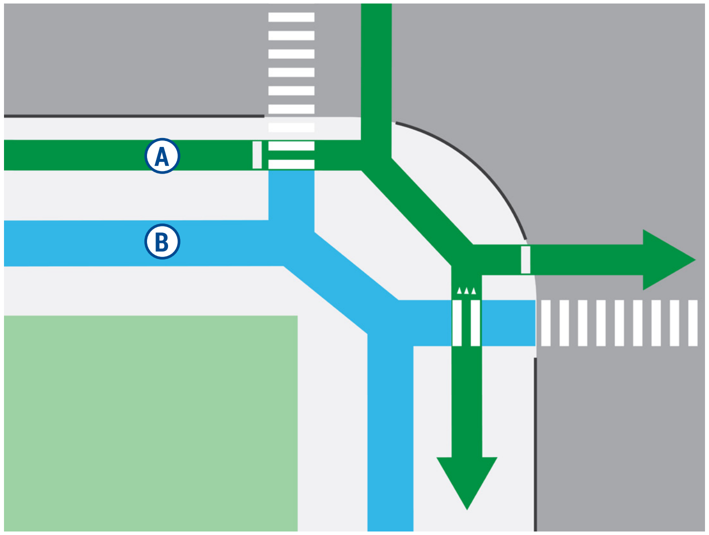



*Figure 4.3. Hybrid protected corner*

Design Features

(A) Cycling path

(B) Pedestrian path

## Dedicated Corner

There may be situations where it may be challenging or even undesirable to achieve a protected corner. This may occur in compact urban contexts or where there is a need to accommodate higher volumes of pedestrians. Dedicated intersections keep people on bicycles on-street, in a physically separated bike lane on the intersection approach. Laurier Avenue West and O'Connor Street is an example of a dedicated intersection.

Guidance for dedicated corners are not included in this Guide.

### Characteristics

- Leading pedestrian/bicycle intervals and forward stop bars may be provided to allow people on bicycles and pedestrians to proceed in advance of motor vehicles, and two-stage queue boxes are provided to accommodate bicycle left turns
- **Fully protected** or **overlap right turn phases** should be considered where there are more than 150 right-turning vehicles per peak hour

### Application

- Dedicated intersections are most suitable in constrained environments with vehicle operating speeds of 50 km/h or less, or where a relative high volume of pedestrians are present
- Dedicated intersections are an appropriate design for all-way stop controlled intersections, where positioning people on bicycles closer to travel lanes will maximize eye contact between motor vehicle drivers and people on bicycles to determine which user has the right-of-way as per the Highway Traffic Act
- A dedicated intersection may be considered where provision of a standard protected corner and its associated cycle track and sidewalk tapers would unreasonably impact the ability to provide pedestrian amenities such as trees and street furniture for significant lengths of the block between intersections. Impacts to amenities may also be resolved by various alternative protected corner types including one-stage protected corners, hybrid protected corners, and partial protected corners

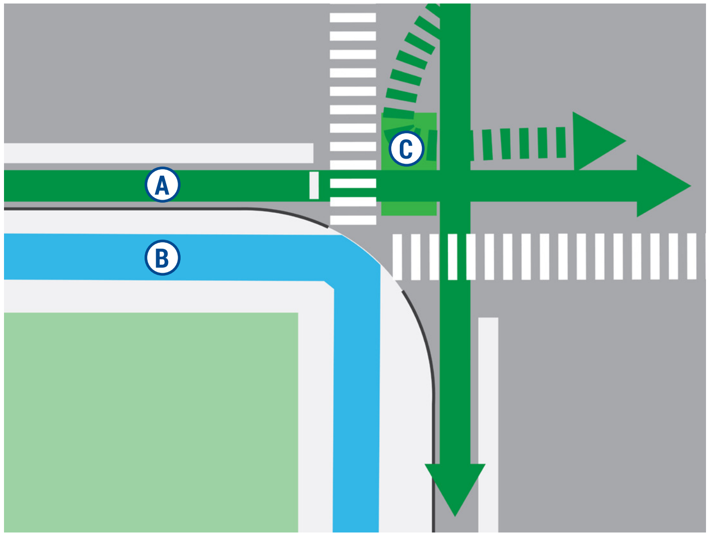



*Figure 4.4. Dedicated corner*

**Design Features**

- (A) Cycling path
- (B) Pedestrian path
- (C) Two-stage queue box

## Partial Protected Corner

On cross streets with low vehicle volumes (posted speed of 40 km/h or less, fewer than 6000 vehicles per day) and a single approach lane, it may be challenging or not desirable to accommodate a protected cycling facility on the approach. The street may have a painted bike lane or require people on bicycles to be in mixed traffic. In this scenario, people on bicycles may use the intersection in the same way as motorists and make direct left turns from a bike box rather than two-stage turns.

### Characteristics

- Bike boxes and/or two-stage queue boxes may be present

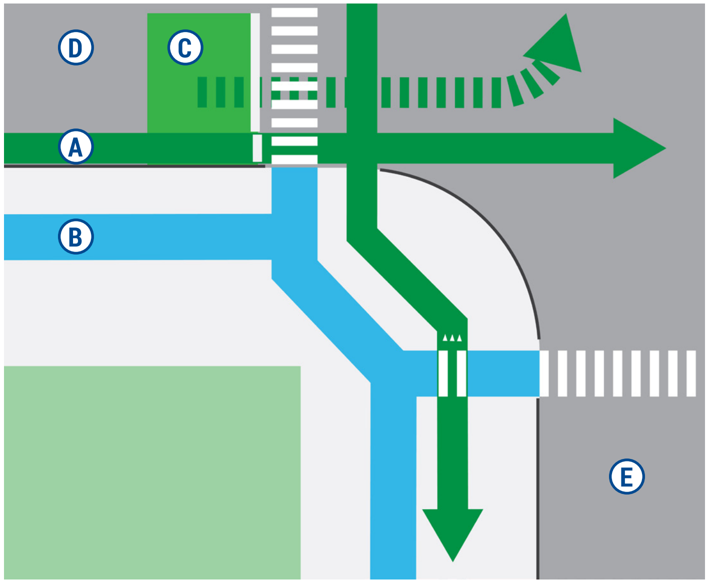



*Figure 4.5. Partial protected corner*

### Design Features

- (A) Cycling path
- (B) Pedestrian path
- (C) Bike box
- (D) Minor street
- (E) Major street

## Smart Channel Protected Corner

Smart channels allow traffic to turn right in a yield condition with the receiving roadway. Traffic in the smart channel intersects the receiving roadway ideally at an angle of 70 degrees, which encourages turning motorists to slow down on the approach and provides more favourable sightlines. Traffic must also yield to crossing pedestrians and people on bicycles in the channel.

Smart channels can be incorporated into protected intersections by keeping bicycle and pedestrian traffic separate on the approaches, at crossings, and within the channel island itself. To improve safety at the pedestrian and bicycle crossings, a raised crossing is recommended which helps slow motor vehicle traffic and encourage yielding. There should be a minimum of one car length between the cross-street and the end of the pedestrian crossing.

### Additional Considerations

Smart channels should be the only form of right turn channelization used in a protected intersection context; a "conventional channel" that intersects the receiving roadway at an angle that is less than 70 degrees is not recommended.

While smart channels may be an effective solution in very specific circumstances, they carry many disadvantages as well:

- Smart channel protected corners do not allow a straight path of travel and are not intuitive for pedestrians to navigate
- Smart channel protected corners require a larger than normal channel island in order to keep people on bicycles and pedestrians separated and to provide adequate maneuvering and queuing space. Because of this, they are typically not the most space-efficient solution and may not be feasible in even moderately-constrained rights-of-way
- Smart channels utilize a yield-controlled right turn, which represents an additional conflict point between motor vehicle drivers and people on bicycles or pedestrians compared to a **fully protected right turn**

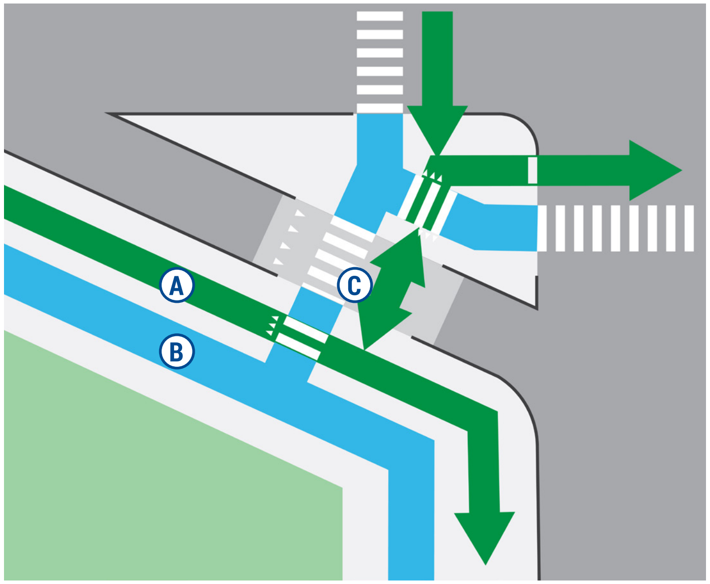



*Figure 4.6. Smart channel protected corner*

Design Features

- (A) Cycling path
- (B) Pedestrian path
- (C) Raised crossing

### Application

As smart channels generally do not provide a straight path of travel for pedestrians, they should not be considered as the default solution. Options for implementing a **fully protected right turn phase**, including lengthening or adding additional right turn lanes, should be considered before considering a smart channel corner. The specific contexts in which they may be considered include:

- At skewed corners with an angle of less than 80 degrees where a **standard protected corner** would otherwise require a very large corner radius in order to accommodate the design vehicle
- Where a **fully protected right turn phase** would not achieve the target Auto Level of Service (LOS), provided Pedestrian LOS and Bicycle LOS targets are met and where
    - There is a very high volume (more than 300 vehicles in the peak hour) of right-turning vehicles
    - There is a bidirectional cycling facility and a moderate volume (150 - 300 vehicles in the peak hour) of right-turning vehicles

## Emerging Measure - Reverse Protected Intersection

This variant reverses the placement of pedestrian and bicycle crossings in the intersection, with people on bicycles crossing further from the intersection and pedestrians crossing closer to the corner apex. In other words, there will be a vehicular lane, crosswalk, then crossride, as one moves away from the intersection, as shown on Figure 4.7.

### Characteristics

- Reverse protected intersections have more conventional pedestrian corner geometry, which means that a reverse protected intersection may not include several important **protected intersection elements** for pedestrians, including a corner safety island and a lateral offset between the motor vehicle lane and the crosswalk.

### Additional Considerations

- Conflicts between users are concentrated on fewer points, however this increases the magnitude of those conflict points.
- Although not tested, the design may confuse drivers' who expect to encounter people on bicycles before pedestrians
- This intersection type has only been constructed in a limited capacity worldwide, and its performance against the guiding principles identified in this document should be monitored over time
- Although this Guide does not include design guidance for reverse protected intersections, the **guiding principles** in this Guide should be used to inform their design

### Application

- As an emerging measure, any proposed application of a reverse protected intersection should evaluate and document the advantages and disadvantages of a reverse protection intersection compared to a standard protected intersection considering the site specific context and constraints. This evaluation must be discussed with all project stakeholders including Traffic Operations, Road Safety, and Transportation Planning
- A reverse protected intersection may be appropriate based on paths of travel for pedestrians or people on bicycles, conflicts between pedestrians and people on bicycles, or space constraints
- Where the dominant cycling route is a right turn or where the dominant pedestrian movement is diagonally across the intersection, a reverse protected corner requires people on bicycles to cross the path of pedestrians fewer times. Conversely, where the dominant cycling and/or walking route is straight across the intersection (i.e. crossing only one leg of the intersection) or where the dominant cycling route is a left turn, a reverse protected intersection may introduce additional conflicts and/or crossing points
- Because the position of the crossride and crosswalk are switched, a reverse protected intersection is not compatible with the other types of protected corners mentioned in this Guide

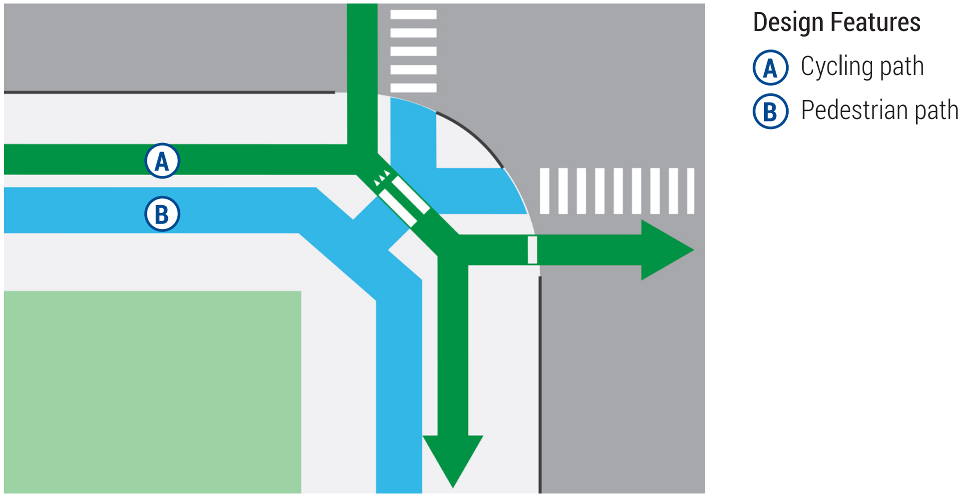



*Figure 4.7. Reverse protected corner*

# 4.2. Selection Process

The following is a process for determining the most appropriate corner type for each corner of the intersection:

1. The default corner type should be the **standard protected corner** (see Figure 4.8). Based on the minimum corner radius and the vehicle lane configuration resulting from the **Functional Planning** process in Chapter 3, the designer should determine if this type will fit in the available right-of-way

2. If the **standard protected corner** cannot be achieved, the designer should first consider options to increase the available corner area. Mode priorities and the trade-off process should be consistent with the **Guiding Principles** outlined in Chapter 2 of this Guide and the City's MMLOS Guidelines. Options to increase space include:

   a. Reduce lane widths to the minimums set out in other City guidelines

   b. Change vehicle lane configuration - Adjust level of service for each mode as per MMLOS targets

   c. Revisit design / control vehicle allowances and determine minimum corner radii

   d. Evaluate feasibility of acquiring additional right-of-way at the corner where needed

3. Where no further increases can be made to the corner area and there is insufficient area for a standard protected corner, the design should consider implementing a hybrid protected corner or a one-stage protected corner design. It is possible to mix protected corner types within the four corners of a single intersection (see Figure 4.9)

4. Where there is insufficient area for a one-stage or hybrid protected corner design, the design should consider implementing a partial protected corner or a dedicated corner. The designer should confirm that vehicle speeds and volumes are suitable for these corner types

The selection process assumes that some type of protected intersection corner is appropriate based on the existing and planned cycling facilities as discussed in Section 3.1, and is desired for the safety and comfort of vulnerable road users. Consult with the Active Transportation Planning Branch and the Traffic, Safety & Mobility Branch if the need for a protected intersection is unclear

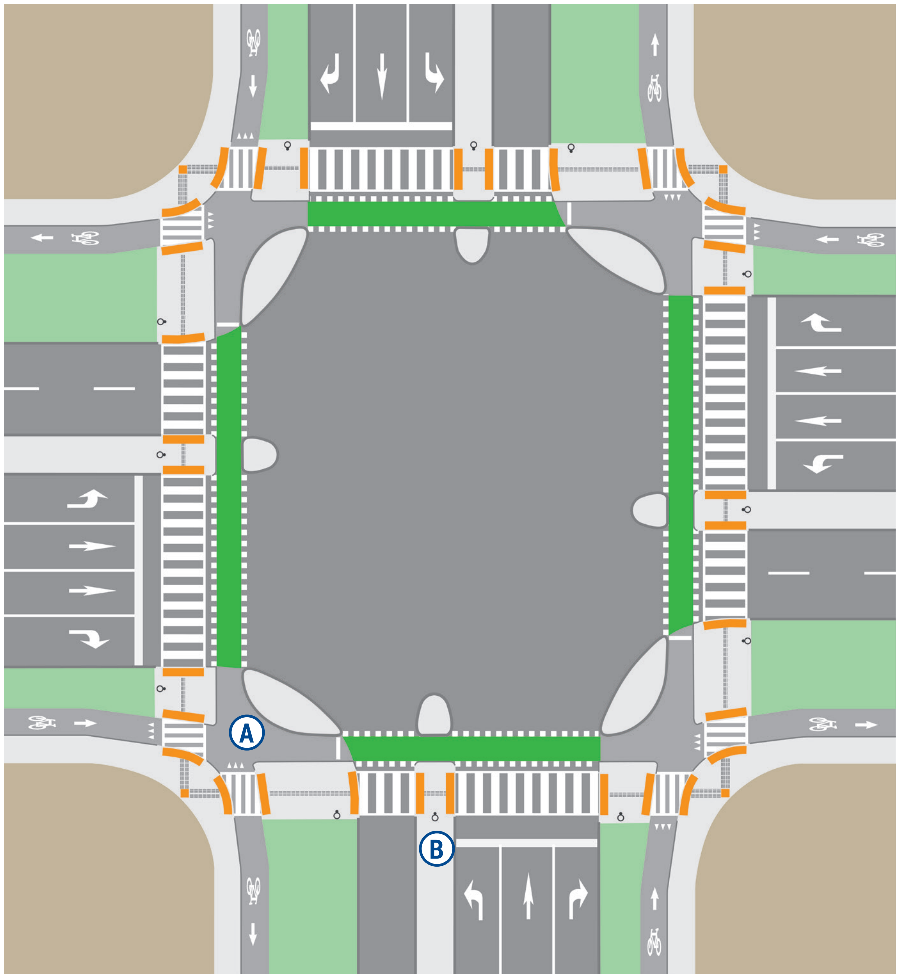



*Figure 4.8. Protected intersection with standard protected corners*

### Design Features

- (A) Standard protected corner
- (B) Median pedestrian refuge

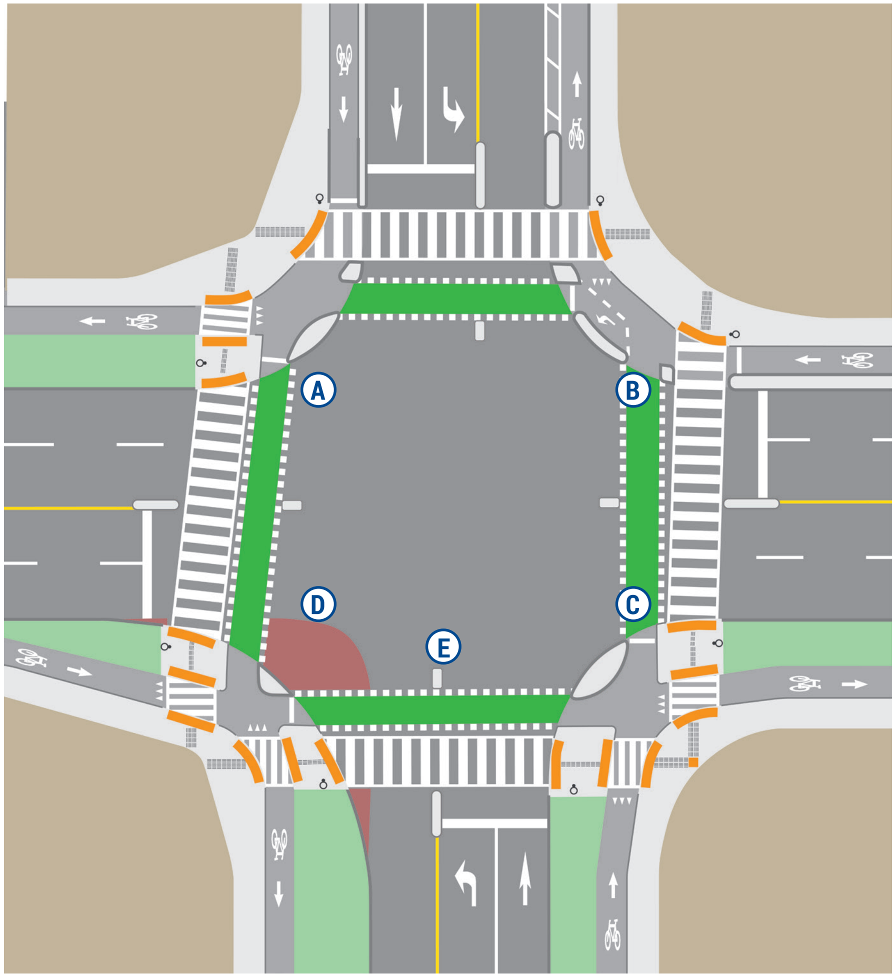



*Figure 4.9. Protected intersection with four different types of protected corners*

### Design Features

- (A) Large radius protected corner with corner apron
- (B) One-stage protected corner
- (C) Standard protected corner
- (D) Hybrid protected corner
- (E) Centreline hardening

5

# FUNCTIONAL DESIGN

*This chapter includes guidance for each of the functional design elements that make up a protected corner.*

# 5.1. Pedestrian Navigation and Access

In choosing an approach for an intersection corner and then refining design elements, a designer should always be cognizant of adhering to the key **guiding principles**, namely: design for universal accessibility; increase safety for vulnerable road users and reduce conflicts between users; and provide comfort and convenience for vulnerable road users. The most vulnerable users should be considered first in ensuring that they can navigate through an intersection with ease. This consideration is relevant to every element of intersection design and overlaps with designing for the comfort and convenience of vulnerable road users, described in the following section.

Considering all users and their different needs entails:

- Providing a straight, clear path of travel where the right-of-way is unambiguous
- Providing tactile and colour contrasted detectable facilities and delineation methods for people who are blind or have low vision to facilitate navigation on the intended path of travel
- Designing for navigability for pedestrians that use wheeled mobility devices, strollers, etc.
- Providing short crossing distances for slower users and which may reduce waiting times for all users
- Adhering strictly to AODA and COADS requirements for detectable warnings, curbs, ramps, and placement of Accessible Pedestrian Signals, wayfinding, accessible pedestrian clearway, and provision of smooth surfaces

There may be cases where the designer must consider trade-offs between the user needs noted above. In these cases, the benefits and impacts on each should be examined based on the context, with the goal of satisfying all the user needs if possible, but recognizing that in each context some user needs may have higher priority. For example, in a constrained context with a high volume of pedestrians, it may be more important to provide a pedestrian crossing where all vehicles (including bicycles) must stop at a signal for pedestrians, while in other contexts in may be more important to reduce the crossing distance.

Protected corner design needs to consider many disparate elements and all sections of this Guide need to be consulted. A few key elements that designers should always keep in mind are:

- Pedestrian straight path of travel
- Elevations of sidewalks, cycle tracks, and raised elements
- Transitions to existing facilities
- Opportunities to reduce corner radii
- Removing or narrowing existing motor vehicle lanes
- Signal pole location
- Drainage and grading
- Signal phasing
- Sightlines to bicycle and pedestrian queuing areas

> "It's essential to pay attention to the design of paths of travel when considering people impacted by blindness. An accessible route will allow them to navigate public spaces safely and independently… A straight path is easier to follow for people impacted by blindness. Curved or winding paths are more difficult to detect, more difficult to describe when giving verbal directions and more difficult for frequent users to memorize." (CNIB. Clearing Our Path, Paths of Travel)

## Straight Path of Travel

A straight path of travel respects pedestrian desire lines and is easier to follow for people who are blind or have low vision. Consequently, straight path of travel is one of the key universal design principles for protected intersections. However, provision of a perfectly straight sidewalk is not always feasible in road and intersection design; roads may widen as they approach intersections to accommodate auxiliary turning lanes, transit queue jump lanes, etc., and similarly roads may contract as they transition to mid-block segments to integrate pedestrian amenities and streetscape elements, and to fit within right-of-way constraints. This expansion and contraction of the right-of-way can be exacerbated in a protected corner design due to the crossride setback. Therefore, on the approach and departure to a protected intersection the sidewalk may need to be laterally shifted (i.e. tapered) to match the alignment of the mid-block sidewalk with the cycle track crossings, pedestrian refuge, and crosswalk(s). If such a shift is required, it should be done as gradually as feasible in a way that respects this Guide's maximum taper angle limit. An abrupt shift will make it challenging for a pedestrian who is blind or has low vision to locate and identify the direction and angle of crossing.

### Guidance

- Where right-of-way space permits, it is preferred that the sidewalk directly approach the parallel crosswalk
- Where the crosswalk and the mid-block sidewalk do not align, the sidewalk will need to taper while maintaining a pedestrian path of travel that is as straight as possible. Sidewalk taper guidance applies to any bends in the sidewalk approaching the intersection as well as the expected path of travel for pedestrians diverting to reach the parallel crossing
- The sidewalk taper angle should be kept as low as feasible given the site constraints. The maximum sidewalk taper angle is 20 degrees (maximum taper of 1:3), and the minimum radius of bends in the sidewalk is 2.0 m
- The sidewalk should be aligned with the crosswalk in order to direct pedestrians in a straight path to the crosswalk. The back of the approaching sidewalk should align with the centre of the crosswalk, as shown on Figure 5.1, and following the taper angle guidance above
- Longer tapers can be utilized where larger setbacks are present in order to achieve the straight path of travel guidance above
- Where property or site constraints result in a sidewalk taper angle that exceeds the 20 degrees, then the designer should:
    - Consider whether the crossride setback can be reduced to the lower end of the target setback range included in **Table 5.1**
    - Reconsider the type of protected corner determined in the **selection process**. Depending on the context (e.g., positioning of the incoming sidewalk) the type of protected corner may allow for a straighter path of travel
- Crosswalks should be aligned such that they maintain a straight path of travel for pedestrians through the intersection, which may result in the crosswalk not being parallel to the adjacent motor vehicle lanes or perpendicular to the curb

- Where a multi-use path splits into a cycle track and sidewalk, the sidewalk should continue the straight path of travel for pedestrians, while the cycle track should deviate, as shown on Figure 5.1

## Additional Considerations

- When the cycle track is separated from the roadway by 3.0 m or more mid-block, the required tapers are typically minimal. Where multiple protected intersections are located in close proximity along the same corridor, consider maintaining a wide mid-block boulevard to reduce deviations in pedestrian path of travel, provided the boulevard width is consistent with other City guidelines and does not preclude other contextual design objectives of the street
- To improve the detectability of tapers, a half-height curb of 60 mm (+/- 10 mm) is necessary, as discussed in more detail in **Chapter 6 Detailed Design Considerations**
- It is not necessary for the cycle track and sidewalk to taper at the same angle, although this is the most common configuration

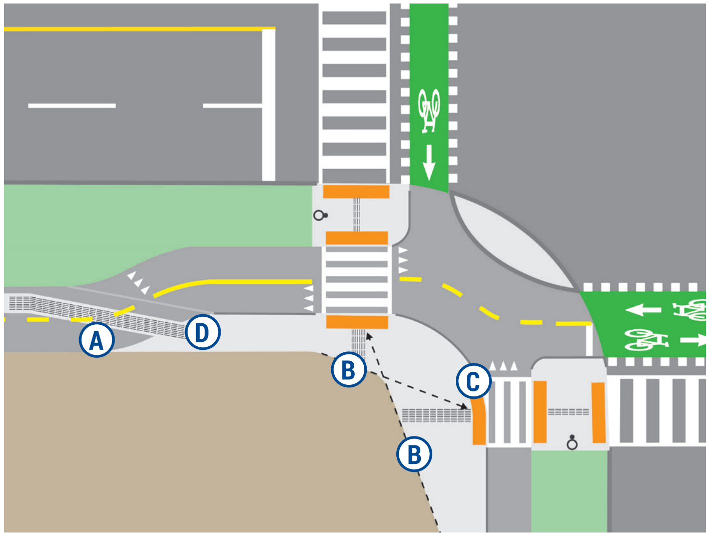



*Figure 5.1. Standard protected corner showing transition from multi-use path to separated facilities and pedestrian path of travel alignment with crosswalks*

### Design Features

- (A) Pedestrian straight path of travel to/from MUP
- (B) Pedestrian straight path of travel to crosswalk
- (C) Attention tactile walking surface indicator
- (D) Directional tactile walking surface indicator

## Delineation and Navigability

Part of providing ease of navigation and access in the intersection is ensuring an effective delineation method between cycling and pedestrian facilities that prevents pedestrians from inadvertently entering the roadway or cycle track without warning and mitigates potential pedestrian-cycling conflicts.

### Guidance

- The delineation method must be detectable by a range of users, including people who are blind or have low vision and people who are neurodiverse, without negative consequences or the creation of barriers to access for other users, such as people using mobility devices and wheelchairs
- Tactile walking surface indicators (TWSIs) must be used appropriately to warn of hazards and help pedestrians navigate
- Additional information on delineation methods and TWSI application is included in **Chapter 6.1 Pedestrian Guidance**

Tactile walking surface indicators (TWSIs) are standardized walking surfaces that convey information to people who are blind or have low vision. There are two common types of TWSIs:

- **Attention TWSIs** are minimum 600 mm wide, have truncated domes and indicate the presence of a hazard or a decision point, such as a flight of stairs, transit platform edge, cycle track, or roadway
- **Directional TWSIs** are either 300 or 600 mm wide and have elongated bars running parallel to the direction of travel to help pedestrians navigate in the correct direction

# 5.2. Pedestrian Safety and Comfort in the Corner

*For a design to be effective, it should recognize elements of providing pedestrian comfort and prioritize their safety as vulnerable road users. In addition, the design should recognize that pedestrians generally traverse an intersection in a way that is most convenient to their intended path of travel.*

## Sidewalk Width

At intersection corners, the sidewalk area providing space for pedestrians to travel and also includes transitions for curb ramps or depressed curbs to serve the crosswalks.

### Guidance

- The target clear width of the sidewalk between obstacles, including signal poles and other utility infrastructure, is 2.0 m, with a minimum of 1.8 m. However, wider targets may be recommended in other City documents, including Downtown Moves
- Where grading and property permits, taper the back of the sidewalk through the corner to match the path of travel to the centre of the parallel pedestrian crossing as shown in Figure 5.1. The taper will provide extra width through the corner, a more direct path, and a detectable edge that can help people who are blind or have low vision navigate the intersection. The recommended taper angle is 1:3 as discussed in the **Straight Path of Travel** section

### Additional Considerations

- The IASR requires that the accessible pedestrian signal (APS) be located within 1.5 m of the curb edge, which may impact the design of the sidewalk or order to achieve the clear width noted above

*Image 5.1. 3.0 m sidewalk on Beechwood Avenue*

## Pedestrian Refuges

Pedestrian refuges provide a dedicated waiting area for pedestrians waiting to cross the roadway. Pedestrian refuges may be located between the cycle track and the roadway, or in the median of a roadway.

*Image 5.2. Example of pedestrian refuge at Donald Street and St-Laurent Boulevard*

### Guidance

- Refuges must provide sufficient area for people using a mobility device, with service animals, strollers, or other devices to comfortably maneuver
- At all signalized intersections, pedestrian refuges shall have Accessible Pedestrian Signals (APS) as per the requirements of AODA and COADS. Conceptual placement of signal poles with APS are shown on the corner graphics included in this Guide, however, discussion with the City's Traffic Operations staff is required to finalize their placement
- The target refuge depth (i.e., the dimension from roadway to cycle track or another roadway) is 3.0 m, measured at the midpoint or centreline of the refuge, with a minimum depth of 2.7 m. The minimum depth accommodates the required TWSIs and sufficient space for a typical mobility device to dwell. Refuges may be deeper than 3.0 m depending on the corner geometry. A minimum depth of 2.4 m may be used:
    - At signalized intersections where there is a physical constraint that prevents the minimum depth being met, and the posted speed of the adjacent roadway is 50 km/h or less, or
    - At unsignalized intersections or crossings
- The target refuge width (i.e., the dimension parallel to the roadway) is 3.0 m. The width should exclude any curbs or steep cross-slopes at the edge of the refuge (i.e., flared sides)
- Median pedestrian refuges should be considered where:
    - A single leg of a crossing exceeds 21.0 m. This is widest road for which a Pedestrian Level of Service "C" can be achieved, which is the lowest target in the urban area
    - There are nearby destinations with a significant volume of children, seniors, or people with disabilities
    - Despite the presence of a median refuge, the pedestrian signal should be timed to allow a pedestrian to cross the entire roadway in one signal phase

Therefore, widening of the roadway to accommodate a median refuge will increase the minimum pedestrian "walk" plus "flashing don't walk" time, which may increase the signal cycle length and increase delay

#### Additional Considerations

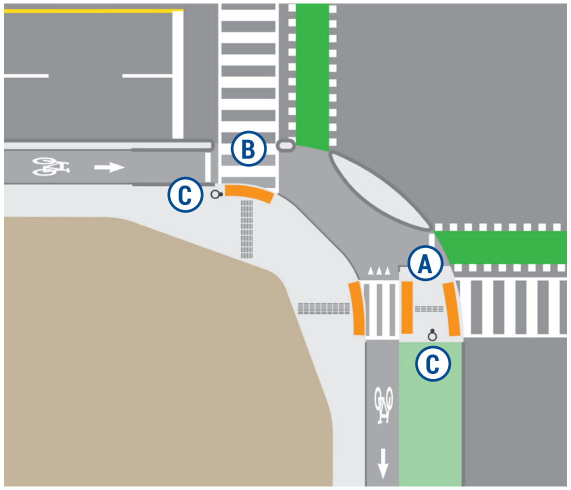
- Intersections with a high existing or planned volume of pedestrians may warrant larger refuges. The width of the refuge should be increased before the depth. The ideal size of the refuge is based on the Pedestrian Level of Service (PLOS) for the site from the City's MMLOS Guidelines and the corresponding pedestrian densities listed below, using the following formula:

$$\text{Size of refuge } (m^2) = \frac{(\text{Number of pedestrians in peak hour X Proportion of "don't walk" time per cycle})}{(\text{PLOS target density (people/}m^2\text{) X Number of cycles per hour})}$$

  For each PLOS target, there is a corresponding pedestrian density:

    - PLOS A: ≤ 0.27 people/$m^2$
    - PLOS B: 0.43 - 0.27 people/$m^2$
    - PLOS C: 0.72 - 0.45 people/$m^2$
    - PLOS D: 1.08 - 0.72 people/$m^2$

- Where the refuge width and depth have been maximized but the refuge area is still below the ideal size necessary to achieve the PLOS target, then a one-stage crossing may be contemplated. When making this decision, the designer should also consider the disadvantages of a one-stage crossing compared to a crossing that includes a pedestrian refuge:
    - One-stage crossings have a longer signalized crossing distance and a longer crossing interval requirement, which may increase overall signal cycle lengths thereby increasing delay for all users
    - One-stage corners require through and right-turning bicycles to stop at the crosswalk on a red signal, and they typically have small bicycle queuing areas, which both function to reduce the capacity of cycling movements
- Refuges adjacent to high-speed roadways may warrant additional safety measures to protect pedestrians from errant vehicles. Consideration should also be given to increasing the depth of the refuge to provide a more comfortable separation from traffic for pedestrians:
    - For refuges between the cycle track and roadway, consider increasing the minimum depth when the posted speed of the adjacent roadway is greater than 70 km/h
    - For median refuges, consider increasing the minimum depth when the posted speed of the adjacent road is greater than 60 km/h
- Median pedestrian refuges create large negative off-sets between opposing left turn lanes, reducing the visibility of oncoming traffic. Where a 3.0 m or deeper median refuge is provided and there are opposing left turn lanes, a **fully protected left turn phase** is required




Design Features

Ⓐ Target pedestrian refuge depth 3.0 m

Ⓑ One-stage pedestrian crossing

Ⓒ Accessible Pedestrian Signal (APS)

*Figure 5.2. Hybrid protected intersection showing pedestrian crossings with and without a refuge*

Ladder crosswalk markings are preferred for general vehicle crossings, subject to the City's warrant process for ladder crosswalk markings

## Cycle Track Pedestrian Crossings

Designated crossings are required at points where pedestrians cross the cycle track to access refuges.

### Guidance

- Ladder or "zebra" crosswalk markings help vulnerable road users navigate the intersection. Cycle track crosswalk markings have a width of 0.4 m and a preferred length of 3.0 m. Cycle track crosswalk markings may be between 2.0 and 3.0 m in length if it helps avoid use of a depressed curb around the entire corner. The cycle track crosswalk should be oriented in line with the roadway crosswalk to provide a continuous straight path of travel. The crosswalk bars should be perpendicular to the path of travel
- Cycle track crosswalks leading to pedestrian refuges should have a yield line or "shark's teeth" across the full width of the cycle track, designed in accordance with OTM Book 18. These should be provided in combination with a "cyclists yield to pedestrians" (Rb-73) sign. To improve compliance, consider mounting these signs at 0.8 m off of the ground to be closer to a person cycling's line of vision
- Crosswalks that cross both cycle track and roadway in a single stage or at a stop sign should have a stop bar across the full width of the cycle track. At a signalized intersection, this should be in combination with "cyclists stop here on red signal" (Rx-79) sign in advance of crossing points
- Where pedestrians cross a bidirectional cycle track, yield bars (or stop bars for a one-stage pedestrian crossing) and signage should be provided across the incoming cycling facility on both sides of the crosswalk
- Where there is a one-stage pedestrian crossing, the incoming cycle track should ramp down to road level with the bottom of the ramp a target of 3.0 m in advance of the bicycle stop bar
- Provide attention tactile walking surface indicators (TWSIs) within the sidewalk on both sides of the crossing

### Additional Considerations

- Raised crossings should be considered at yield-controlled cycle track crossings to encourage people on bicycles to slow down and yield to pedestrians, provided grading and drainage of the cycle track can be accommodated. Raised cycle track crossings should have a sinusoidal profile per City of Ottawa standard R15.1

## Transit Stops

Transit stops are commonly found either before or after signalized intersections, making it likely that a protected intersection may need to integrate transit stops. While designers should use the latest version of the *OC Transpo Bus Stops and 'Off-Road' Cycling Facilities Interaction Zone Design Guidelines* when designing the bus stops themselves, these stops will need to be incorporated into the design of the intersection.

### Guidance

- When the bus pad is 3.0 m or wider, it functions as an island platform stop, and is designed for passengers to wait for the bus between the cycle track and the roadway. Where this is the case, consider providing a clear path of travel with directional TWSIs directly between the pedestrian refuge and the platform. This will provide more direct access to the stop, and prevents the need for pedestrians to cross the cycle track twice to reach the platform, as shown in Figure 5.3. Provision of a clear path of travel may require locating the signal pole with the APS on the opposite side of the refuge or deepening the refuge to provide the minimum **sidewalk width**
- The front of near side bus stops should be immediately upstream of the stop bar, and the back of far side bus stops should be located a minimum of 5m from the crosswalk. When designing bus stops around large radius corners, it should be noted that the bus stop must be located so the curb is tangent for the entire length of the platform

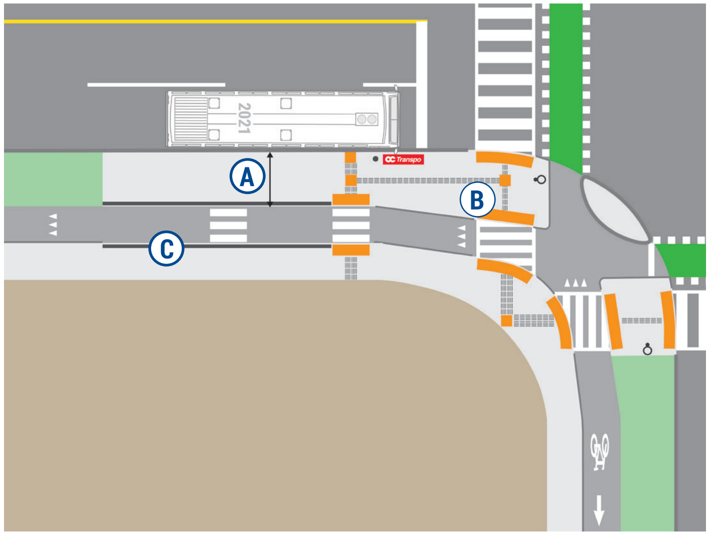



*Figure 5.3. Standard protected intersection showing pedestrian crossings with and without a refuge*

#### Design Features

- (A) Bus stop island platform width 3.0 m
- (B) Direct connection from pedestrian refuge to bus stop island platform
- (C) Delineation pavers with width of 0.2 m (This delineation feature is currently under review, and may be replaced by a new standard in the near future)

The City's preference at signalized intersections is to locate bus stops on the far side of the intersection, but there are many exceptions that may require a near side bus stop including bus turning movements, key origins/destinations, and space/driveway conflicts on the far side of the intersection. Consult with Transit Services – Operational Planning for preferred bus stop locations

# 5.3. Mitigating Turn Conflicts

Where there are permissive turns, there is potential for a conflict between turning vehicles and pedestrians and people on bicycles. It is important to create an environment that will maximize yielding and minimize potential for conflict and the severity if there is a collision.

Turning motorists' visibility of people on bicycles and pedestrians is maximized when the turning angle of the vehicle is at a steep angle (approximately 70 degrees or higher) at the point of conflict, as a motorist can more easily see an oncoming user through the passenger window.

Multiple design features work together to create this condition:

- A **compact corner radius** helps to slow turning motorists and increases the turning angle
- A **crossride setback** allows turning motorists to queue without blocking traffic and achieve a sharper turning angle before the point of conflict
- **Corner aprons** create the effect of a smaller radius for managed vehicles (e.g., passenger vehicles) when a larger radius is required to accommodate design and control vehicles
- **Centreline hardening** reduces the left-turning radius, thereby slowing left-turning vehicles and increasing the turning angle, which may protect the pedestrian and bicycle crossing
- At **smart channels**, raised crossings can slow vehicles on the approach to the crosswalk and crossride and improve the likelihood that turning vehicles will yield to pedestrians and people on bicycles
- **Signalization measures** can reduce or eliminate turn conflicts between users

## Crosside Setback

The crossride setback is the lateral distance between the inside edge of the crossride and the adjacent parallel motor vehicle lane. A bikeway crossing with a setback of less than 2.0 m is referred to as an "adjacent crossing", while a crossing with a setback of 2.0 m or more is referred to as a "set back crossing".

Set back bicycle crossings offer improved safety for people on bicycles compared to adjacent crossings by achieving a larger turning angle for motorists at the point of conflict, making it easier for right-turning motorists to see approaching people on bicycles. Ideally, this turning angle should be 70 degrees or greater. Where no dedicated right turn lane is present, setbacks also allow right-turning motorists to queue without blocking the through traffic lane while yielding to crossing pedestrians and people on bicycles. Setbacks are also important for creating a **bicycle queuing area** for people on bicycles.

*Image 5.3. Example of set back crossing at Donald Street and St-Laurent Boulevard*

### Guidance

- The target crossride setback depends on the curb radius of the corner, as well as the expected speed of vehicles through the turn. Table 5.1 shows the target setback range for a series of typical curb radii, which shows both minimum and maximum target setbacks. Determining the appropriate setback within the target range should consider sightlines and **straight path of travel** guidance
- For curb radii 10.0 m or less, safety benefits decrease for setbacks larger than 6.0 m, as motorists may begin to accelerate out of their turns before the point of conflict
- The setback should be based on the radius of the **corner apron**, where one is present
- Right turn lanes require additional boulevard space at corners, which reduces the available boulevard for providing a protected corner and may reduce the achievable setback. Where right turn volumes are low and the through traffic speeds are 50.0 km/h or less, a right turn lane should not be provided, which will allow for additional corner boulevard area and setback to be provided

*Table 5.1. Target setback ranges for typical curb radii*

| Curb Radius (m) | Target Setback Range (m) |
|---|---|
| 5.0 | 3.0 - 6.0 |
| 8.0 | 4.0 - 6.0 |
| 10.0 | 5.0 - 6.0 |
| 12.0 | 6.0 - 8.0 (or use setback for **corner apron** radius) |
| 18.0 | 6.0-8.0 (or use setback for **corner apron** radius) |

### Additional Considerations

- Where a **fully protected right turn phase** is intended to be used, achieving the desired setback is less important, as permissive conflicts will not need to be managed. In order to provide space for two-stage bicycle turns within the protected corner, a small setback will still be necessary
- Where a setback less than the target stated in Table 5.1 is used, people on bicycles are less visible to motorists through both the mirrors and side window. Setbacks less than the target but greater than 2.0 m still provide a safety improvement over setbacks less than 2.0 m. In these cases, greater consideration should be given to other safety measures such as implementing a **fully protected right turn phase**, **overlap right turn phase**, or **LPI/LBI** (refer to Figure 7.4 for right-turn signalization measures flowchart) using a **corner apron**; or decreasing the **corner radius**
- Where there are constraints that only allow for a setback less than 2.0 m and the speed limit is 50.0 km/h or less, a **dedicated corner** may be used in conjunction with a **fully protected right turn phase**, **overlap right turn phase**, or **LPI/LBI** (refer to Figure 7.4 for right-turn signalization measures flowchart)
- Where there are constraints that prevent the **straight path of travel** guidance on sidewalk taper angle from being met, the setback targets range in Table 5.1 should still be followed. However, consider reducing the crossride setback to the minimum target distance to provide the straightest possible path of travel
- Where permissive left turns are present, large setbacks may increase the vehicle left-turning radius, potentially encouraging higher turning speeds. In these cases, consideration should be given to a **fully protected left turn phase** to separate the conflict or **centreline hardening** to reduce the effective left turn radius
- At all-way stop controlled intersections all vehicles are required to stop before proceeding. Achieving the target setback is therefore less important, provided people riding bicycles are as visible as possible through the location of the forward stop bar. Dedicated intersections are an appropriate design for all-way stop controlled intersections, where positioning people on bicycles close to travel lanes will maximize eye contact between motor vehicle drivers and people on bicycles to determine which user has the right-of-way as per the Highway Traffic Act

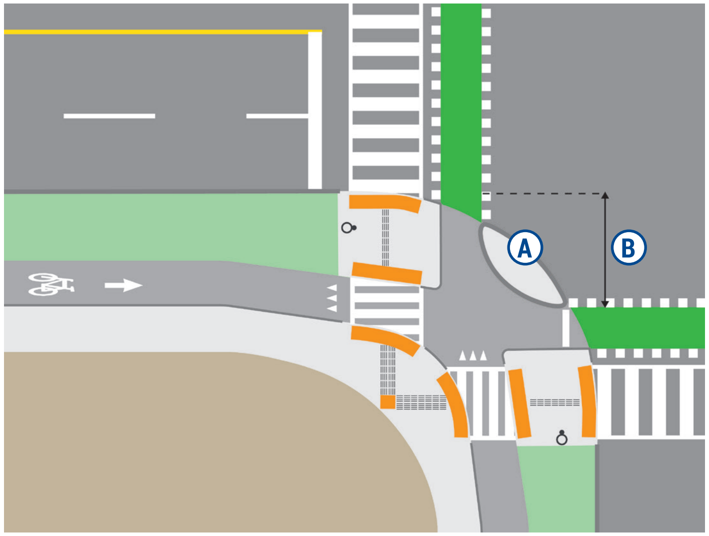



*Figure 5.4. Standard protected corner with 10.0 m radius showing 5.0 m crossride setback*

#### Design Features

- (A) 10.0 m curb radius
- (B) 5.0 m crossride setback

## Intersection Approach Clear Zone

The clear zone is the area in the approach to the intersection where sightlines should not be obstructed. Keeping this area clear of obstructions allows motor vehicle drivers, pedestrians, and people on bikes to get clear line of sight to each other. This gives motor vehicle drivers more time to stop if making a right turn and people on bikes time to stop if a right-turning vehicle crosses its path in the intersection.

### Guidance

- The length of the intersection approach clear zone measured from the edge of the intersecting street along the approaching street should be:
  - 6.0 m for driveways and public lanes
  - 12.0 m where the curb radius is 4.0 m or less
  - 14.0 m where the curb radius is 8.0 m or less
  - 16.0 m where the curb radius is 15.0 m or less
- The intersection approach clear zone should provide an unobstructed line of sight from the driver of a vehicle at the stop bar to the pedestrian queuing area for the parallel pedestrian crossing
- At stop-controlled approaches, the clear zone should be measured from the edge of the intersecting street to the stop bar
- Objects should not obstruct the line of sight to a child walking or person on a bicycle, or an object height range of approximately 0.6 - 1.8 m. Within the intersection approach clear zone:
  - No stopping or parking should be permitted, with the exception of buses
  - No large immovable obstructions should be placed, such as mailboxes, or utility boxes
  - Landscaping may be placed provided foliage does not obstruct the clear line of sight

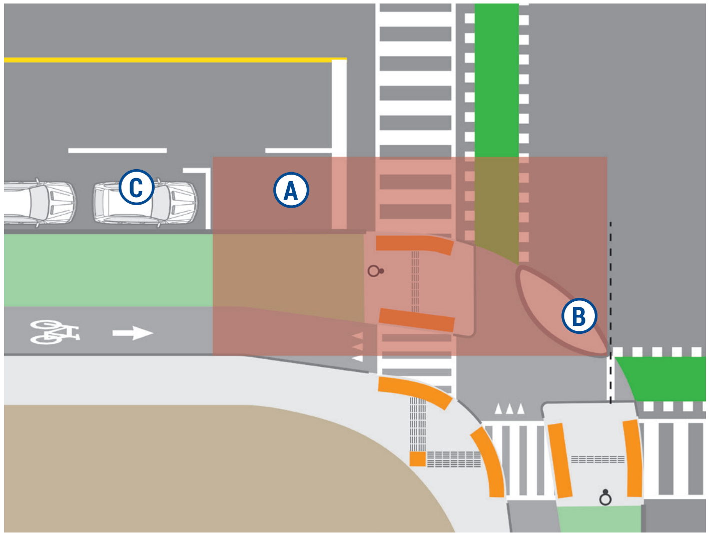



*Figure 5.5. Standard protected corner showing clear zone in advance of intersection*

**Design Features**

- (A) Clear zone of 16.0 m
- (B) Corner radius 10.0 m
- (C) On-street parking

## Corner Aprons

Where larger corner radii are required due to the design or control vehicle, corner aprons may be used to create a second smaller radius for managed (e.g., passenger) vehicles. This encourages the majority of motorists to turn at a smaller radius and therefore at slower speeds and a larger angle while still accommodating infrequent larger motor vehicles. Corner aprons have been found to be successful in encouraging the majority of passenger vehicles to turn at a smaller radius and appears to contribute to high rates of yielding to pedestrians.

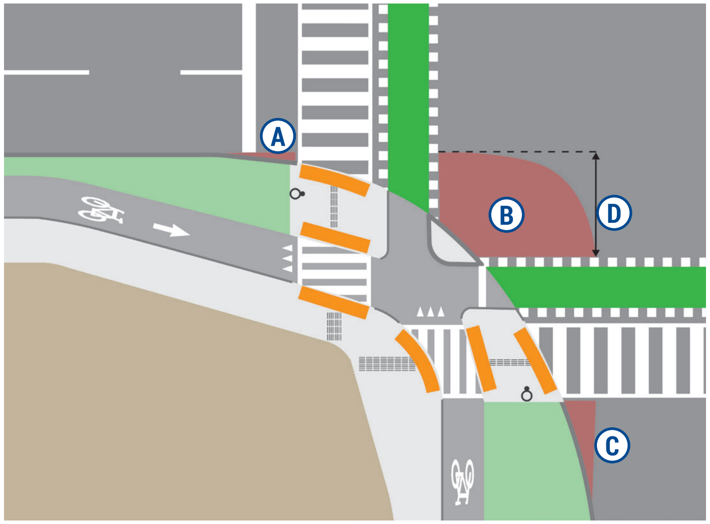



*Figure 5.6. Standard protected intersection with large radius and corner apron*

### Design Features

- (A) Corner apron approach
- (B) Corner apron
- (C) Corner apron departure
- (D) Crossride setback

### Guidance

- A corner apron is recommended where the curb radius is 12.0 m or greater
- A corner apron should be considered where the curb radius is less than 12.0 m but the target crossride setback cannot be achieved
- Where a fully protected right turn phase is present, a corner apron is not necessary as the conflict between turning vehicles and people on bicycles/pedestrians is eliminated
- The target corner apron radius is 4.0 m, and the maximum radius is 5.0 m. The maximum radius may be increased to 8.0 m where the corner is at an acute angle of less than 80 degrees
- Where the combined frequency of one or more bus routes is 4 or more buses per hour, then the corner apron should be sized such that a turning bus does not encroach onto the corner apron. Despite the previous clause, a corner apron may be considered where 4 or more buses turn per hour where the corner apron is deemed necessary for managing right turn conflicts and there are no other feasible options to improve safety (such as signal phasing or timing), provided its design is approved by Transit Services
- Where the combined frequency of one or more bus routes is less than four buses per hour, then a corner apron may be considered, provided its design is approved by Transit Services

- Aprons should not be extended across cycle tracks or crosswalks, as this may encourage pedestrians or people on bicycles to dwell on them, and the change in surface material may cause confusion for people who are blind or have low vision. However, in order to guide managed vehicles on the desired travel path, a section of the apron should be provided in advance of the leading crosswalk and beyond the trailing crosswalk. The corner apron material should be separated from the edge of the crosswalk markings by a minimum of 0.3m
- Corner aprons are not required at all-way stop controlled intersections
- Guidance on design options is included in **Section 6.4**
- Guidance on corner aprons may be updated over time as the City monitors the safety outcomes of corner aprons implemented in a variety of contexts and protected corner types

## Centreline Hardening

At protected intersections, centre medians need to be located further from the intersection to allow for both a crosswalk and crossride, which has the unintended consequence of enlarging the left-turning radius. Placing a physical barrier in the centreline of a roadway between the crossride and the intersection encourages left-turning vehicles to take a tighter radius, which in turn reduces vehicular speeds.

### Guidance

- Centreline hardening can consist of a full median with concrete curbs, a mountable median, a flush rumble strip, or temporary curbs and bollards. Temporary measures may be left in place year-round or removed seasonally depending on the durability of the material used. Additional information on detailed design options for centreline hardening is available in **Section 6.4**
- Centreline hardening should be considered for all protected intersections. However, centreline hardening is an emerging measure within the City of Ottawa's intersection design practice and should therefore be discussed and approved by each project's Technical Advisory Committee prior to implementation
- **Section 3.3** should be used to determine the minimum viable radius as it applies to left turns and median geometry
- Centreline hardening measures should accommodate the travel path of the right- and left-turning design vehicles (including maintenance vehicles), but control vehicles may encroach, provided any median pedestrian refuge (if present) is not encroached upon and is protected by a barrier curb

- Where a **fully protected left turn phase** is present, centreline hardening is less important as bicycle/pedestrian and vehicle conflicts are separated. Despite this, where there is a median **pedestrian refuge**, centreline hardening can provide additional protection from errant vehicles for pedestrians waiting on the refuge

*Image 5.4. Example of flush concrete ribbed centreline hardening at Gladstone Avenue and Rochester Street*

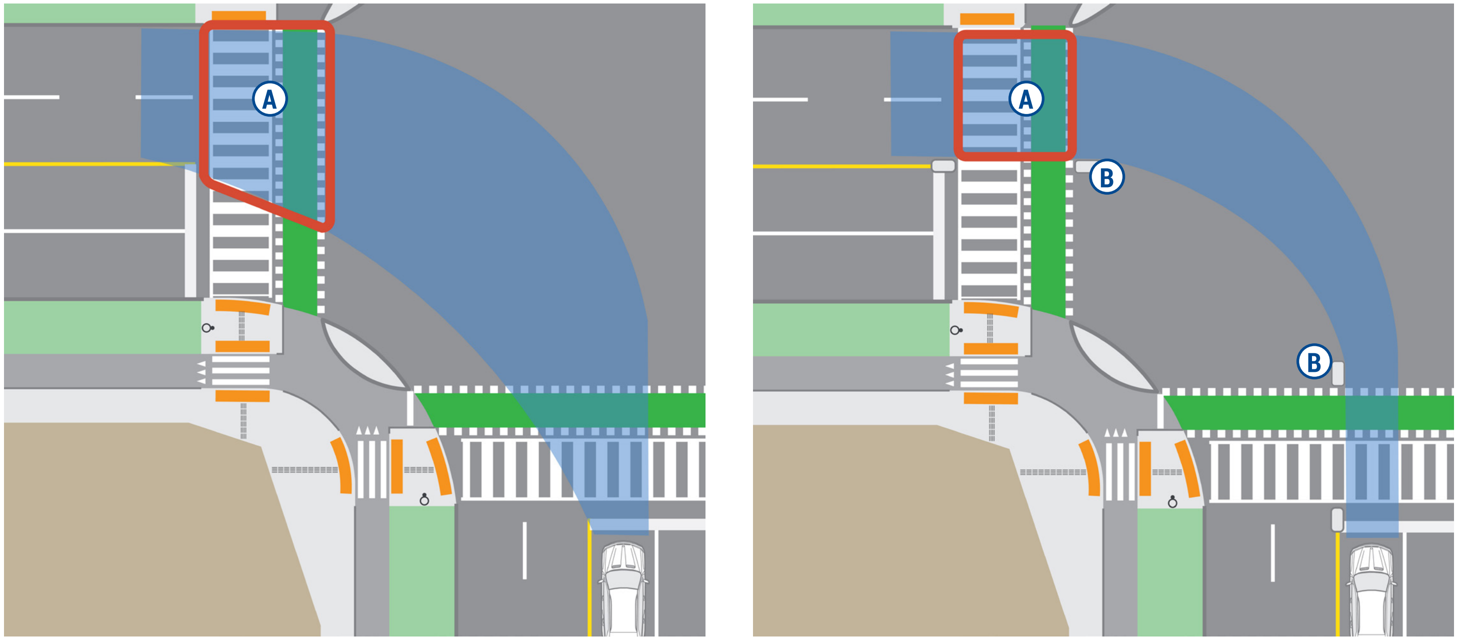



*Figure 5.7. Comparison of turn radius and conflict zone for left turns without (left) and with centreline hardening (right)*

### Design Features

Ⓐ Conflict zone between left-turning vehicles and vulnerable road users

Ⓑ Centreline hardening

## Smart Channels

As discussed in **Chapter 4**, smart channels can form one or multiple corners of a protected intersection and are warranted in specific circumstances, such as where a corner is significantly skewed or where right-turning volumes are very high.

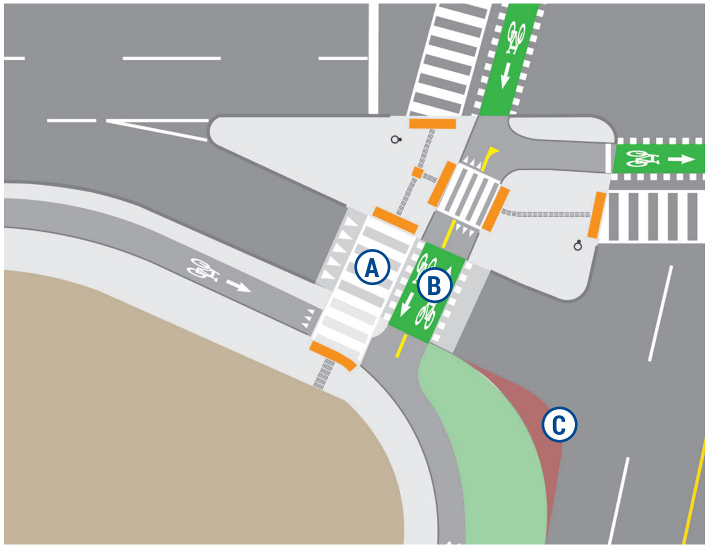



*Figure 5.8. Smart channel corner*

### Design Features

Ⓐ Raised crossing

Ⓑ 3.0 m bidirectional crossride

Ⓒ Corner apron

### Guidance

- Pedestrians and people on bicycles should remain separated on the channel island using the City's standard for **delineation**
- **Pedestrian refuges** of adequate width and depth must be provided for each pedestrian crossing
- The cycle track on the channel island must have a minimum queuing depth of 1.8 m in advance of the pedestrian crossing of the cycle track
- The pedestrian crossing of the vehicle channel may be located before or after the crossride, depending on the geometry of the corner. Designers should implement the option that provides as intuitive a path as possible for pedestrians and maximizes the functional space within the corner island
- The crosswalk and crossride shall be yield-controlled (i.e., motor vehicle drivers must yield to people on bicycles and pedestrians)
- A bidirectional cycle track and crossride are needed to connect the cycle tracks on the island to the cycle track in the boulevard
- The crosswalk and crossride should be designed to be perpendicular to the channel
- Turning radii for people on bicycles should be maximized throughout the corner, with the goal of meeting the **bicycle turning radius** guidance
- On corners with a smart channel, a minimum crossride setback of 1.0 m is sufficient due to the absence of a right-turning conflict at the signalized crossing

- A **corner apron** should be considered to keep the travel lane narrow to slow down passenger vehicles while allowing larger vehicles to navigate the channel

### Additional Considerations

- To reduce vehicle speeds in the channel and improve yielding rates, a raised crossing is recommended for the crosswalk and crossride, and a **corner apron** is recommended where the channel meets the intersecting roadway
- Smart channels typically require significantly more right-of-way compared to a conventional corner and as a result may prove infeasible in many contexts
- Smart channels do not allow for a **straight path of travel** for pedestrians and therefore should only be considered in the circumstances described in **Section 4.1**
- Smart channels with associated cycling facilities can be more confusing for people who are blind or have low vision

# 5.4. Bicycle Safety and Comfort

*People on bicycles need to feel safe while traversing an intersection, and at the same time have a comfortable and convenient experience. The design should use a variety of measures to provide dedicated and protected space in the corner and intersection, while also making sure that the riding experience is smooth.*

## Crossrides

Crossrides indicate the designated area outside the projected curbline of an intersection where people on bicycles are encouraged to cross the intersection.

### Guidance

- Crossride markings, or "elephant's feet", should be 0.4 m by 0.4 m, spaced at 0.4 m
- The width of the crossride is measured as the space between the crossride markings and should match the width of the incoming cycling facility, which are generally 1.8 m or larger for unidirectional and 3.0 m for bidirectional facilities. Unidirectional crossrides should be a minimum of 1.5 m and bidirectional crossrides should be a minimum of 3.0 m
- The crossride should be separated from the crosswalk by a minimum of 0.3 m from the outside edge of the "elephant's feet" markings to the outside edge of the crosswalk markings
- The transition from cycle track to crossride should be curbless (i.e., no depressed curb) for the safety and comfort of people on bicycles

### Additional Considerations

- Consider applying green surfacing treatment within the crossride to increase its conspicuity. The green paint should be applied through the length of the crossride where there is a conflicting turn movement, and should not be added within the protected corner. Consider also adding "Turning Vehicles Yield to Bicycles" signage (Rb-37) at conflict points where drivers are required to yield to bicycles
- Crossrides that are 1.5 m wide should be used with caution since the connecting cycle tracks may not be feasible for **seasonal maintenance** depending on curb elevations

## Bicycle Turning Radius

The turning radius for people on bicycles provides a smooth path of travel for people on bicycles travelling through the protected corner, while encouraging people on bicycles to slow down through the corner.

### Guidance

- 5.0 m is the lowest practical turning radius of a person moving on a bicycle, corresponding with a travel speed of roughly 11.0 km/h. Radii tighter than this may be challenging for all users to negotiate while remaining mounted, and may lead to increased single-bicycle collisions, especially in wet and winter conditions
- A 4.0 m physical (i.e., curb) radius provides a 5.0 m effective (i.e., centreline) radius, and as such, 4.0 m is the minimum physical radius for a cycling facility in a protected corner
- Right turn or left turn corner radii greater than 10.0 m are not desirable as they may facilitate faster bicycle speeds within the corner where people on bicycles are expected to yield to pedestrians and other people on bicycles

### Additional Considerations

- When a **one-stage protected corner** is combined with a large vehicle turning radius, the result may be a large turning radius for people on bicycles turning right in the protected corner. This can be mitigated by instead implementing two 5.0 m radii corners with a straight portion in between, which also helps to create more space for people on bicycles turning left in the protected corner (see Figure 5.9)

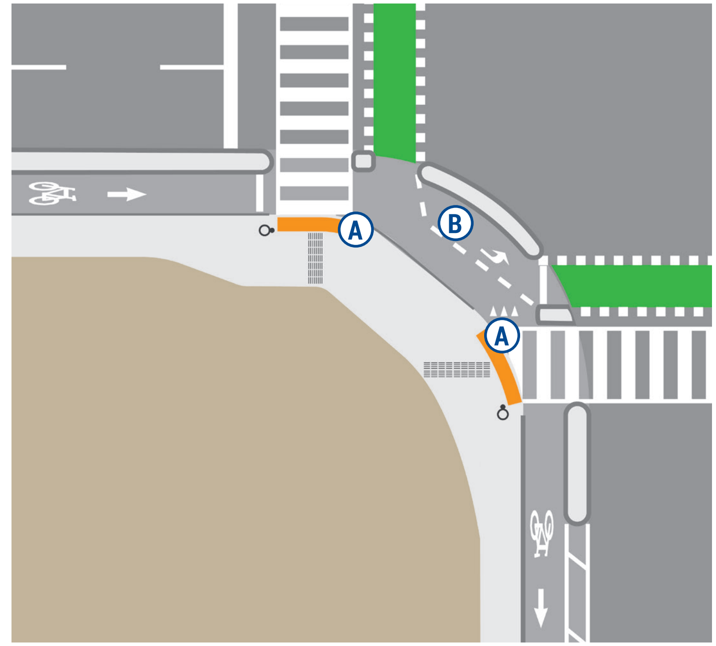



*Figure 5.9. One-stage protected corner showing two 5.0 m radius curves*

### Design Features

- (A) 5.0 m radius curve
- (B) Bicycle queuing area

## Corner Safety Island

The corner safety island physically separates the protected corner area from the vehicle travel area. Vehicles are not expected to cross the safety island, and as such it is important for designers to ensure that sufficient radius is provided for the applicable design and control vehicles to traverse the corner without encroaching onto the safety island.

*Image 5.5. Example of corner safety island at Donald Street and St-Laurent Boulevard*

### Guidance

- The roadway edge of the corner safety island should be outlined by a full-height curb (150 mm) to deter motorists from traversing the island and to remain detectable for the blades of winter maintenance equipment
- The minimum recommended width of the corner safety island for constructability purposes is 1.0 m, but a wider island may be provided

### Additional Considerations

- Where there is concern that motorists may strike or drive over the safety island, the WA-33R Hazard Marker sign or bollards may be used as a supplementary measure to highlight the hazard. For new installations, temporary flexible bollards may be helpful for supporting motorists' behaviour change
- In high bicycle volume applications, consider narrowing the corner safety island to the minimum width, which will create a wider corner diagonal, which in turn provides more storage and queueing area for people on bicycles
- The orientation or size of the bicycle queuing area may result in people on bicycles waiting in unusual orientations or locations that are difficult to detect with the induction loops embedded in the surface of the cycle track. In these cases, a separate bicycle push button may be required on the corner safety island

## Bicycle Queueing Area

The bicycle queueing area provides a dedicated area for people on bicycles to wait to cross, without blocking other bicycle traffic travelling through the protected corner. For actuated crossings, the queueing area is also where detection equipment should be placed to trigger a green signal or bicycle signal.


*Image 5.6. Example of bicycle queuing area at Ottawa River Pathway and Booth Street*

### Design Features

(A) Bicycle queuing area

### Guidance

- Sufficient queueing area depth is required to enable a people on bicycles to queue parallel to the crossride and be detected without blocking right-turning bicycle traffic. The width of the turning path for right-turning bicycles should match that of the connecting cycle track. The target depth of the queuing area is 2.4 - 3.0 m, measured from the centre of the stop bar to the edge of turning path for through bicycles; 2.4 m is the typical length of a cargo bike, and 3.0 m is the length of a bicycle with a trailer. In constrained situations, a minimum depth of 1.8 m may be acceptable, which is the length of a standard bicycle (see Figure 5.10)
- The width of the queueing area should be equal to or greater than the width of the incoming bicycle facility, to ensure that a pinch-point is not created at the crossing. Wider areas should be considered where there is expected to be a high volume of people on bicycles or where there is a short signal phase for bicycles
- Additional bicycle storage space can be gained by reducing the width of the **corner safety island**; this should be considered at locations where a higher volume of people on bicycles are anticipated or at **one-stage protected corners**
- The bicycle stop bar of 0.3 m in width should be located in the bicycle queueing area, with a target setback of 0.2 - 0.5 m from the roadway. Consider included a “cyclists stop here on red signal” sign (Rx-79). In future, the City may investigate the use of a curved bicycle stop bar that is parallel to the roadway to maximize the bicycle queuing area

## Additional Considerations

- A queuing area 3.0 m by 2.0 m or 6.0 $m^2$ in area can accommodate approximately four people on bicycles. Intersections with a high volume of bicycle traffic (e.g., more than 300 bikes per peak hour using a single crossride) may warrant a larger queueing area
- Where a bicycle detection loop is provided, it is located in the bicycle queuing area. The target size of a bicycle detection loop is either 1.0 m wide by 3.0 m long and the minimum size is 1.0 m wide by 2.0 m long. Where the bicycle queuing area length is very constrained (i.e. 2.0 m or less), a bicycle push button pole may be considered on the adjacent corner safety island or pedestrian refuge in addition to the detection loop. Where a bicycle push button is provided, a 2.0 m long bicycle detection loop is still required to extend the bicycle signal phase's green time

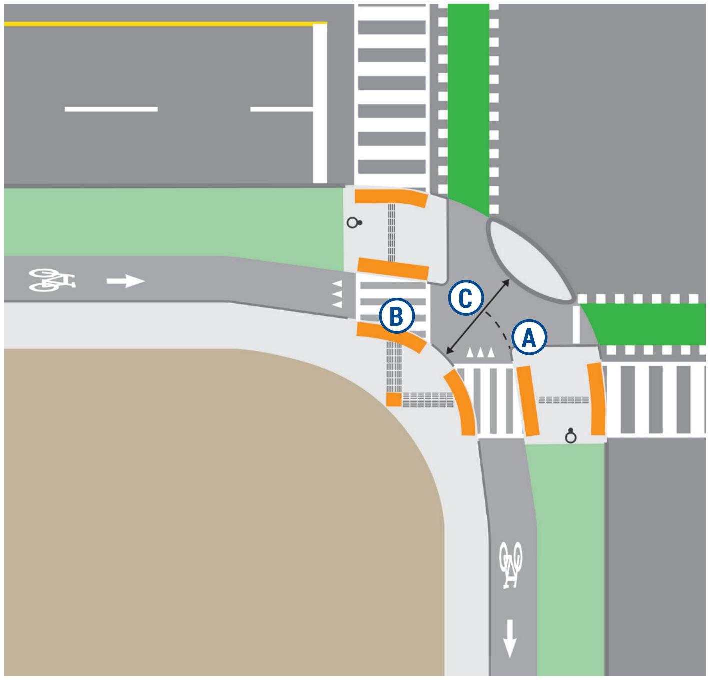



*Figure 5.10. Standard protected corner showing right turn path clear of bicycle queue space*

### Design Features

- (A) Minimum bicycle queuing area depth 2.4 m (2.7 m shown)
- (B) Turning path for right-turning bicycles to match connecting cycle track
- (C) Corner diagonal

## Corner Diagonal Area

The corner diagonal area is located at the centre of the protected corner, behind the **corner safety island**. It provides a space for intersecting bicycle movements to safely mix and negotiate the right-of-way.


*Image 5.7. Example of corner diagonal at Donald Street and St-Laurent Boulevard*

Design Features

- (A) Corner diagonal width
- (B) Corner safety island
- (C) Pedestrian refuge

### Guidance

- The target width for the diagonal dimension between the pedestrian corner and the corner safety island is 3.0 m (2.0 m minimum) for a unidirectional protected corner and 4.0 m (3.0 m minimum) for a bidirectional protected corner
- In high bicycle volume applications, it may be desirable to increase the diagonal dimension beyond the target

### Additional Considerations

- In constrained conditions, high-volume applications, or in **one-stage protected corners**, consider using pavement markings to delineate a left turn lane from the through travel lane for people on bicycles. The bicycle left turn lane should have a minimum width of 1.2 m
- When bidirectional facilities are present, consider providing a dashed yellow centreline through the corner to clarify directionality of bicycle travel

## Cycle Track Tapers

In many cases, the cycle track and sidewalk will need to be laterally shifted from the midblock arrangement to match the protected corner alignment on the approaches and departures. A sharp taper may also be difficult for people on bicycles to traverse while remaining mounted.

*Image 5.8. Example of cycle track taper at Fisher Avenue and Dynes Road*

### Guidance

- The target for the cycle track taper is less than 20 degrees or 1:3. To provide a smooth path of travel for people on bicycles, the target radii of the curves to start and end the taper are 12.0 m, with a minimum of 4.0 m

### Additional Considerations

- To ensure the detectability of tapers, **delineation between the cycling facility and sidewalk** is required as described in Chapter 6
- In high-volume applications where the target cannot be met, consider a **one-stage protected corner** design
- When the cycle track is separated from the roadway by 3.0 m or more, the required tapers are typically minimal
- It is not necessary for the cycle track and sidewalk to taper at the same angle

# 5.5. Transitions

Good transitions to and from the cycling facility in the protected corner provide a comfortable experience for and enable seamless use of the protected intersection by people on bicycles. In all cases, transitions between cycling facility types should be curbless, with no depressed curb between the incoming or outgoing facility and the cycle track in the protected corner.

## Approaches

Transitions from cycling facilities on approaches to a protected intersection should be designed to create a smooth path for people on bicycles that allows access by maintenance vehicles while preventing motor vehicle access.

### Cycle track to protected corner

- A cycle track on the approach provides the most direct connection to a protected corner. Ensure that the guidance for **cycle track tapers** is used on the approach

### On-street protected, buffered, or painted bike lane to protected corner

- Where on-street cycling facilities transition to protected corners, exceptional care must be taken to ensure that the transition will not appear to be a route or cut through for motorists. Especially if the pre-construction condition is a right turn only lane or channel, motorists may expect to continue to be able to use the corner in similar way
- Mitigation measures include:
    - Transition the bike lane or paved shoulder to a raised cycle track along the straight section farther in advance of the protected corner
    - Physically separate the bike lane or paved shoulder up to 100.0 m before the transition (or back from the nearest driveway) to the protected corner with bollards and/or pinned curbs
    - Place signage to direct vehicles to the left and bicycles to the at the boulevard bullnose (Rb-25 and Rb-84a), and place appropriate object marker signage (WA-33) to warn of the bullnose hazard
    - Provide green thermoplastic in advance of the transition from the bike lane or paved shoulder to raised cycle track
- In all cases where an on-street facility transitions to a protected corner, ensure that the cycle track taper is designed to be comfortable for people on bicycles and does not inhibit maintenance vehicle access by maintaining a minimum of 1.8m between curbs

### Paved shoulder to protected corner

- Where there is a paved shoulder and an adjacent pedestrian facility, follow the guidance under the previous heading.
- Where there is a shared paved shoulder, the paved shoulder should split into a dedicated pedestrian and bicycle facility in advance of the intersection. The design of the split should follow the guidance for the split of a MUP as described in **Section 6.1 Pedestrian Guidance**

### Mixed traffic to protected corner

- Where people on bicycles operate in mixed traffic on the approaching leg, the preference is to add a short stretch of cycling facility (on-street bike lane or raised cycle track) on the intersection approach, where space permits, and follow the guidance in the above subheadings.
- Where there is insufficient road width to provide a cycling facility, the cycle track should diverge directly from the travel lane. In these cases, additional care should be taken to ensure the transition does not appear to be a route for motorists. All mitigation measures that are feasible given the space constraints should be considered. These include:
    - Place signage to direct vehicles to the left and bicycles to the at the boulevard bullnose (Rb-25 and Rb- 84a), and place appropriate object marker signage (WA-33) to warn of the bullnose hazard
    - Provide green thermoplastic on the first few meters of the cycle track

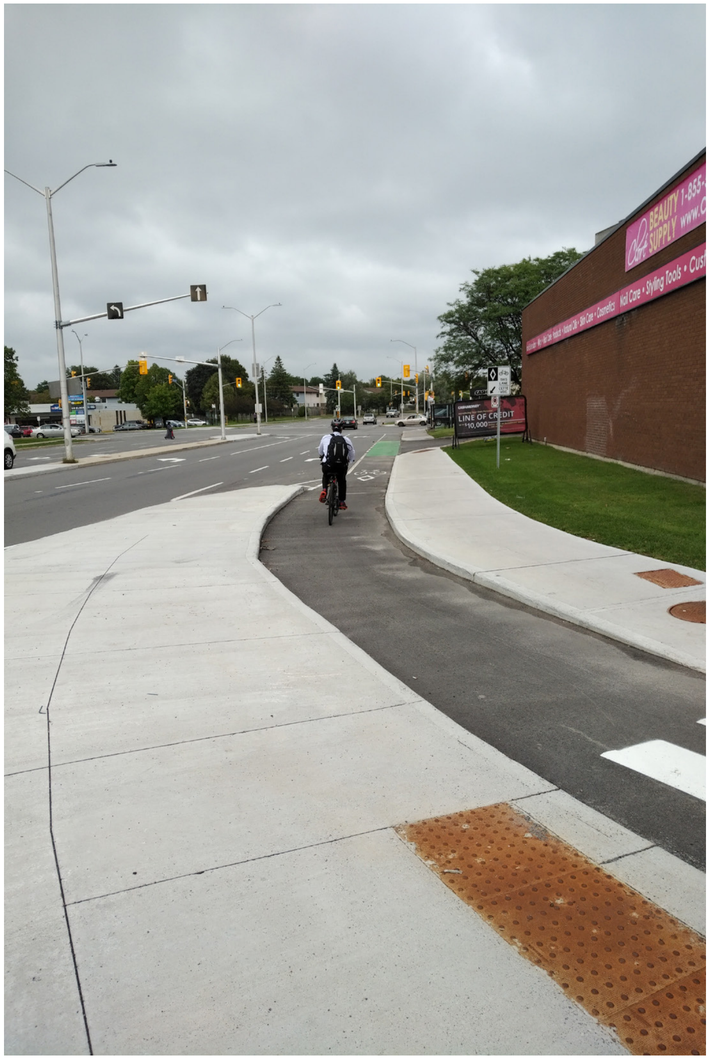



*Image 5.9. Example of transition from cycle track to on-street bike lane at Donald Street and St-Laurent Boulevard*

## Departures

Departures should be designed to comfortably transition people on bicycles into the midblock facility in a way that is safe and predictable.

### Protected corner to cycle track

- A cycle track on the departure provides the most direct connection from a protected corner as no transition to an on-street facility is required. Ensure that the guidance for **cycle track tapers** is used on the departure

### Protected corner to on-street protected, buffered or painted bike lane

- When transitioning from a standard protected corner, ensure that the guidance for **cycle track tapers** is used on the departure and that the design enables maintenance vehicle access by maintaining a minimum of 1.8 m between curbs
- For the benefit of grading and mitigating conflicts, when a driveway is very close to the intersection, it may be preferable to maintain a raised cycle track across the driveway prior to merging into an on-street facility

### Protected corner to paved shoulder

- Where there is a paved shoulder and an adjacent pedestrian facility, follow the guidance under the previous heading.
- Where there is a shared paved shoulder, the dedicated pedestrian and bicycle facility in the corner should combine into a paved shoulder on the departure from the intersection. The design of the transition should follow the guidance for the split of a MUP as described in **Section 6.1 Pedestrian Guidance**

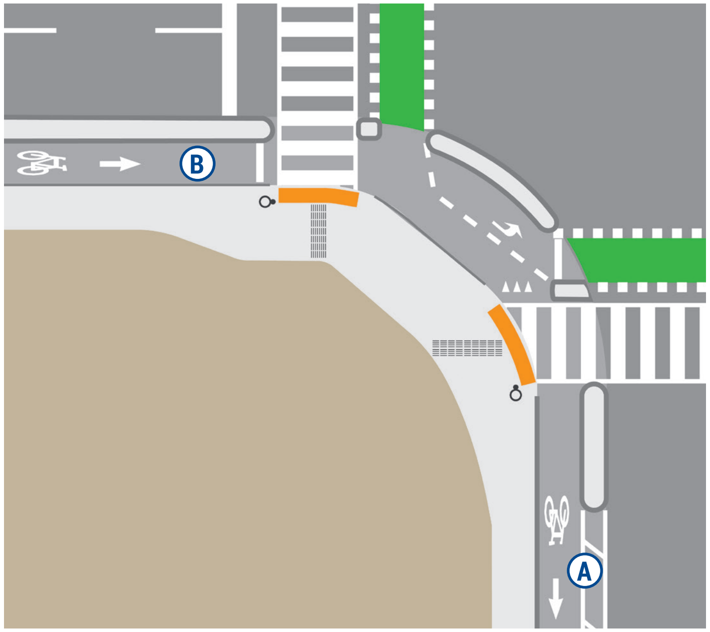



*Figure 5.11. One-stage protected corner showing transition to buffered bike lane*

Design Features

- (A) Buffered bike lane
- (B) Cycle track

### Protected corner to mixed traffic

- When transitioning to roads with posted speeds greater than 50 km/h, the transition should occur at the corner and no dedicated cycling facilities should be provided. This will direct people on bicycles to stop at the intersection and wait for a gap to turn right, or proceed during the green signal, which will reduce the potential for conflicts. Where space permits, the edge of pedestrian refuge adjacent to the **bicycle queuing area** should be curved to enable easier right turns by bicycles, provided the pedestrian refuge still meets the targets described in this Guide. The designer should consider if space should be protected for a future cycle track extension, as shown in Figure 5.12. Despite the above, the City may determine that the cycle track should be continued to a mid-block transition on a case-by-case basis

- When transitioning to a mixed traffic environment on roads with medium-low speeds (50 km/h or less), the recommended design is to carry a short stretch of on-street bike lane from the protected corner that merges into traffic. OTM Book 18 recommends a 15.0 m stretch of solid painted white line bike lane followed by a 15.0 to 30.0 m taper with a dashed white line

- In low-speed, low-volume environments such as local streets (posted speed of 40 km/h or lower, 1000 vehicles per day or lower), it may be acceptable to directly taper the cycle track onto the receiving street without an acceleration lane. A yield bar should be placed across the cycle track at the roadway interface in conjunction with a yield sign (Ra-2) to indicate that people on bicycles must wait for a gap in traffic

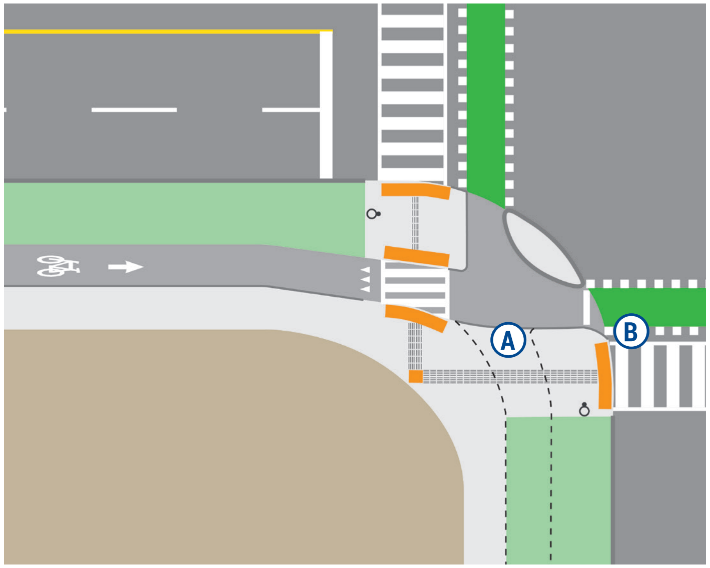



*Figure 5.12. Standard protected corner with transition to major road without cycling facilities*

#### Design Features

Ⓐ Space protected for future cycle track connection

Ⓑ Curve to facilitate bicycle right turns

# 6

# DETAILED DESIGN CONSIDERATIONS

*This chapter describes the detailed design elements, including materials and construction.*

# 6.1. Pedestrian Guidance

Chapter 5 introduces delineation methods under the discussion of universal design and the principle of providing navigable and accessible intersection corners. A navigable and universally accessible design will provide intuitive pedestrian routes from the mid-block sidewalks to the crosswalks, and will discourage pedestrians from encroaching onto the cycling facility or into the roadway without warning. Therefore two key factors in designing for universal accessibility are the delineation between pedestrian and cycling spaces, as well as sidewalks that follow **straight path of travel** guidance and are clear of obstacles on the approach to, and through the intersection. An additional measure to enhance accessible design is the use of directional indicators to facilitate navigation through the intersection.

## Delineation Between Cycling Facility and Sidewalk

- Delineation between the cycling facility and the sidewalk must be detectable by a range of users, including people who are blind or have low vision and people who are neurodiverse, without negative consequences or the creation of barriers to access for other users, such as people using mobility devices and wheelchairs. In development of this Guide, several representatives of organizations of and for people with disabilities were invited to participate in an engagement session of site visits to test various delineation methods used in the City. The findings from this workshop and additional research informed the following guidance.

It is important to design for the most vulnerable road users, which includes people who are blind or have low vision. They use a variety of cues and methods to navigate the built environment. Consistency in design elements, including but not limited to placement of the APS, use of attention and guidance TWSIs and depressed curbs are essential for people who are blind or have low vision to safely and independently navigate intersections. The most common methods used are a long white cane and/or a guide dog:

- A **long white cane** is used by sweeping the tip along the ground or by periodically tapping from side to side to identify hazards and confirm direction. A long white cane can be used to identify attention and directional TWSIs, as well as changes in elevation
- Guide dogs are trained to avoid obstacles in the built environment that are hazardous to their handler, such as curbs, elevation changes or tripping hazards, and overhead obstacles. Unless trained to do so, most **guide dogs** do not interpret TWSIs to have any meaning, but can interpret changes in elevation (such as a half-height curb) as a 'hazard', and can find accessible pedestrian signals

### Guidance

- The recommended approach to delineation between a sidewalk and cycle track is a half-height barrier curb at 60 mm (with +/- 10 mm variation for differential pouring or settling) as it has been found to be detectable by most users and traversable by some users, beneficial to cycling comfort and safety (no pedal strike hazard), and possible to clear with a sidewalk plow
- Where a MUP splits into a sidewalk and cycle track, a gutter curb (City of Ottawa Standard SC1.3 with 0 - 6 mm depressed curb height) should be used in place of a half-height curb to allow people on bicycles to comfortably traverse the curb, yet still maintain detectability, as shown in Figure 6.2 and Figure 6.3

- In locations where there is soft landscaping of at least 0.6m between the cycle track and sidewalk, the recommended half-height curb delineation is not required as the soft landscaping is sufficient to warn pedestrians who are blind or have low vision of the edge of the sidewalk. **Section 6.4** includes additional guidance on appropriate conditions for use of soft landscaping

- Grading and **drainage** with a half-height curb can be accommodated via several different alternative configurations. On this basis, it is not necessary to provide for an alternative delineation method (with the exception noted above where a MUP splits). Furthermore, using the half-height curb method universally throughout the City will achieve consistency, which is beneficial to people with low vision in navigating the City effectively

- In Design Priority Areas there may be additional objectives for the pedestrian realm that preclude the use of a half-height curb, in which case, consultation with an accessibility expert and the City's Urban Design staff is recommended to determine the most appropriate alternative delineation method


*Image 6.1. Half-height curb between sidewalk and cycle track on Rideau Street*

### Additional Considerations

- Attention TWSIs along the full route of sidewalks and cycle tracks should not be used as a delineation method as it lessens the effectiveness of attention TWSI at other more dangerous locations

- Where the sidewalk is directly adjacent to the cycle track, a 0.2 m buffer should be provided to provide a warning of the change in elevation. The 0.2 m buffer may be included as part of the overall sidewalk width. It may be the same material as the sidewalk (i.e., monolithic sidewalk) separated by a hand formed control joint

- To warn people on bicycles of the presence of the half-height curb, a painted white line may be provided on the cycle track parallel to the half-height curb and offset from the curb by 0.2 m

## Hazard Warning at Intersections

Attention TWSIs are used to alert those who are blind or have low vision of a hazard such as a flight of stairs, a transit platform edge, or a roadway.

### Guidance

- Provide attention TWSIs at depressed curbs where a dedicated pedestrian facility such as a sidewalk meets the roadway, typically (but not always) where a crosswalk is provided. For TWSIs provided at depressed corners the TWSI should be applied along the entire length of the depressed curb (not just in front of the crosswalks), however TWSIs at depressed corners should be provided in two parts with a 300 mm (+/- 50 mm) space provided between the two TWSI plates per the current standard
- Provide attention TWSIs at designated pedestrian crossings of the cycle track, within the sidewalk on both sides of the crossing
- Provide attention TWSIs where a MUP meets the roadway at an unsignalized intersection
- Attention TWSIs should not be provided across a cycle track or used as delineation between a cycle track and sidewalk

*Image 6.2. Attention TWSI*

## Directional Guidance at Intersections

Tactile Directional Indicator (TDI or directional) TWSIs are commonly used to facilitate navigation through large open spaces (e.g., outdoor plazas) or to specific destinations (e.g., transit stop, directory, reception counters, etc.). Directional TWSIs are particularly relevant where they facilitate safety and navigation in complex or potentially hazardous environments. They have an elongated flat top bar surface oriented parallel to the path of travel, which can be followed by people who are blind or have low vision.

The installation of directional TWSIs must not be a substitute for good design. All efforts must be made to follow **straight path of travel** guidance, to provide appropriate **delineation**, and to provide all other elements integral to **pedestrian navigation**. Designers should prioritize providing a pedestrian route that reduces the number of decision points and ensures that the alignment of the curb ramps and depressed curbs facilitate crossings that are parallel or perpendicular to the original path of travel (i.e. crossings are not angled or otherwise require a significant deviation from the straight path of travel). Directional TWSIs are intended only as a supplementary tool to provide an additional level of navigation assistance for pedestrians, and to reduce stress for people who are blind or have low vision; the pedestrian route should be intuitive enough that the directional TWSIs are not required. For example, directional TWSIs should be provided where a MUP splits into a separated sidewalk and cycle track to help orient pedestrians at the transition, but the preferred design is still for pedestrians to have a straight path of travel (Figure 6.2) while a straight path of travel for bicycles rather than pedestrians is not preferred (Figure 6.3).

*Image 6.3. Directional TWSI*

Protected intersections have elements that have the potential to make them more complex or challenging to navigate by people who are blind or have low vision. These include:

- Pedestrian refuges between the cycle track and roadway at **standard** and **hybrid protected corners**
- Deviations to pedestrian path of travel caused by additional space for bicycle setbacks in the corner
- Multi-use pathways that split into a sidewalk and cycle track at the corner
- Permitted conflict points with people on bicycles at **standard** and **hybrid protected corners**

## Guidance

- Directional TWSIs shall be implemented at all protected intersections in order to reduce the impact of the complexities noted above, and to maintain consistency for users
- Directional TWSIs should be installed as per the following guidance and as shown in Figure 6.1
    - When used to notify pedestrians of a diverging route (e.g., the need to make a decision to change direction to cross the road), the width of the directional TWSI shall be 600 - 650 mm. The directional TWSI should begin a maximum of 300 mm from the backside of the sidewalk and extend to the attention TWSI at the curb edge
    - When used to guide pedestrians along a route in a straight path (or with minimal bends), the width of the directional TWSI shall be 250 - 300 mm. They can be used to orient pedestrians to the correct direction of a crosswalk
    - At the junction of more than one directional TWSI, a decision block that is 600 mm by 600 mm attention TWSI should be provided to notify pedestrians of the decision point
- Directional TWSIs should be cast iron, as precast concrete and other composite materials are not durable enough to withstand winter maintenance activities

## Additional Considerations

- There is no current legislative requirement for the installation of directional TWSIs as of 2021 at the time of publication of this Guide. However, codes and standards are continually evolving and should be referenced prior to design
- For reference, the CSA B651 Accessibility of the Built Environment Standard provides technical information on the design and installation of both attention and directional TWSIs

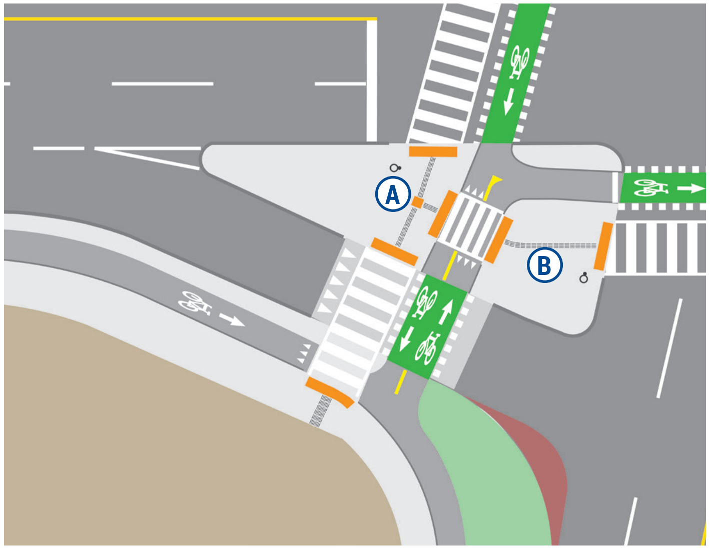



*Figure 6.1. Smart channel corner shown directional and attention TWSIs at junction*

### Design Features

(A) Attention TWSI at junction of two paths

(B) Single-wide directional TWSI bends to orient pedestrians of correct path at crosswalks

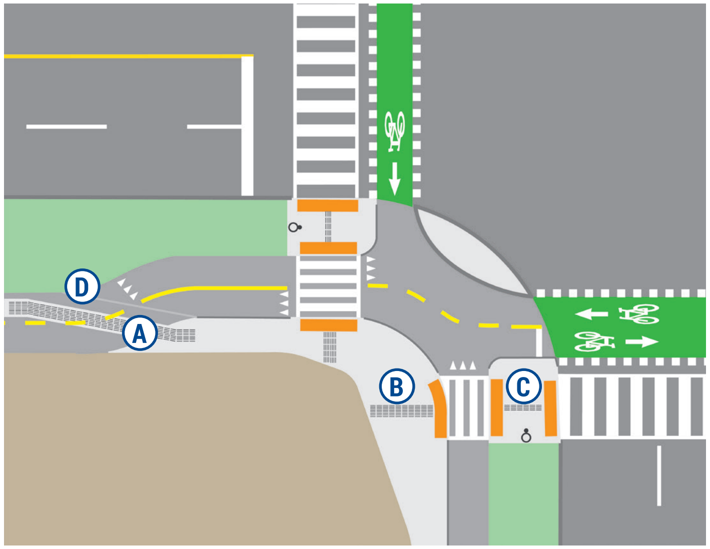



*Figure 6.2. Standard protected corner showing directional TWSI at transition from MUP to separated facilities where pedestrians have the straight path of travel (preferred)*

### Design Features

- **A** Double-wide directional TWSI at MUP alerts pedestrians to correct path at transition
- **B** Double-wide directional TWSI alerts pedestrians of a intersecting path
- **C** Single-wide direction TWSI keeps pedestrians on correct route
- **D** Gutter curb to provide additional delineation between cycling facility and MUP

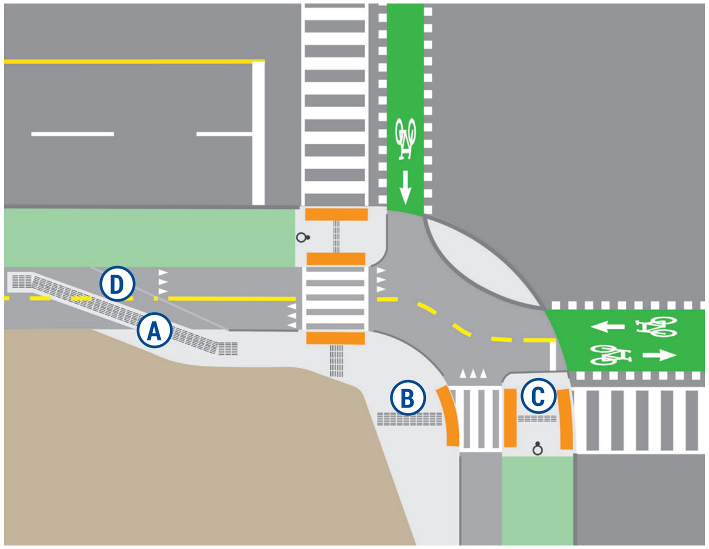



*Figure 6.3. Standard protected corner showing directional TWSI at transition from MUP to separated facilities where pedestrians do not have straight path of travel (not preferred)*

### Design Features

- **A** Double-wide directional TWSI at MUP orients pedestrians on correct path, even when path of travel is not straight
- **B** Double-wide directional TWSI alerts pedestrians of a intersecting path
- **C** Single-wide direction TWSI keeps pedestrians on correct route
- **D** Gutter curb to provide additional delineation between cycling facility and MUP

# 6.2. Elevations and Drainage

*There are a variety of options for the elevation of facilities and protected intersection elements, as well as the grading and drainage design in a protected corner. Decision-making will depend on the existing grades and drainage infrastructure, existing utilities, the type of protected corner, elevation of pedestrian and cycling facilities, amount of potential setback, and opportunities for reconstruction through the project.*

## Elevations

Decisions made about the relative elevation of elements such as the cycling facility, corner refuge islands, and raised corner islands will impact the grading/drainage design, winter maintenance, available space for signal and signage infrastructure, and navigability in the intersection.

While there are several options for how to construct protected corner features, the following guidance details the recommended approach. Cross-sections of two possible options are shown in Figure 6.5 and Figure 6.6.

### Guidance

- The preferred design is for the sidewalk to be elevated above the cycle track and separated by a half-height curb of 60 mm +/- 10 mm (see **Delineation** section)
- The target slope of transitions between raised cycling facilities and road grade cycling facilities is 5 per cent, with a maximum slope of 8.3 per cent
- The separation between sidewalk and cycling facility with a half-height curb (60 mm +/- 10 mm) should be maintained in the **pedestrian refuge** island
- Where the cycling facility is protected at street level, the sidewalk and cycle track may be separated by a full-height curb (see Delineation section)
- Concrete features within the protected corner should have a standard full-height curb (150 mm) per SC1.1 or SC1.2 on the traffic side to discourage turning vehicles from mounting the corner safety island and driving through the cycling queuing area
- Curb ramps or depressed curbs are required at cycle track pedestrian crossings to help people negotiate the elevation change created by the half-height curb between the cycle track and the sidewalk. Curb ramps are preferred over depressed curbs, and are particularly favoured over fully depressed corners because the flared sides of the curb ramps provide additional directional orientation for people who are blind or have low vision. However, provision of two separated curb ramps at a corner where no boulevard is present is considered a deviation to City standards and is subject to the associated deviation process

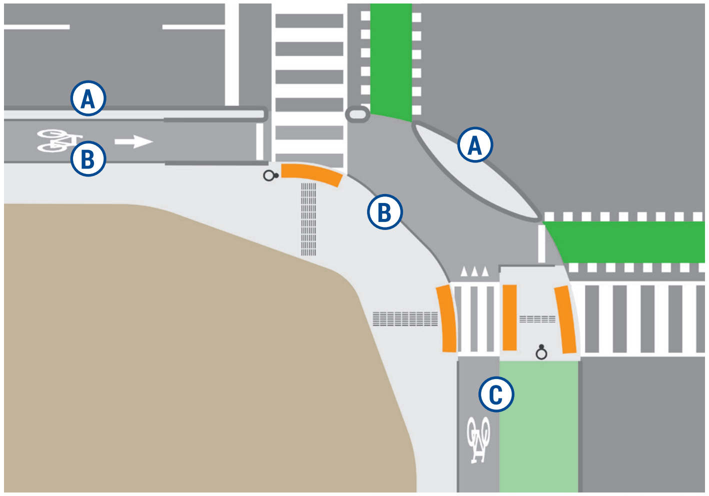



*Figure 6.4. Hybrid protected corner showing relative curb heights*

**Design Features**

- (A) Full-height (150 – 200 mm) curbs (thick grey line)
- (B) Half-height (60 mm high) curbs (thin grey line)
- (C) No curb (no line)

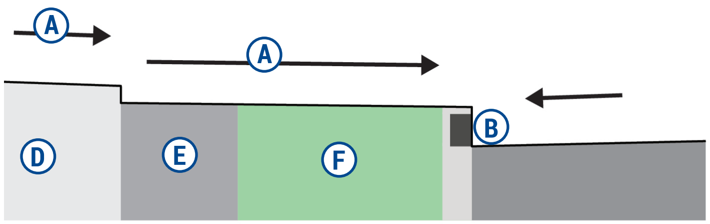



*Figure 6.5. Elevation cross-section example 1, with drainage directed to roadway catch basin*

### Design Features

- (A) Maximum cross-slope of 2%
- (B) Catch basin within full-height (150 mm) curb
- (C) Supplementary catch basin within half-height (60 mm +/- 10 mm) curb
- (D) Sidewalk
- (E) Cycle track
- (F) Boulevard

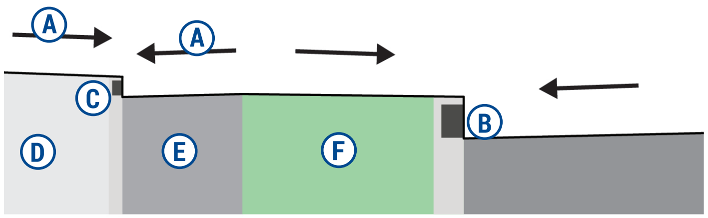



*Figure 6.6. Elevation cross-section example 2, with drainage directed to supplementary catch basin*

### Design Features

- (A) Maximum cross-slope of 2%
- (B) Catch basin within full-height (150 mm) curb
- (C) Supplementary catch basin within half-height (60 mm +/- 10 mm) curb
- (D) Sidewalk
- (E) Cycle track
- (F) Boulevard

## Drainage

Designing for drainage is important to avoid pooling of water and formation of ice on pedestrian and cycling facilities in the protected corner. To provide adequate drainage, a target slope of 1% should be applied within the protected corner, with a minimum of 0.5%. Maximum running and cross-slopes must meet the requirements of AODA-IASR and COADS.

### Guidance

- Snow melt and water from the sidewalk or roadway may impact the usability of the cycle track during certain weather conditions. Therefore, the preferred approach is to accommodate drainage in a way that minimizes the flow of water and snowmelt across the cycle track. One option is to provide a supplementary drainage inlet (e.g., catch basin or low impact development infrastructure) to accept drainage from the sidewalk
- Drainage should be directed away from the corner at the roadway to prevent ponding where the cycle track meets the roadway. Where a protected corner is implemented as a retrofit (i.e., retained some or all existing curbs) reducing drainage across the cycle track should be considered
- Side inlet catch basins (City of Ottawa Standard S22) should be used as drainage grates and utility covers may result in additional safety risks for people on bicycles. However, challenges are anticipated integrating standard side inlet catch basins within the half-height (60 mm +/- 10 mm) curb. Where conditions prevent the use of side inlet catch basins, an alternative should be used that does not present a safety hazard for people on bicycles

### Additional Considerations

- Additional grading options are possible depending on the design, including low-impact development (LID) features


*Image 6.4. Side inlet catch basins at Rideau Street*

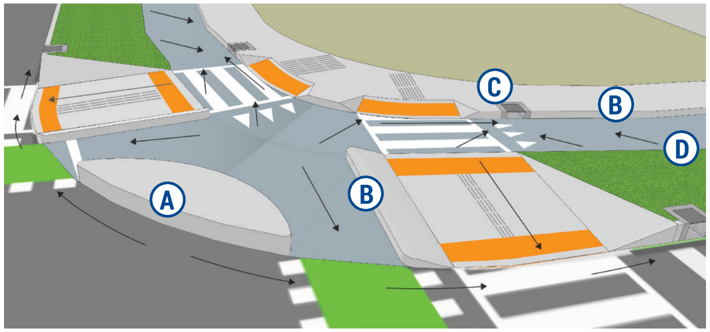



*Figure 6.7. Standard protected corner showing relative curb heights and arrows showing direction of drainage*

**Design Features**

- (A) Full-height (150 – 200 mm) curbs
- (B) Half-height (60 mm high) curbs
- (C) Supplementary side inlet catch basin
- (D) No curb

# 6.3. Seasonal Maintenance

Ensuring that protected corners remain useable and safe year-round means designing for seasonal maintenance and drainage.

### Guidance

- Reflective flex bollards should be considered on corner safety islands within the intersection as the bollards improve visibility of curbs and medians in the winter months
- 1.8 m minimum of clear width is required between vertical features (e.g., curbs) at the sides of the cycle track in order for a maintenance vehicle (for snow clearance and sweeping) to pass through
- Using dual catch basins will prevent snow melt from the sidewalk from traversing the cycle track, which will significantly reduce likelihood of icy conditions on the cycle track

### Additional Considerations

- Delineation methods between sidewalks and cycle tracks impact the ability for effective snow clearance. The half-height curb and vertical features required within protected intersection corners increase the level of effort required for winter maintenance compared to a typical intersection corner. Additional winter maintenance resources may be required to maintain sidewalks and cycle tracks as the City constructs new protected intersections
- Wider mid-block boulevards increase space for snow storage adjacent to protected corners
- Snow accumulation on raised intersection features including corner safety islands and median bullnoses may require removal if the accumulated snow will impact sightlines between turning vehicles and other road users

*Image 6.5. Ottawa's sidewalk and cycling facility maintenance vehicles and plows*

*Image 6.6. Ottawa's snow plow clearing Laurier Avenue bikeway with reflective post on features*

# 6.4. Materials and Construction of Protected Corner Elements

The protected intersection introduces new physical elements which play important roles in the function of the corner design. The corner safety island defines the radius while other raised islands separate users and provide space for signage and signal infrastructure. Consistency in use of materials is important as well, where users expect cycle tracks to be asphalt and sidewalks to be concrete. These features must also be constructible and facilitate maintenance in the corner.

## General Surface Materials

- Sidewalks, pedestrian refuges, bus stops, and other dedicated pedestrian surfaces are typically to be constructed from concrete to minimize life-cycle costs and to clearly distinguish them as pedestrian-only facilities.
- Cycle tracks and multi-use pathways are typically to be constructed from asphalt.
- The most recent relevant City Guidelines should be cited when determining the appropriate width of  turf or soft landscaping between the cycle track and the sidewalk or between the cycle track and the road edge
- Unit pavers and other hardscaping may be appropriate for use in an amenity zone between the cycle track and clear sidewalk width depending on the context and whether or not the location falls within a Design Priority Area. However, unit pavers and hardscaping do not intrinsically function as **delineation between the cycling facility and sidewalk** and should typically be combined with a half-height curb or other approved alternative delineation method specific to the Design Priority Area
- The use of unit pavers is to be avoided on pedestrians surfaces in the vicinity of directional or attention TWSIs. Unit pavers result in a similar tactile 'feel' underfoot and when using a long white cane, and therefore result in people with vision loss experiencing difficulty in identifying TWSIs, particularly attention TWSIs

The use and width of a softscape or hardscape space between the cycle track and the sidewalk or between the cycle track and the road edge should consider the context and applicable City guidelines. These buffer and amenity spaces should be developed with appropriate internal stakeholders, including Roads Services, Urban Design, and Forestry, during all stages of the design

## Corner Safety Island and Raised Elements

The corner safety island is a key component of the protected intersection and is typically constructed with concrete. The shape of the corner safety island will depend on the intersection design. In less constrained scenarios, it may be formed into an “almond” to provide a left turn radius for people on bicycles around the corner. When more constrained or where there is expected to be a high volume of people on bicycles, the width of the island may be reduced to 1.0 m into an “eyebrow” shape.

In addition to the corner safety island, there are segments between the cycle track and sidewalk and adjacent the roadway form raised features within the protected corner. These features delineate spaces and discourage vehicle encroachment into the corner. For this reason, features should have a standard full-height curb on the side facing traffic, however, a full-height curb may not always be achievable between the pedestrian refuge and the cycle track.

### Guidance

- The minimum width of the corner safety island is 1.0 m
- Where there is pedestrian refuge, a half-height curb should be provided to delineate between cycle track and pedestrian space on the refuge. In order to achieve this, the refuge may be raised above the cycle track (as shown in Image 6.7) or the refuge may include a raised curb facing the cycle track (which may include a flared side), with the refuge at cycle track and roadway level (as shown in Image 6.8)
- The width of other vertical elements should consider constructability and the provision of adequate width where the intent is for them to support placement of signage or utility infrastructure. The element between the bicycle queuing area and the pedestrian refuge will need to be at least as wide as the width of the pavement markings (e.g., elephant’s feet) and separation between crosside and crosswalk
- If infrastructure (e.g., traffic signal pole) is placed within the corner safety island or pedestrian refuge or other vertical elements, sufficient horizontal clearance to the roadway and to pedestrians and people on bikes within the queue spaces, should be provided. The typical clearance is 0.6 m

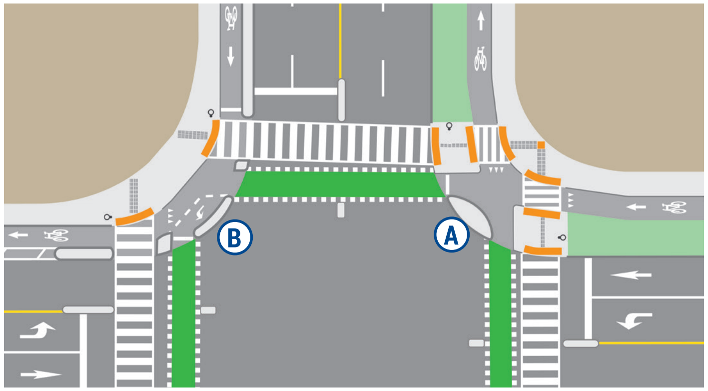



*Figure 6.8. Mixed protected intersection showing "eyebrow" and "almond" corner safety island designs on left and right corners, respectively*

### Design Features

- (A) "Almond" corner safety island
- (B) "Eyebrow" corner safety island


*Image 6.7. Raised corner safety island and raised features in standard protected corner at Donald Street and St. Laurent Boulevard*

*Image 6.8. Vancouver protected intersection with raised island and traffic infrastructure*

## Quick Build Materials

In some cases, such as retrofits where some or all existing curbs are retained, protected corner elements can be built using quick build materials such as pinned curbs, rigid bollards, or flexible posts. This approach may be applicable where the incoming cycling facility is street level protected, or where a one-stage pedestrian crossing protected corner type is implemented.

## Centerline Hardening

As noted in Chapter 5, placing a physical barrier in the centreline of a roadway between the crossride and the intersection encourages left-turning vehicles to take a tighter radius, which in turn reduces vehicular speeds and improves the viewing angle between drivers and pedestrians and people on bicycles through the crossing. Centreline hardening can be implemented using a wide range of materials, where the ultimate choice must consider winter durability.

### Guidance

- A full height bull-nosed concrete median extension should be used except:
    - Where the turning path of the control vehicle encroaches on the median, in which case a mountable median should be used. Where there is a median pedestrian refuge, a mountable median may be used provided a full height curb is provided between the mountable median and the refuge
    - Where the size of the median extension is less than 3 $m^2$, in which case a mountable median should be used
    - Where there is no median, in which case rumble strips in the centreline and/or quick-build materials should be used
- Quick-build materials, such as molded rubber and plastic speed humps that can be secured to asphalt road surfaces (Image 6.9), may be used where:
    - There is no median
    - The intersection is being reconstructed in the near term
    - The centreline hardening is intended as a pilot
- Reflective flex bollards with WA-33L signs should be used to ensure visibility year round

*Image 6.9. Quick build materials implemented on Elgin Street*

## Corner Aprons

Corner aprons, their function, and where they should be implemented are discussed in Chapter 5 Functional Design. This section focuses on the material and construction of corner aprons. Additional detail on corner apron design may be provided in the future through new City of Ottawa standard detail drawings.

### Design Options

- Raised apron with mountable curb and ripple strips
  - A raised apron adds an additional deterrent for passenger vehicles compared to the flush concrete apron
  - This design treatment is most commonly seen in the centre of roundabouts but has been applied to intersection corners as well in various jurisdictions outside of Ottawa
  - A raised apron can be designed to be compatible with snow removal operations
- Flush concrete apron with ripple strips per Ontario Provincial Standard Drawing (OPSD) 503.010
- Flush painted apron with seasonal installation of rubber speed bumps in the apron area
  - This option should only be used as a pilot or short term installation

### Guidance

- Where any in-service bus traverses a corner apron, the corner apron must be a flush concrete grooved apron
- Raised aprons should only be considered between crossrides (i.e. approach and departure aprons should be flush concrete grooved aprons only) and provided drainage can be accomodated

*Image 6.10. Flush concrete grooved apron at Donald Street and St-Laurent Boulevard*

*Image 6.11. Raised apron at roundabout at Bayview Station Road and Slidell Street*

7

# SIGNALIZATION MEASURES

*This chapter considers prerequisites, considerations, and potential impacts for specific signalization measures at protected intersections. Certain signal treatments and lane configurations contribute safety benefits for people on bicycles and pedestrians at protected intersections.*

# 7.1. Leading Pedestrian Interval and Leading Bicycle Interval (LPI/LBI)

Also referred to as a leading pedestrian and bicycle interval (LPI/LBI), this treatment provides an advance bicycle green/walk for pedestrians (minimum 5 seconds) to enter the intersection and become more visible to turning motorists. It reduces conflict potential between right-turning vehicles and vulnerable road users at the start of the phase.

### Considerations for Application

- Volumes of pedestrians and people on bicycles
- Right turn volumes
- Collision history
- Sightlines
- If there is a protected-permitted left turn phase present, consider implementing straight through arrows during the leading bike/ped interval (followed by green ball display) to reduce potential for conflicts
- May reduce vehicle capacity of intersection (reduced effective green time) if straight through arrows are not implemented

### Guidance

- Leading pedestrian/bicycle intervals are **recommended** at:
    - **Protected corners** and **dedicated corners** where the bicycle stop bar (and pedestrian refuge) is not forward of the vehicle stop bar
    - Crossings with more than 250 pedestrians or people on bicycles in the peak hour
    - Crossings where f**ully protected left** or **right turn phases** are not warranted or not feasible
    - Skewed intersections
    - Other locations where necessary based on the Considerations for Application above
- No Right Turn On Red is strongly **recommended** where leading pedestrian / bicycle intervals are used

### Requirements

- Bicycle signals must be present in order to provide leading interval for people on bicycles. If bicycle signals are absent, people on bikes are legally required to obey the motor vehicle signal or may dismount and walk their bicycle

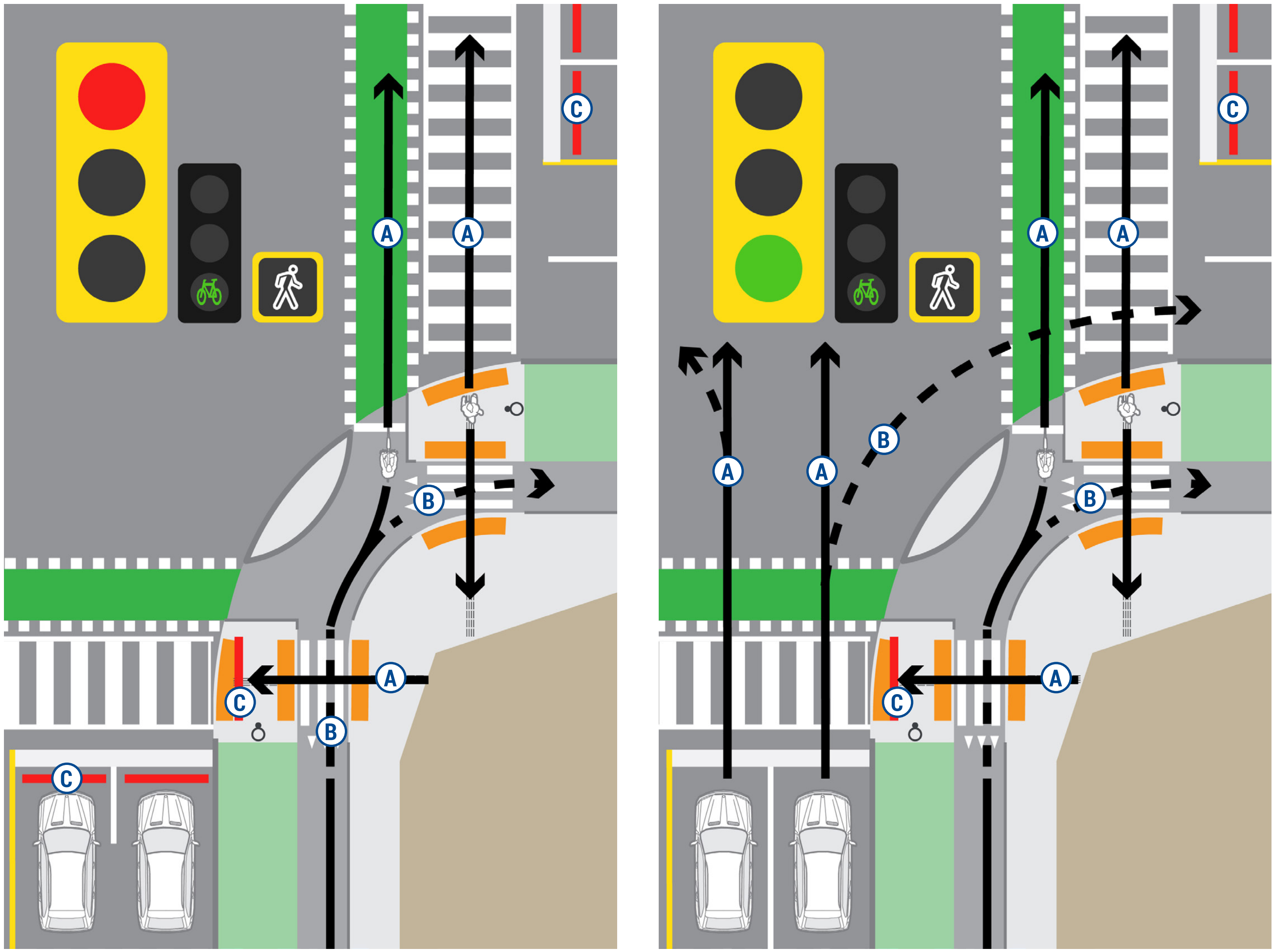



*Figure 7.1. Leading pedestrian and bicycle interval phase (left) and typical green ball phase (right)*

### Design Features

- (A) Solid line: User has right-of-way
- (B) Dashed line: User must yield to another mode
- (C) Red line: User must stop. Once stopped, vehicles may turn right while yielding to other traffic, unless prohibited to do so by RB-79R no right on red sign(s)

# 7.2. No Right Turn on Red (NRTOR)

This treatment involves posting regulatory signage to prohibit motorists from turning right on red. The restriction may be applied at all times, or during specific times, as indicated using supplementary tabs. It reduces motor vehicle conflicts with vulnerable road users at both the perpendicular and parallel crossing to the right turn approach, and reduces likelihood of motor vehicles blocking the crosswalk.

### Considerations for Application

- Right turn volumes
- Volumes of pedestrians and people on bicycles
- Cycling facility configuration, with a higher conflict potential with bidirectional crossrides or where the crossride setback target is not met
- Collision history
- Sightlines
- Increases right-turning vehicle delay and may reduce capacity, especially where cycle length is long. Using NRTOR in conjunction with overlap right turn phasing can offset some of the increased delay, subject to the prerequisites for **right turn overlap phase** being met

### Guidance

- A right turn on red prohibition is **required** where there is:
  - a **fully protected right turn phase**
  - a bike box or two-stage left turn box
- Right turn on red prohibition is **strongly recommended** where there is a **right turn overlap phase**, **leading pedestrian/bicycle interval**
- Right turn on red prohibition **should be considered** at:
  - all protected intersections within the urban area, or
  - other locations based on the Considerations for Application above

### Requirements

- RB-79R no right turn on red sign(s)

# 7.3. Fully Protected Left Turn Phase

This measure fully separates conflicts between left-turning vehicles and oncoming traffic, as well as pedestrians and people on bicycles on the conflicting crossing.

### Considerations for Application

- Left turn volumes (general traffic and heavy vehicles)
- Number of left turn lanes (two or more left turn lanes must always run protected)
- Oncoming traffic volumes and number of lanes crossed
- Visibility and sightlines
- Collision history
- Operating speed
- Available length for adequate vehicle storage
- Configuration on conflicting bikeway crossing (one-way or two-way facility)
- Lane designation for specific classes of vehicles (ex. Transit/heavy vehicles in one lane of a dual-left turn lane)
- May increase delay for left-turning vehicles and other users due to requirement for dedicated phase

### Guidance

Where a left turn movement at a signalized intersection crosses a bidirectional cycling facility, a fully protected left turn phase is required. This is consistent with current City of Ottawa practice. Where a fully protected left turn phase is not feasible due to constraints, permissive left turns across a bidirectional cycling facility may be considered in very limited circumstances if discussed with and approved by Traffic Operations and Road Safety staff. Conditions that should be reviewed to determine if permissive left turns may be considered include the following:

- The number of opposing lanes that must be crossed, and volume of opposing traffic, with fewer lanes and lower volumes reducing the burden on left-turning drivers
- The volume of left-turning vehicles, with higher volume of vehicles corresponding to greater conflict potential
- The length of **crossride setback**, where a setback greater than 6.0 m allows for a vehicle to dwell without obstructing traffic
- Presence of a **leading bicycle interval**, which allows people on bicycles to proceed before vehicles
- Ability to provide **centreline hardening**

*Table 7.1. Peak hour left-turning volumes (vehicles/h)*

| | 1 oncoming general purpose through or right turn lane | 2 or more oncoming lanes |
|---|---|---|
| Fully protected left turn phase should be considered when left-turning volumes exceed | 100 | 50 |

Where a left turn movement crosses a unidirectional cycling facility, the Considerations for Application and the thresholds in Table 7.1 should be considered.

Every effort should be made to safely accommodate bidirectional crossings where appropriate based on desire lines and incoming cycling facilities. Detouring of people on bicycles on an alternative unidirectional route around the intersection to avoid a bidirectional crossing may result in low compliance

**Requirements**

- Dedicated left turn lane(s)
- Centre median for signal pole
- Minimum two Type 2 signal heads
- Rb-41 left turn lane designation sign(s) where there are two or more left turn lanes
- Opposing left turn movement (if present) must also be fully protected

# 7.4. Permissive Right Turn and Right Turn Overlap Phase

This measure occurs where a protected or protected-permissive left turn movement is provided on the intersecting street, and an overlapping right turn phase provides a green arrow to right-turning motorists during the phase such that right-turning vehicles may proceed without any conflict. This is a protected movement when the green right turn arrow is displayed. The signal cycle also includes a separate "green ball" phase where vehicles turn permissively across crosswalk and crossride.

### Considerations for Application

- Right turn volumes
- Available length for adequate vehicle storage
- Adjacent pedestrian and/or people on bicycle crossing volumes
- May only be used on leading phase
- Decreases delay and increases capacity for right-turning vehicles
- May reduce required right turn storage length
- May increase overall cycle length of the intersection
- May reduce frequency of conflicts between right-turning vehicles and vulnerable road users, especially if supplemented with NRTOR regulatory signage
- May increase required corner radius if control vehicle is not permitted to straddle adjacent lane to complete right turn

### Guidance

- Where a right turn movement crosses a bidirectional cycle track, a **fully protected right turn phase** should be considered where right turn volumes exceed 100 vehicles in the peak hour. Where right turn volumes are less than 100 vehicles in the peak hour, the measures described in the "low right turn volumes" branch in Figure 7.4 should be considered. Where a fully protected right turn phase is not feasible due to constraints, the conditions present should be reviewed to determine if permissive right turns may be considered, such as:
    - The volume of right-turning vehicles, with higher volume of vehicles corresponding to greater conflict potential
    - The length of **crossride setback**, where a setback greater than 6.0 m allows for a vehicle to dwell without obstructing traffic
    - Presence of a **leading bicycle interval**, which allows people on bicycles to proceed before vehicles
- Where a right turn movement crosses a unidirectional cycle track, the application of **fully protected** and right turn overlap phases should consider whether the target **crossride setback** is achieved as well as right-turning vehicle volumes. Figure 7.4 describes the measures that are recommended for consideration in addition to the Considerations for Application listed above
- Every effort should be made to safely accommodate bidirectional crossings where appropriate based on desire lines and incoming cycling facilities. Detouring of people on bicycles on an alternative unidirectional route around the intersection to avoid a bidirectional crossing may result in low compliance

### Requirements

- Dedicated right turn lane
- If overlapped with a protected left turn phase on adjoining street, sufficient corner geometry to allow right-turning vehicles to coincide with left-turning vehicles without design vehicle paths conflicting and without design vehicle straddling adjacent lane
- If overlapped with a protected left turn phase present on adjoining street, U-turns must be prohibited
- Sufficient corner geometry to allow right-turning vehicles to coincide with left-turning vehicles without vehicle paths conflicting
- Rb-42 right turn lane designation sign
- Type 9R or 9AR signal head

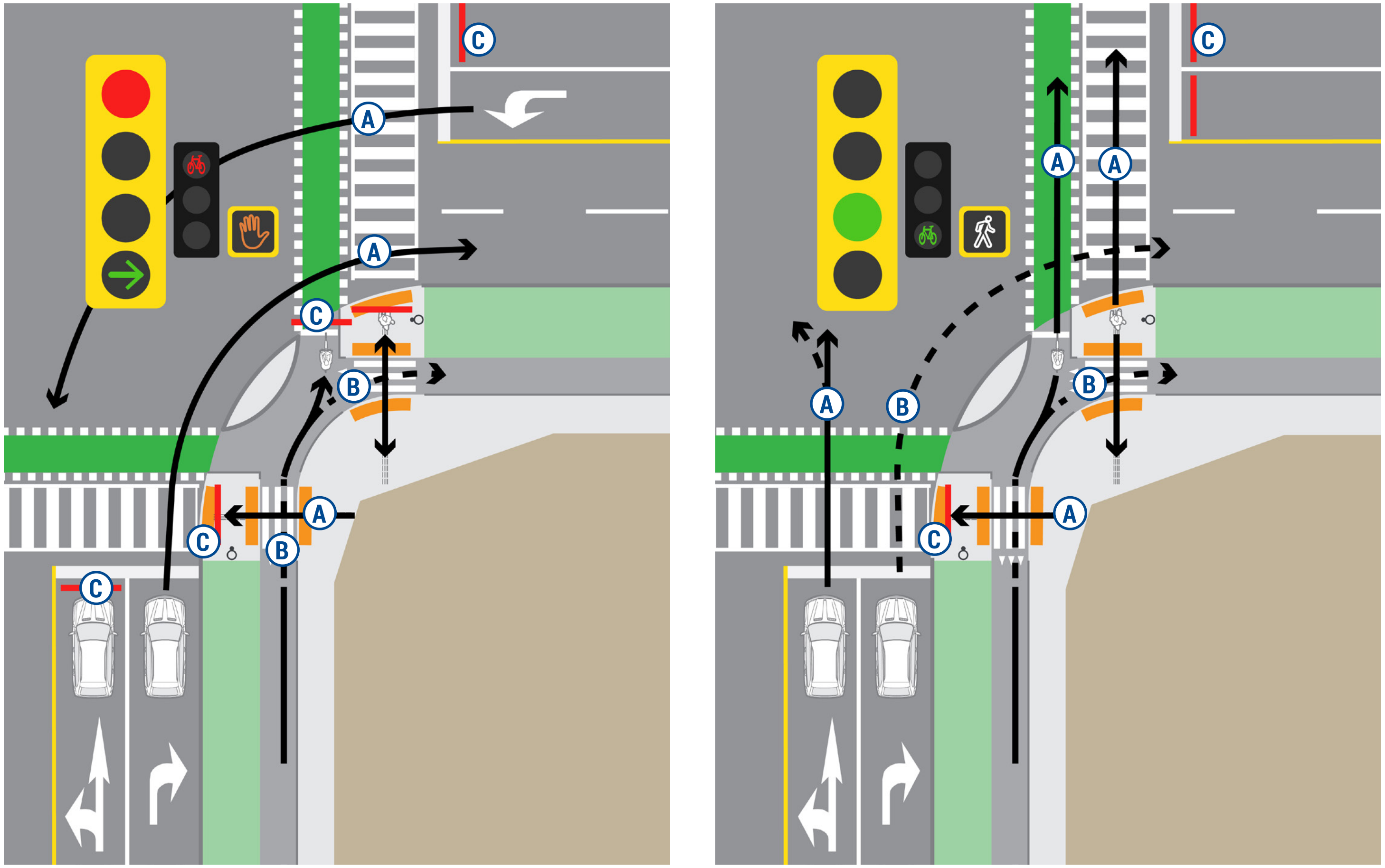



*Figure 7.2. Overlap right turn phase (left) and green ball phase (right)*

### Design Features

- (A) Solid line: User has right-of-way
- (B) Dashed line: User must yield to another mode
- (C) Red line: User must stop. Once stopped, vehicles may turn right while yielding to other traffic, unless prohibited to do so by RB-79R no right on red sign(s)

# 7.5. Fully Protected Right Turn Phase

This operation fully prohibits right-turning vehicles except when a green right turn arrow is displayed. Right-turning vehicles are fully separated from the adjacent pedestrian and cycling phase, eliminating conflicts. This phase could operate concurrently with the left turn phase of the intersecting street, which would improve efficiency of intersection operations.

### Considerations for Application

- Right turn volumes
- Available length for adequate vehicle storage
- Designated queueing area for people on bicycles that is outside of the right-turning vehicle path
- Increases delay and may reduce capacity for right-turning vehicles compared to conventional right turn operation
- May require dual right turn lanes, increasing intersection width and crossing distance for pedestrians
- May increase required right turn storage
- May increase required corner radius to accommodate the control vehicle

### Guidance

- Where a right turn movement at a signalized intersection crosses a bidirectional cycle track, a fully protected right turn phase should be considered where right turn volumes exceed 100 vehicles in the peak hour. Where right turn volumes are less than 100 vehicles in the peak hour, the measures described in the “low right turn volumes” branch in Figure 7.4 should be considered. Where a fully protected right turn phase is not feasible due to constraints, the conditions present should be reviewed to determine if permissive right turns may be considered, such as:
    - The volume of right-turning vehicles, with higher volume of vehicles corresponding to greater conflict potential
    - The length of **crossride setback**, where a setback greater than 6.0 m allows for a vehicle to dwell without obstructing traffic
    - Presence of a **leading bicycle interval**, which allows people on bicycles to proceed before vehicles
- Where a right turn movement crosses a unidirectional cycle track, the application of fully protected and right turn overlap phases should consider whether the target **crossride setback** is achieved as well as right-turning vehicle volumes. Figure 7.4 describes the measures that are recommended for consideration in addition to the Considerations for Application listed above

- Every effort should be made to safely accommodate bidirectional crossings where appropriate based on desire lines and incoming cycling facilities. Detouring of people on bicycles on an alternative unidirectional route around the intersection to avoid a bidirectional crossing may result in low compliance
- Pole locations for right turn signals should be considered early in the design process to avoid grading and drainage conflicts. The placement of signal heads where the right turn movement needs to be fully separated from the bicycle movement can be challenging – particularly where a signalizing approach has a narrow receiving leg or a small crossride setback – and therefore under these conditions it is more likely that the City's Traffic Signals Design staff will have site-specific geometry requirements to accommodate the more-complex signal infrastructure

**Requirements**

- Dedicated right turn lane(s)
- If overlapped with a protected left turn phase on adjoining street, sufficient corner geometry to allow right-turning vehicles to coincide with left-turning vehicles without design vehicle paths conflicting and without design vehicle straddling adjacent lane
- If overlapped with a protected left turn phase on adjoining street, U-turn prohibition on corresponding intersecting street left turn movement
- Rb-42 right turn lane designation sign(s)
- Two or more type 3 signal heads
- RB-79R no right turn on red sign(s)
- Signal placement should follow OTM Book 12: Traffic Signals and OTM Book 12A: Bicycle Traffic Signals

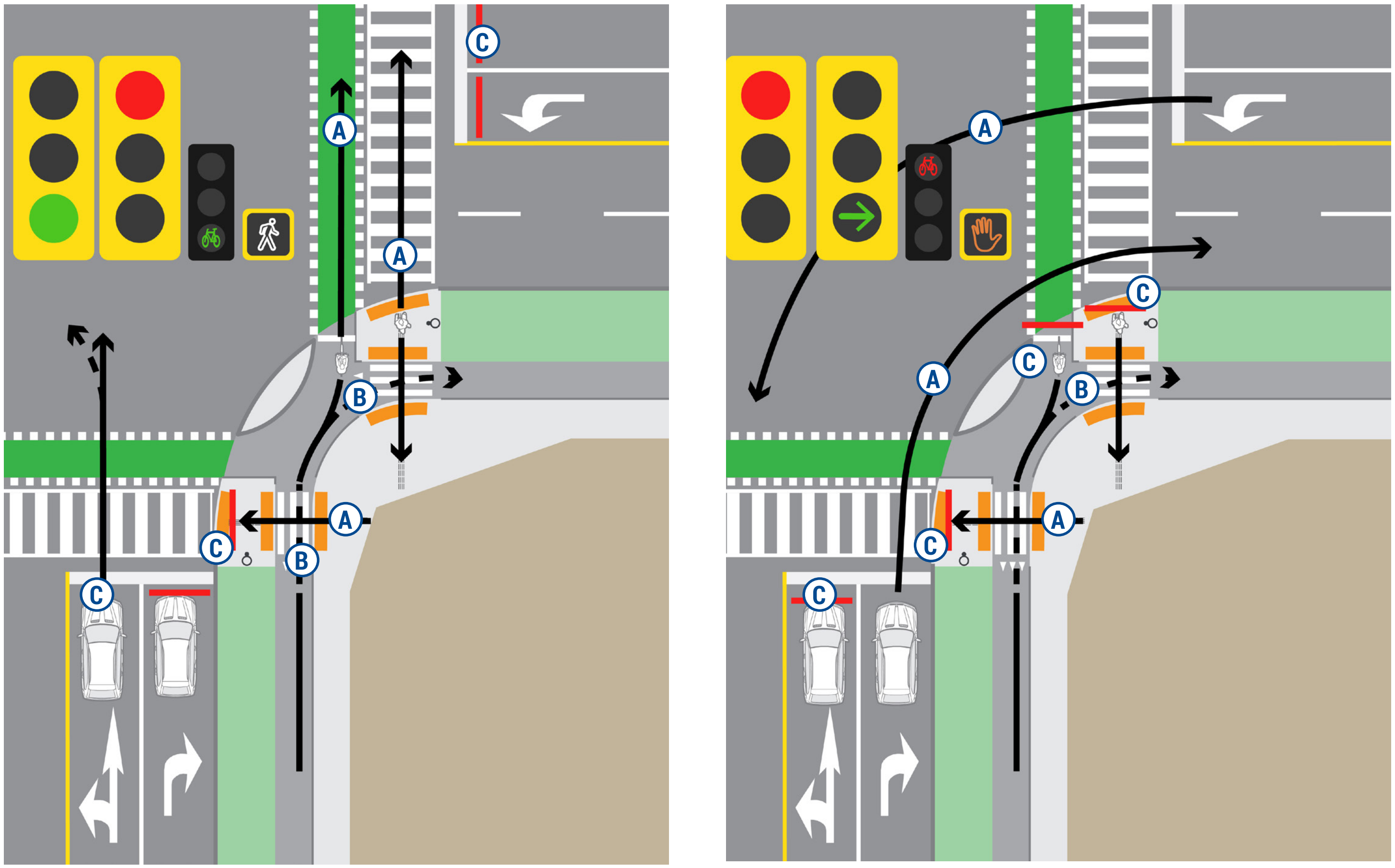



*Figure 7.3. Bicycle and pedestrian-only phase (left) with fully protected right turn phase (right)*

### Design Features

- (A) Solid line: User has right-of-way
- (B) Dashed line: User must yield to another mode
- (C) Red line: User must stop. Once stopped, vehicles may turn right while yielding to other traffic, unless prohibited to do so by RB-79R no right on red sign(s)

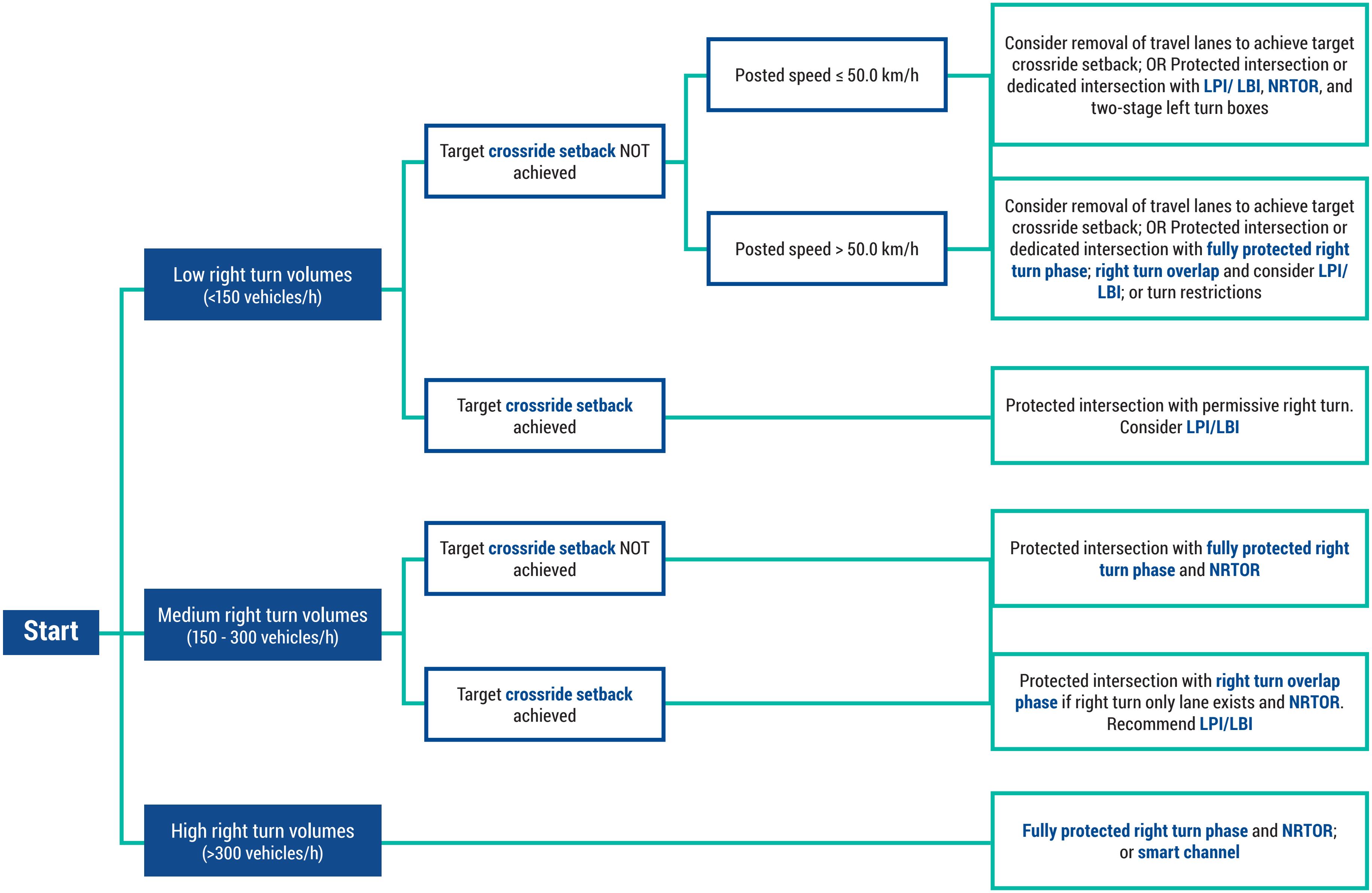



*Figure 7.4. Flowchart of considerations for right turn signalization measures*

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