Appendix V. Bicycle Facility Design Best Practices

The Cycling Master Plan update recommends that bicycle facility design guidelines be produced for the City of Mississauga. (See main report section 3.3, recommendation 2.1.2.) While developing a design guide was beyond the scope of the Cycling Master Plan update project, research was undertaken to identify references and best practices that would support implementation of this recommendation. This Appendix lists relevant supporting research, highlights the key themes of this research, and summarizes the strategic direction the 2018 Cycling Master Plan supports for bicycle facility design guidance.

Bicycle Facility Design Guidance

Bicycle facility design in North America is a field that is rapidly changing and evolving. Design guidance is regularly updated as design solutions are reviewed and adapted to improve cycling safety and comfort, encourage cycling for a variety of trip purposes, and support people of all ages and abilities to ride bicycles. Several bicycle facility design manuals have been developed and updated since Mississauga's first Cycling Master Plan and have informed the direction and recommendations of this Cycling Master Plan update. These resources include:

- Transportation Association of Canada *Geometric Design Guide for Canadian Roads Chapter 5—Bicycle Integrated Design* (June 2017);
- Transportation Association of Canada and Institute of Transportation Engineers. *Canadian Guide to Traffic Calming* (April 2017);
- Transportation Association of Canada. *Canadian Roundabout Design Guide* (February 2017);
- *Ontario Traffic Manual Book 18* (2013, on schedule for update in 2018);
- *Ontario Traffic Manual Book 15* (June 2016);
- Ontario Ministry of Transportation. *Bikeways Design Manual* (2014);
- Ontario Ministry of Transportation. *Integration of Cyclists and Pedestrians at Highway Interchanges* (March 2012);
- National Association of City Transportation Officials (NACTO). *Urban Bikeway Design Guide, 2nd edition* (2014);
- CROW. *Design Manual for Bicycle Traffic* (2017), the national design standard for bicycle facilities in the Netherlands;
- City of Toronto. *Multi-Use Trail Design Guidelines* (2015);
- City of Toronto. *Road Engineering Design Guidelines 6.0 Curb Radii Guideline*, version 1.1 (June 2017);
- Institute for Transportation Engineers. *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach: Fact Sheet 3: Design Factors to Control Speed* (2010);
- Vélo Québec. *Planning and Design for Pedestrians and Cyclists* (2010);
- Massachusetts Department of Transportation. *Separated Bike Lane Planning & Design Guide* (November 2015);
- U.S. Department of Transportation Federal Highway Administration. *Small Town and Rural Multimodal Networks* (December 2016);
- Alta Planning. *Lessons Learned: Advisory Bike Lanes in North America* (August 2017); and
- Alta Planning. *Lessons Learned: Evolution of the Protected Intersection* (December 2015).

There is also a growing body of academic research and evaluation looking at the effect of different bicycle facility design treatments and other factors on bicycle safety and comfort.

Intersection Design

Safe and comfortable intersection design reduces delays for all travel modes while also reducing conflicts and the risk of injury in the event of a collision. Intersections are where conflicts are most likely to occur. For this reason, intersection designs must include provisions for cyclists and should be intuitive to all road users.

Intersection Design Variables

Several different variables have an impact on designing intersections to improve bicycle safety and must be taken into consideration when developing appropriate design solutions. These variables include:

- **Bicycle Facility Type and Operation**
  - *Type of bicycle facility* impacts cyclists' level of comfort. Greater spatial separation between cyclists and motor vehicles increases level of comfort and appeals to a broader population; however, further separation from the roadway has an impact on the geometric design of intersections to safely accommodate bicycles.
  - *One-way bicycle facilities* operate in a similar way to motor vehicle traffic making typical intersection operations relatively straightforward.
  - *Two-way bicycle facilities* (boulevard multi-use trails, two-way separated bike lanes or two-way raised cycle tracks) introduce unexpected movements at intersections against the flow of traffic. This contra – flow operation must be accounted for where two-way bicycle facilities cross through, terminate or transition to one-way facilities at intersections.
- **Traffic Volumes**. Current and future expected volumes of bicycles, pedestrians and motor vehicles impact the appropriate width of bicycle facilities, sidewalks, and the number of traffic lanes required.
- **Design Speed**. Approach speeds of all road users must be considered when determining sight distances and making geometric design decisions at intersections. Bicycles typically operate at speeds much higher than pedestrians (bicycles typically travel between 15 km/h and 30 km/h and up to 50km/h on a downhill)[1] and therefore cannot be treated the same as pedestrians. Motor vehicle turning movements pose a key safety risk for cyclists. Turning vehicle speeds are limited by the geometry of an intersection.
- **Delay**. Reducing delay for all modes improves convenience, minimizes frustration and may improve user behaviour and compliance.
- **Current and Future Land Use** including block size, and type of development influences the frequency of driveways and volume of cyclists.
- **Roadway Width** limits the space available to accommodate all travel modes and can be further limited by dedicated turn lanes at intersections.

- **On-Street Parking** can reduce sight distances at intersections and driveways which may require parking restrictions on the approach to intersections particularly where there are cycling facilities present. Parking-protected bicycle lanes use on-street parking to increase the degree of separation between cyclists and motor vehicle traffic. These facilities improve cyclist and motorist levels of comfort, but increase the frequency of pedestrians crossing the separated bike lane to access parked cars.
- **Roadway Geometry and Topography** such as offset intersections, curves or hills can obscure sight lines and make the path of travel unclear for all users.

Design Solutions for Intersections

Intersections are important locations for design solutions. Intersection improvements must be considered in the context of each project. Options for improvements include design elements that have already been used in Mississauga and new design elements and principles such as:

- Unsignalized and signalized crossrides;
- Green pavement markings;
- Pavement markings through intersections;
- Protected mid-block crossings;
- Protected crossings at roundabouts;
- Fully protected intersections;
- Recessed crossings;
- Reduced corner radii to slow down turning traffic;
- Removal of channelized right turn lanes;
- Reduced radii on highway ramps to slow down turning traffic at highway interchanges;
- Two stage left turn bike boxes; and
- Pavement markings and geometry at driveways to slow traffic and improve visibility of cycling facilities, particularly multi-use trails.

Understanding how these design elements can be used and what they will accomplish is important for making the right design decisions. Following the example of the *Massachusetts Department of Transportation Separated Bike Lane Planning & Design Guide*,[2] potential intersection design solutions can be categorized under the four key design principles for safe intersection design:

1. **Provide adequate sight distance;**
2. **Minimize exposure to conflict;**
3. **Reduce speeds at conflict points; and**
4. **Clearly communicate who has priority.**

Provide Adequate Sight Distance

In order to avoid conflict it is necessary to provide adequate sight distance for motor vehicles, bicycles and pedestrians as they approach intersections and driveways. The distance required will depend on the approach speeds of different users. Typically bicycle design speeds of 20-30 km/h are used with 40-50 km/h advised in certain circumstances.[3] Standard sight distances for street design are generally applicable to on-street cycling facilities. Areas where additional consideration may be needed include:

- **Mid-Block Multi-Use Trail Crossing**. Adequate sight distance is needed along the roadway so that motorists

have enough time to react and cyclists can choose when to safely cross. TAC has developed a formula to calculate minimum sight distance based on roadway width and design speed.[4]

- **Parking Protected Bike Lanes**. When a separated bike lane is located between on-street parking and the curb (see **Figure V-1**), it may be necessary to restrict parking further from an intersection or driveway to be sure appropriate sight distances are provided. For example, Massachusetts has developed specific guidance for the approach clear space needed based on motor vehicle turning speeds.[5]

Figure V-1: This parking protected bike lane has restricted parking near to the intersection and includes pavement markings through intersections to indicated the correct positioning and priority for cyclists. (Image credit: Fred Sandoval)

Minimize Exposure to Conflict

The majority of bicycle collisions in Mississauga are related to motor vehicle turning movements at intersections. Minimizing cyclists' exposure to conflict helps to reduce the risk of collisions and injuries. Different types of geometric designs at intersections are associated with different levels of exposure to potential conflict for cyclists. **Figure V-2** shows an example of five intersection types and the different level of exposure they create for cyclists.

The following list highlights the different exposure level each facility type presents to cyclists and motorists at intersections. Solutions that improve the visibility of bicycle facilities, indicate who has priority, and decrease the speed of approaching vehicles (as detailed in following sections) are critical to improving safety at these intersections.

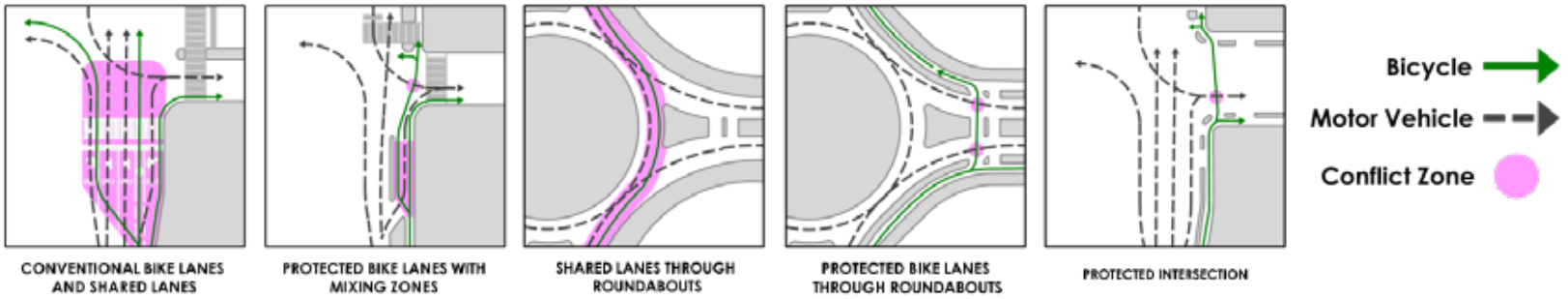
- **Conventional Bike Lanes and Shared Routes**—Exposure to conflicts: HIGH

  The majority of on-road bicycle facilities in Mississauga fall within this category and introduce cyclists to high potential for conflict at intersections. The potential for conflict increases as vehicular volumes increase.

- **Conventional Bike Lanes and Shared Lanes with Channelized Right Turns**—Exposure to conflicts: HIGH

  Channelized right turn lanes create a high risk of conflict to cyclists because of the weaving movements required by motor vehicles to cross the path of cyclists and enter the channelized right turn roadway. For safety reasons, channelized right turn lanes are not recommended along cycling facilities.[6]

Figure V-2: Conflict zones for cyclists at different types of intersections
(Image credit: Adapted from *MassDOT Separated Bike Lane Planning & Design Guide*)



- **Highway Interchanges**—Exposure to conflicts: MEDIUM to HIGH

  Depending on the configuration of highway interchanges and the design of merging and diverging ramps, these intersections can create high exposure to conflicts. High speed ramps with acceleration lanes or parallel lanes extend the conflict area for on-road bicycle facilities at potentially high traffic speeds. This has a significant impact on level of comfort and risk for cyclists.

- **Separated Bike Facilities with Mixing Zones at Intersections**—Exposure to conflicts: MEDIUM to HIGH

  Mixing zones are locations where motorists and cyclists mix at the approach to an intersection—creating a shared lane condition. When one-way protected cycling facilities transition to a mixing zone the comfort and safety provided by a separated bicycle facility is lost where it is most needed. Because there is a high to medium level of exposure in shared use facilities, mixing zones

Figure V-3:
A mixing zone is where a separated bicycle lane transitions to a conventional bike lane. (Image credit: *NACTO Bikeway Design Guide*, 2012)

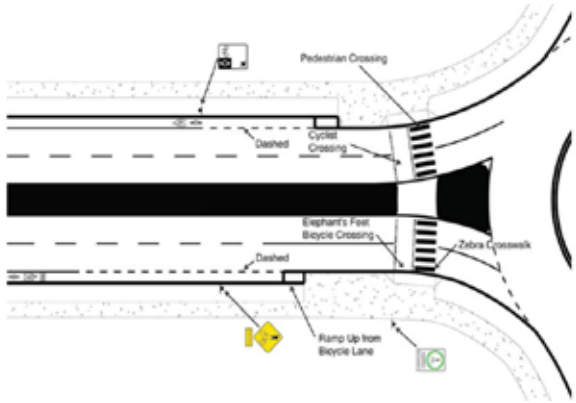


Figure V-4: Bicycle lane at a multi-lane roundabout with bicycle bypass [Image credit: *OTM Book 18* (*TAC Bikeway Traffic Control Guidelines for Canada*, 2012, Figure 35, p. 89)]

should be used only where traffic volumes and speeds are low.[7] In locations where traffic speeds and volumes are higher, protected intersections provide a safer, more comfortable environment for cycling.

- **Separated Bike Facilities at Roundabouts**—Exposure to conflicts: MEDIUM to LOW

  New roundabouts being designed in Mississauga include some located on proposed cycling routes. This intersection type has the potential to reduce potential conflicts and improve comfort for cyclists if a dedicated bicycle crossing (e.g. crossride) is provided. Canadian, Ontario (see **Figure V-4**) and US design guidance shows this type of treatment at roundabouts.[8,9,10] Ontario guidance, however, also indicates that pedestrian crossovers are the appropriate treatment for controlled pedestrian crossings at roundabouts.[11] As discussed in section 3, bicycles are prohibited from riding through pedestrian crossovers according to the Ontario Highway Traffic Act.

Figure V-5: Protected bike lane (or separated cycle track) at a roundabout with dedicated bicycle crossings Bicycle Bypass (Image credit: Alta Planning)

- **Boulevard Multi-use Trails with Crossrides at Signalized Intersections**—Exposure to conflicts: MEDIUM to LOW

  Implementing **crossrides** at multi-use trail crossings to replace the current dismount and walk condition at the majority of signalized intersections has the potential to reduce conflict and improve cyclist safety and comfort. These retrofits must take into account the geometry of the intersection as well as the addition of pavement markings and signals.

The design of **intersection approaches** is critical to creating a legible environment where pedestrians, cyclists and motorists understand the correct positioning and right-of-way for each mode, and where motorists will anticipate contraflow bicycle traffic at intersections.

- The placement of traffic signal poles, bollards and other elements must not block a motorist's view of approaching cyclists or vice versa, or block the view of approaching or waiting pedestrians. These obstacles also create potential collision hazards for trail users.
- A consistent asphalt or other differentiated trail surface should be carried through to the intersection with appropriate pavement markings to indicate the correct path for cyclists and pedestrians (see **Figures V-8 and V-9**).

Figure V-6: The image on the left shows a legible and clear multi-use trail crossing that separates pedestrians from cyclists. The intersection shown in the right hand image has not been designed to accommodate cyclists. The change in trail surface from asphalt to concrete and the placement of obstacles within the trail clearway do not communicate the correct positioning for cyclists or pedestrians, nor signal the possibility of bicycle activity to motorists.

Recessed crossings set back from the intersection are a key element of protected intersections that can reduce the risk of conflicts at multi-use trail crossings by creating more space for motorists to yield to cyclists and pedestrians. As shown in **Figures V-7 and V-8**, recessed crossings position motorists so that the trail is more within their field of view at the crossing, and provide a waiting area so that cars are not forced to block the pathway while waiting to enter the intersection. Reduced curb radii at these locations slow traffic turning speeds.

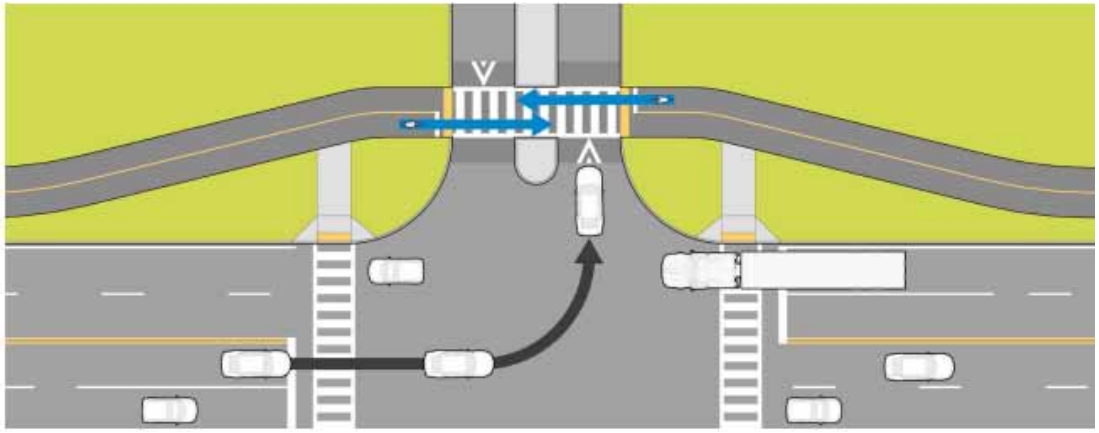


Figure V-7: Recessed crossing, also known as a "bend out," on a boulevard multi-use trail (Image credit: *MassDOT Separated Bike Lane Planning & Design Guide*)

- **Protected Intersections**—Exposure to conflicts: LOW

  According to Alta Planning's white paper on protected intersections, as of December 2015, there were six of these designs implemented in the US and Canada.[12] Separated bike lanes, boulevard multi-use trails, conventional bike lanes, shared roadways, or bicycle boulevards can be connected to a protected intersection design by transitioning the bikeway into short separated bike lane segments on the approaches to the intersection. Protected intersections can be designed at signalized and at stop-controlled intersections. Canadian design guidance for protected intersections has recently been made available.[13]

Figure V-8: Example of a recessed crossing along the waterfront trail in Toronto. The trail crossing at this busy driveway has been raised to slow motor vehicles crossing the trail.

Figure V-9: A protected 'T' intersection in Vancouver. A consistent asphalt trail surface that is carried through to the intersection with appropriate pavement markings improves legibility and indicates the correct path for cyclists and pedestrians so that the bike lane is not confused for a walkway.

There is a **higher potential for conflict** and higher risk of collision and injury on streets with **higher operating speeds, high traffic volumes, multiple lanes, and high volumes of turning vehicles**. Many roadways in Mississauga with existing or planned bicycle facilities have these characteristics. For protected bicycle facilities such as boulevard multi-use trails, raised cycle tracks or separated bike lanes, design solutions in addition to protected intersection geometry are needed to mitigate conflict. These measures include:

- Protected bicycle signal phasing to separate bicycle through movements from turning vehicle movements;
- high visibility green paint in addition to pavement markings indicating cyclists' path through the intersection;
- raised crossing; and/or
- recessed crossing, or "bend-out."

Clearly Communicate Who Has Priority

Many elements of intersection design—including geometric design, bicycle signals, signage and pavement markings—work together to communicate the correct positioning of cyclists and motorists, and who has priority at an intersection.

- **Signage**: Signage indicating the requirement of turning vehicles to yield to cyclists, used in combination with pavement markings, has been shown to improve driver behaviour and reduce risk of collisions.[14,15]
- **Through Intersection Pavement Markings**: Markings through an intersection such as dashed lines, chevrons, sharrows and coloured pavement or a crossride (elephant's feet) indicate the intended path of cyclists in an intersection, driveway or other conflict zone and highlight the potential for conflict in this area.[16,17] It is important to be consistent with the treatment used across the cycling network to ensure legibility of intersection markings. **Figure V-10** shows an example of sharrows used through an intersection.

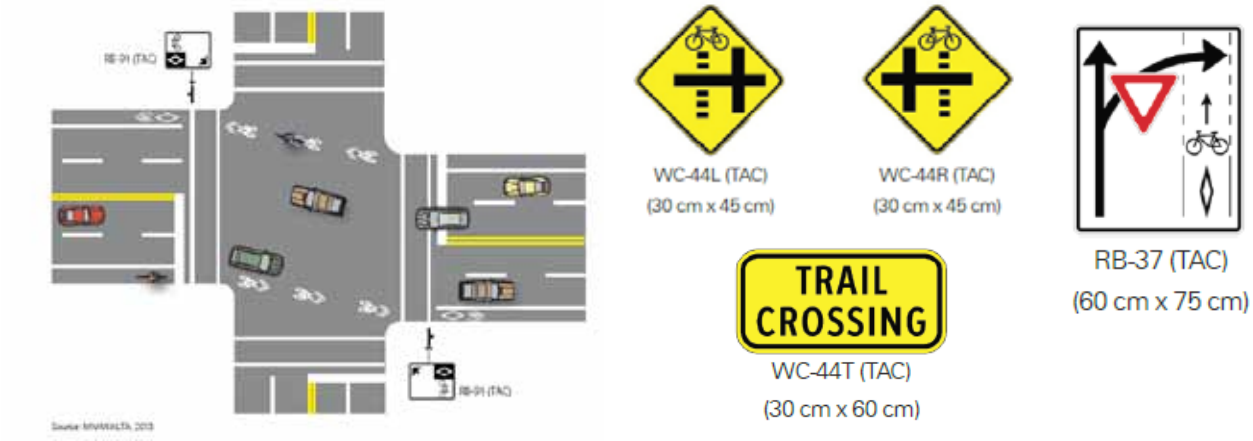


Figure V-10: Through intersection pavement markings and trail crossing and bicycle priority signage (Source: *OTM Book 18*)

Figure V-11: Signage and through intersection pavement markings at this driveway access to Dixie Road clearly indicate the trail crossing. Symbols or arrows to indicate bi-directional cycling would improve this treatment by indicating to drivers that cyclists may be approaching from either direction.

- **Green pavement markings** are recommended in locations like mixing zones where motor vehicle paths may encroach on unprotected bicycle facilities (e.g. sharp curves in the roadway) or at other locations where motor vehicle paths may conflict with through cyclists.[18] Coloured pavement markings and signage have been shown to increase motorists yielding to cyclists and increase cyclists following the correct path where bicycle routes must cross channelized right turn lanes.[19] Coloured pavement is also recommended in Ontario Ministry of Transportation guidance for integrating bicycle facilities at low speed diverging ramps at highway interchanges.[20,21]
- **Two Stage Turn Queue Bike Boxes**: These pavement markings provide guidance for cyclists to make two stage left turns particularly on multiple lane roadways where a "vehicular" left turn is uncomfortable and exposes cyclists to significant risk of conflict with motor vehicles. Bike boxes are also important to provide legible transitions between different types of cycling facilities, particularly two-way boulevard facilities to one-way facilities. Depending on the configuration, a right-turn-on-red restriction may be required for cross street vehicles.[22]

Figure V-12: Two-stage turn queue boxes are placed in a protected area such as in front of an on-street parking lane or between a bicycle lane and the pedestrian crossing. (Image credit: *NACTO Urban Bikeway Design Guide*)

Examples:

- **Mid-Block Multi-Use Trail Crossings**: Treatment options include signage for trail users and motorists, a contrast in surface texture, centre refuge islands, and/or pavement markings such as zebra crossings and crossrides.[23] Curb cuts or ramps are needed to allow access between trails and the roadway for cyclists or pedestrians with mobility devices such as wheelchairs or scooters. Several mid-block multi-use trail crossings in Mississauga are currently not controlled, do not have warning signage, lack curb cuts or ramps and are not AODA compliant.
- **Highway Interchanges**: Ministry of Transportation design guidance as well as TAC and *OTM Book 18* design guidance provide direction on through intersection pavement markings, coloured (green) pavement and warning signage to increase visibility of cyclists at highway interchanges.

Reduce Speeds at Conflict Points

Many roadways are designed with generous dimensions that are suitable for speeds higher than the posted speed limit. This allows and encourages motorists to travel at speeds higher than desired thereby compromising the safety of other road users. Reducing motor vehicle speeds along roadways and at intersections gives motorists more time to react and yield to cyclists and pedestrians and reduces the risk of severe injuries and fatalities in the event of a collision—a risk that is much higher for vulnerable road users like cyclists and pedestrians.

"Design speed" and "design vehicle" are tools used by engineers to determine the geometry of a road, which influences traffic speeds. Design speed can be higher or lower than the maximum safe speed. A "design vehicle" influences the lane width on roadways and curb radii

at intersections. Designing for large vehicles increases intersection crossing distances and increases the speed of turning vehicles.

In 2010, the Institute of Transportation Engineers (ITE) released a document called *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach*. One of the recommended actions is to replace design speed with a "target speed." The target speed is the highest speed at which vehicles should operate that would allow mobility for motor vehicles without compromising the safety of pedestrians, cyclists and other road users.[24] Similarly, the ITE-recommended practice promotes using the largest design vehicle that is expected to use the roadway "with considerable frequency" and recommends considering a "control vehicle" (the largest vehicle expected to use the roadway although rarely) with the understanding that "encroachment into the opposing traffic lanes, multiple-point turns, or minor encroachment into the streetside (the area between the curb and property line)" is acceptable for the control vehicle.

Reducing Corner (Curb) Radii

Motor vehicle turning movements at intersections pose a key safety risk to cyclists. An important intervention to improve safety for cyclists and all road users is to slow the speed of turning traffic. The larger the corner radius, the faster a driver may travel around the corner without losing control of her vehicle. The size of the corner radius at intersections is determined by the type of vehicle expected to use the intersection (design vehicle).

Using a smaller design vehicle when designing an intersection effectively allows for smaller curb radii to be used. On existing intersections, curb extensions can be applied to reduce the existing curb radii. Smaller curb radii reduce the speed of turning vehicles, which has been identified as a significant risk for cyclists and improve sight distances between cyclists and motorists. Existing guidelines on pedestrian safety also recommend smaller turning radii to reduce turning speeds, shorten the crossing distance for pedestrians, and improve sight distances. City of Mississauga standards allow for larger curb radii than may be appropriate for all contexts. Standard curb radii for the City of Mississauga are:

- 8.0 m where minor residential roads, residential roads or minor collector roads intersect;
- 12.0 m where collector roads intersect with collectors or minor residential roads;
- 15.0 m where collector roads, minor arterial roads or industrial roads intersect; and
- 20.0 m and channelized right turn lanes where two 4-lane divided arterials intersect.

In many cases these radii are larger than what is needed to accommodate the types of motor vehicles frequently using these intersections and are larger than those used in other urban jurisdictions.

The impacts of these standards on cycling and pedestrian safety should be assessed and revised as needed. For cycling, particular attention should be paid to cycling routes identified in the 2018 Cycling Master Plan where bicycle use is intended to be prioritized.

Cities are setting clear policies around roadway design with an effort to control traffic speeds and improve safety for all road users. This includes identifying appropriate design and control vehicles based on roadway classification and context, and setting minimum and maximum curb radii. For example, City of Toronto roadway design guidelines call for a minimum

curb radius of 4.0 m and a maximum curb radius of 15.0 m. *Intersection corners with all day no right turn restrictions are designed with a radius of 1.0 m.*[25] (Mississauga standards range from 8.0 m – 20.0 m as outlined in section 3).

Figure V-13: Examples of curb extensions (from left to right: a) temporary treatment using paint and bollards (Austin, Texas); b) retrofitted curb extension at signalized intersection (FHWA)

Intersections with approaching bicycle facilities and particularly those with facilities that offer a higher level of comfort to cyclists—like separated bike lanes, raised cycle tracks or boulevard multi-use trails—should be designed to ensure slow-speed turning movements. For example, Massachusetts Department of Transportation guidelines recommend designing for a turning speed of 10 mph (16 km/h) or less at intersections along protected bicycle facilities to maintain a consistent level of comfort throughout the full length of the facility.

The following examples reduce motor vehicle and cyclist speeds at different types of intersections to improve comfort and safety.

Mid-block multi-use trail crossings

As discussed in section 3, mid-block multi-use trail crossings may occur on local roadways, minor or major collector roads, or minor or major arterials. The appropriate treatment to improve safety and comfort for trail and road users at these locations is context dependent and must take into consideration factors such as the type of roadway that intersects the trail, the proximity of the crossing to nearby signalized crossings, sight lines for vehicles on the roadway and for trail users, and other factors. The following examples discuss some of the key design tools or approaches to improve mid-block crossings.

- **Traffic Calming Devices**: Traffic calming can improve cyclist comfort and safety along roadways where cycling

is prioritized and at trail crossings or other cycling facility intersections. According to the *Canadian Guide to Traffic Calming*[26] traffic calming devices can help to encourage cycling and other modes of active transportation by:

- Improving comfort or the perception of safety;
- Decreasing the speed difference between motor vehicles and active transportation users like cyclists and pedestrians, which reduces the likelihood of severe injury or death in the event of a collision; and
- Creating a healthier, more pleasant environment for active transportation by reducing noise and vehicle emissions, and improving aesthetics with plantings and high quality materials.

Traffic calming on cycling routes must take into account the possibility that some traffic calming devices may require cyclists and motor vehicles to change their path of travel. Other devices such as speed humps, may unintentionally encourage vehicles to change their path of travel to avoid driving or riding directly over them. Field observations showed some motor vehicles encroaching into the bicycle lanes on Fifth Line West at the Sheridan Trail crossing where speed humps do not extend through the bike lane.

Maintaining adequate width for lanes shared by bicycles and cars as they pass through narrowings or chicanes, providing bicycle channels, or designing cycling-friendly bump-outs that allow cyclists to ride-over or through are examples of ways that some of these concerns might be addressed.[27]

- Elements such as **alignment or uphill grade changes** can reduce speed on trail approaches to crossings.[28]
- **P-Gates, bollards or other obstacles in the centre of the trail are potential hazards** and have resulted in cyclist collisions and legal action in other jurisdictions. They are also potential hazards for visually impaired trail users. As a result, trail design guidance in other cities recognize "gateways" as "more extreme" measures and recommend using with caution and including warning signage.[29] Due to the accessibility barriers created by these obstacles and the potential hazards for pedestrians and cyclists, bollards and/or P-gates should be seen as a last resort to be used in locations where vehicles are unlawfully entering the trail and where other measures to deter this activity have proven unsuccessful.[30]

Channelized Right-Turn Lanes

Channelized right turn lanes are not recommended along bicycle facilities. Where channelized right turn lanes are present, exclusive right-turn lanes on the approach should be kept as short as possible since the length of the right-turn lane influences the speed of the vehicles in that lane and the amount of cyclist exposure to traffic driving on either side of them. Small corner radii, to ensure slower turning speeds are necessary on cycling routes to improve safety. A decrease in yielding to pedestrians by motorists has been observed as a result of higher motor vehicle turning speeds.[31]

Roundabouts

As with all intersections, reducing the speed of motor vehicles in roundabouts will improve safety for all road users by providing more reaction time to avoid conflicts, and reducing the level of injury should a conflict occur.

Canadian guidance on designing single lane roundabouts for shared use between cyclists and motorists includes

curb radius and centre island geometry that limit motor vehicle speeds to 30 km/h or 40 km/h in cases where traffic volumes are low (less than 1,000 vehicles per day).[32]

Multi-lane roundabouts typically have higher traffic volumes and entry speeds than single lane roundabouts on local roads and may pose a safety risk for cyclists. More than one entry or exit lane can make it difficult for drivers to see crossing cyclists or pedestrians. As a result, multi-lane roundabouts are not suitable for shared-use and a ramp to a separated bike path is recommended on the approach to the roundabout.[33,34]

Australian design guidance recommends that if single lane roundabout speeds cannot be reduced to 30 km/h through geometric design (small turning radius, i.e., < 20 m, on the entry curve and increasing the central island size), bicycles should be separated from motorized vehicles using an off-road path.[35] Where there are bicycle lanes on the approach that must merge with traffic at the roundabout, treatments such as a sharrows, are recommended to show the correct position for cyclists at the entry lane.

Dutch design guidance recommends that cyclists and motorists may share road space on a roundabout if traffic volumes are less than 6,000 vehicles/day, unless there are already separated bicycle facilities that connect to the roundabout in which case these should be continued as separated facilities through the roundabout. Maximum traffic speeds for any roadway shared between motorists and cyclists according to Dutch design standards is 30 km/h in urban settings, and 60 km/h in rural.[36]

Highway Interchanges

There are several existing and proposed bicycle routes in Mississauga that cross provincial highway interchanges. Integrating bicycle facilities at these locations is a complicated process subject to approvals from other jurisdictions including the Ontario Ministry of Transportation (MTO). In addition to pavement markings and signage treatments mentioned above, MTO design guidance recognizes the safety impact of motor vehicle speeds at conflict points and recommends that operating speed categories (and volumes) be used to categorize low, medium, and high exposure to conflict and thereby determine appropriate bicycle facility design.[37] MTO design recommendations for accommodating active transportation at different highway interchange configurations include options to reduce motor vehicle operating speeds such as ramp radius modification and cross street design elements.[38]

PXOs at Roundabouts and Mid-block Crossings

Currently, there are several locations in the existing cycling network where mid-block crossing treatments are needed to improve safety and comfort for cyclists. Mid-block crossings are needed to provide access across major roadways at uncontrolled intersections. These may be locations where local roadways intersect with major roadways, or where off-road trails intersect with roadways mid-block. Internal and external stakeholder feedback identified these locations as a key priority for improving pedestrian and cycling comfort and safety.

The Ontario Highway Traffic Act (HTA) requires that motor vehicles yield to pedestrians only at controlled crossings. A crossing is considered to be “controlled” when there are intersection signals, mid-block pedestrian signals, pedestrian crossovers (PXOs), stop signs, yield signs, or when a school crossing guard is present at a school crossing.

Roundabouts are classified as uncontrolled crossings, where pedestrians must wait for a safe gap in traffic before crossing unless a crossing control is provided. Many mid-block locations where cycling routes cross a roadway between traffic signals (including trail crossings or intersections with a minor roadway) are also uncontrolled. Uncontrolled crossings are assessed for pedestrian crossing control treatments using the methodology provided in *Ontario Traffic Manual Book 15*.[39] Depending on the speed and volume of traffic and expected volume of pedestrians and cyclists, mid-block crossings may warrant pedestrian crossing control. For roundabouts, provincial guidance identifies Type 2 PXOs and crossing guards as the two appropriate crossing controls for roundabouts.[40]

This introduces a challenge to developing bicycle-friendly intersections. The Highway Traffic Act states that "No person shall ride or operate a bicycle across a roadway within a pedestrian crossover."[41] As a result, installing pedestrian crossovers at roundabouts and mid-block crossings will create a barrier to cyclists by requiring them to dismount and walk at roundabouts or mid-block crossings with PXOs. Compliance to this law is expected to be low based on observations of cyclist behaviour at similar dismount and walk intersections and due to the significant energy required by cyclists to stop and start. Dismount and walk signage is not recommended by provincial guidance and "should not be relied upon in lieu of adequately accommodating cyclists through appropriate road design."[42]

There are a small number of existing roundabouts in Mississauga and several more are in the process of being planned and designed. Several of these locations are on designated cycling routes and other roadways used by cyclists.

Multi-Use Trails

Multi-use trails are an important part of Mississauga's active transportation network. They are in parks, along green corridors (creek and river valleys, and hydro corridors), and in the boulevard of several major arterial roads. Multi-use trails are shared by pedestrians and cyclists, including people pushing strollers or using walkers, roller blades, skateboards, wheelchairs, or other non-motorized modes of transportation. Because they are separated from the roadway, multi-use trails offer a comfortable environment for people of all ages and abilities. But, there is also potential for conflict at intersections and driveways, and between different kinds of users travelling in different ways and at different speeds which can impact safety on multi-use trails.

Available design guidance, research and feedback from community members and other stakeholders show the following elements would improve conditions on existing trails and ensure safety and comfort on new trails:

- Separating cyclists and pedestrians on busy multi-use trails and trails that are intended to provide for higher speed commuting;
- Using consistent surface materials along the full length of a multi-use trail, to clearly communicate where the trail begins and ends and where pedestrian-only areas exist, including at intersections;
- Providing a paved or suitably compacted surface to allow for bicycles to operate safely;
- Designing new trails and upgrading existing trails so that obstacles like utility poles, bollards, and other street furniture are not located on the operating portion of the trail;

- Avoiding the use of barrier gates (P-gates) as they can be a hazard for trail users including persons with visual or other impairments;
- Designing driveway crossings so that they are visible, reduce conflicts and communicate the right of way for cyclists and pedestrians;
- Installing a continuous centreline (broken or solid where appropriate) and other pavement markings as needed to communicate the correct location and direction of travel and where overtaking is permitted; and
- Considering lighting on linear trails that function as comfortable commuter cycling route alternatives to major roadways.

Separating Pedestrians and Cyclists

Most modern design guides recommend that cyclists and pedestrians be separated in most cases.[43] As well, countries with high cycling rates, such as the Netherlands and Denmark generally separate cyclists and pedestrians, except in rural locations. Converting space from sidewalks to multi-use trails can be seen by residents and advocates as misappropriating space from pedestrians, to a facility that is less desirable for both user groups.[44]

In terms of bicycle infrastructure, Mississauga has an advantage of a suburban built-form with large street rights-of-way and wide boulevards, as well as parkland and greenspace. This has led to a greater focus on implementing boulevard multi-use trails, whereas cities with narrower streets and more urban forms have focused on bike lanes and on-street infrastructure.

Current Ontario and national design guidance as well as guidance from countries like the Netherlands (with much higher bicycle mode shares) recommend alternate routes or separated bicycle infrastructure for streets with the width, number of lanes, operating speeds, and traffic volumes that are found on most arterial roads and major collectors in Mississauga. Boulevard multi-use trails are one facility type that may provide a comfortable cycling facility, in the right context, however the selection of an appropriate facility requires a context sensitive approach that takes into account many factors including the recommended separation of bicycles and pedestrians where space allows.[45]

Public feedback through the 2018 Cycling Master Plan included suggestions to separate pedestrians and cyclists at locations such as the Burnhamthorpe Trail, Waterfront Trail, Etobicoke Creek Trail, Culham Trail, and various popular trails in Meadowvale.

Designing Multi-Use Trails for the Mississauga Context

Many of the operational issues related to multi-use trails that were raised through stakeholder consultation indicate opportunities for improved design. A review and comparison was conducted of the most up-to-date design standards and guidelines for multi-use trails and dedicated bicycle facilities in the boulevard—such as raised cycle tracks and bike-only paths. Some highlights of best practices as they pertain to multi-use trails are included below.

Figure V-14: Two-way bike path with adjacent pedestrian path, through a park in the Netherlands. Red asphalt and white markings are standard for all bike infrastructure in the country.

Splash Pad

Splash pads are the area between the curb and the boulevard multi-use trail or boulevard bike facility. The Mississauga standard width for splash pads is 0.75 m. Open doors from a parked vehicle may extend up to a metre, and so that should be the target width if curbside parking is present.

Trail Width

For two-way multi-use trails or bike paths, recommended widths vary, but are generally 3.0 to 4.0 m. These can narrow to 2.4 m at an absolute minimum in constrained spaces, for very short distances and should include warning signage at these locations. Recommended widths are consistent with the widths currently implemented in Mississauga.

Lateral and Vertical Clearances

A horizontal clearance of 1.0 m is typically recommended from the edge of off-road trails. This can take the form of a splash pad, a cleared area of vegetation, pedestrian buffer, or sidewalk/pedestrian path (if space is constrained). The horizontal clearance allows for better sightlines, and an additional cleared surface for emergency maneuvers. Vertical clearance on all bikeways must be a minimum of 2.5 m.

Clearances from street trees are determined according to the size and species of tree. Forestry staff are consulted in the design and alignment of trails to determine tree impacts and necessary mitigations.

Obstacles

Utility poles, traffic signal poles and light standards represent the most common obstacles on boulevard trails in Mississauga, particularly at intersections. Recommended best practices suggest 1.0 m of clearance from trail edge and obstacles. Minimum clearance from these and other obstacles should be established and applied on all trails.

Pedestrian Buffer

Design guidance generally recommends a minimum 0.3 to 0.6 m buffer between a boulevard bicycle facility and a sidewalk. The buffer can either be raised, such as a curb or planters, or flat, such as grass or textured pavement. Bricks, pavers, or textured concrete should provide a contrasting colour, as well as a tactile feature to help those with visual impairments. A crossable buffer is useful when the cycle track and sidewalk are at their minimum widths, so as to allow users to temporarily cross over if necessary. This buffer area, if wide enough, may also be used for poles and other street furniture.

Sidewalk/Pedestrian Path

In locations where it is not feasible to install a separate sidewalk, but separation of cyclists and pedestrians is desired, it is possible to use bicycle and pedestrian symbols to guide users along the intended path. These facilities should be designed with extra width to accommodate this separation. Sidewalks or pedestrian paths are recommended to be furthest away from the roadway. This is a more

comfortable side for pedestrians, being farther away from motor traffic, potentially being under tree shade, and having direct access to destinations and connections along the street. Pedestrian paths beside bike paths outside of the street right-of-way should be on the side of the trail that provides better access to destinations, or provides a better view, such as being closer to the river on a trail that runs alongside it.

Figure V-15: Example of separated path in Quebec City, which runs both in street boulevards, and on its own alignment along the waterfront.

Figure V-16: Example of multi-use trail with adjacent sidewalk in Toronto. Note the use of a red tactile buffer between bicycle and pedestrian areas. As well, poles and obstacles are placed in the buffer or out of the way of the pedestrian and cycling areas.

Upgrading Trails and Unpaved Multi-Use Trails

There are locations where park paths and unpaved multi-use trails could be upgraded to provide safer and more comfortable riding surfaces. Paved trails are also more accessible to users with limited mobility, or those using wheelchairs or other mobility devices.[46] The Culham Trail is a major trail that is unpaved, but both popular and useful to cyclists. Unpaved sections along the Etobicoke Creek Trail are being upgraded through Public Transit Infrastructure Funding as this route supports access to transit facilities.

There are locations where park paths form important connections in the cycling network. There is an opportunity to identify, and upgrade some of these paths to multi-use trail standards, including comfortable and intuitive interfaces to adjacent bicycle infrastructure. A consideration of park paths and off-road cycle routes is crime prevention through environmental design. Mississauga Crime Prevention Through Environmental Design (CPTED) principles indicate that park paths used at all hours should be closer to areas with more people, such as being close to residences, as opposed to being through a wooded or hidden area.[47] This is an important consideration when identifying path connections for commuting purposes.

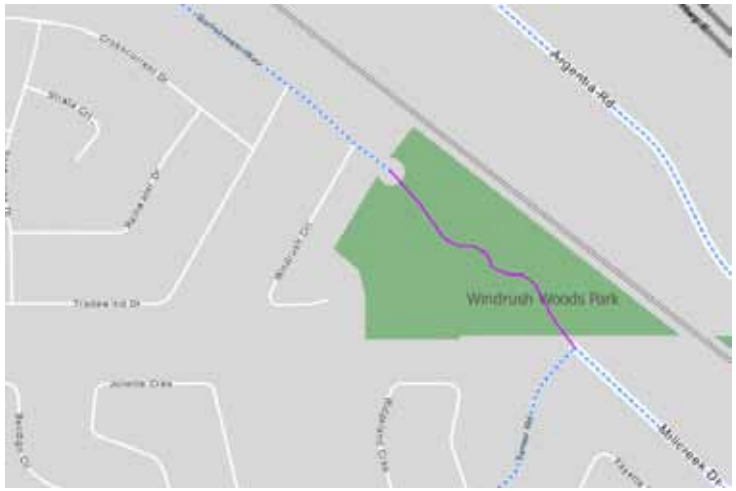


Figure V-17: An example of an existing park path connecting two sections of a neighbourhood. This path (in Windrush Woods Park) also leads to a GO rail station, and illustrates a situation where a separate bike path or multi-use trail built to modern design standards and with destination signage (to GO) could benefit and attract cyclists.

Figure V-18: Culham Trail is an unpaved path which runs along the Credit River. Paving the trail and ensuring connections to surrounding neighbourhoods could increase its safety and comfort for all users.

Figure V-19: A multi-use trail in Mississauga, on Lakeshore Road West. This is an example of an easy conversion to a two-way cycle track, due to an existing adjacent sidewalk. Pavement markings and intersection improvements would be needed for the conversion.

Figure V-20: A section of the Culham Trail. Paving trail surfaces would increase their utility and attractiveness to cyclists, and their accessibility to everyone. In wider sections such as this, cyclists and pedestrians can be given their own paths.

Pavement Markings

Centreline

All the design manuals consulted recommend centrelines for two-way cycle track and multi-use trails. These should be yellow, as per standard practice for North America. However, other centreline colours can be used for branding purposes. Centreline markings can be broken where passing is permitted, or solid, to indicate that passing is discouraged. A number of trail design guidelines indicate that centrelines should be solid within 10 m of a crossing, or on blind curves. Centrelines are also recommended to be solid on steep hills. Canadian design guidance recommends a centreline 0.1 m in width.[48]

Symbols

Bicycle and pedestrian symbols are recommended in *OTM Book 18* and *TAC Bikeways Design Guide* for use on multi-use trails, and pedestrian symbols on adjacent pedestrian paths/ sidewalks if they are asphalt and there may be confusion to users. Along with the symbols, arrows are recommended to show the direction of travel for bicycles in areas of potential confusion, such as a transition between a one-way and two-way facility.

Trail Edge Lines

Edge lines on cycle tracks and multi-use trails are useful for delineating the trail from similar surrounding pavement, or when the trail is unlit. The CROW manual recommends edge lines for unlit paths, and says they may be preferable to lighting in some situations, as they provide more contrast on dark surfaces.[49] In Mississauga, there is an opportunity to improve unlit trails through dark parklands, or those that are in street boulevards, but some distance from the road lighting.

Branding

Markings can be used for trail branding. In Toronto, the Waterfront Trail/Martin Goodman Trail uses a blue and green double centreline, and the Pan Am Path uses a red centreline. A blue colour, for example, could be used for the Waterfront Trail in Mississauga, both as a centreline, and for wayfinding through the various segments. On-road sections of the trail could use blue-coloured branding as well, such as a logo, or blue sharrows.

Figure V-21: Pavement markings for cycle tracks, bike paths and multi-use trails

Yellow Broken Centreline
Used on multi-use trails (with bicycle and pedestrian symbols) and cycle tracks (with only the bicycle symbol).

Yellow Solid Centreline
Used on multi-use trails/cycle tracks near intersections, on blind curves, on steep hills, or any combination of those.

White Edge Lines
Improve visibility on unlit paths, especially when not in a street right-of-way.

White Separation Line
A white line can be used to separate a multi-use trail into a bike path and pedestrian path. In addition to bicycle symbols on the bicycle section, pedestrian symbols should be on the pedestrian section.

Figure V-22: Hydro corridor trail in Toronto. All new major trails in the city have centrelines.

Figure V-23: Separated multi-use trail with adjacent pedestrian area, in Toronto. The blue and green lines provide branding and wayfinding for the Martin Goodman Trail/ Waterfront Trail.

Lighting

Adequate lighting helps cyclists feel safe at night. The *TAC Bikeway Design Guide* and *Vélo Québec Planning and Design for Pedestrians and Cyclists* (2010) recommend that bicycle facilities more than 5 m away from the lit part of the roadway should have their own lighting. *OTM Book 18* and Vélo Québec recommend that lighting be "pedestrian-scale" or 3–6 m tall.[50]

Lighting is desirable on urban routes, particularly those which make important connections off the roadway, such as through parks. Lighting may not be desirable in trails through sensitive natural areas, as it may disrupt wildlife. Animal-friendly lighting (low-level and/or automatically-triggered by trail users) is advocated by the CROW manual. As well, some CPTED resources say that lighting is only beneficial for crime prevention if there are nearby potential witnesses, such as residential units around a suburban park.[51] In the absence of trail lighting, white trail edge markings can provide good contrast of the pavement edges.

Parks and Forestry currently do not provide lighting on new trails to discourage use after dark. For linear trails that may function as important commuter cycling routes, lighting may help to encourage commuter cycling particularly during darker seasons or for people working outside of daytime working hours.

Trail Intersections

The point where two or more trails meet can be a hazard if not designed well. Guidelines suggest the use of coloured pavement or other contrasted surfacing to highlight intersections, as well as widening the trail and ensuring clear sightlines to help users navigate around each other.[52]

Trail Access Control

Restricting trail access to only authorized users is important to prevent the encroachment of vehicles onto trails. However, it is important to consider the impact that these measures have on intended trail users. Current design guidance suggests only the use of a single centre bollard on the trail, should there be a concern of trail incursion. Bollards should be a contrasting colour, and plastic flex-posts may offer a safer alternative in case they are struck by a cyclist.[53]

P-gates or barrier gates are not recommended in most design guides, and are discouraged in the *OTM Book 18*, Toronto and Vélo Québec trail design guidelines, as they pose a hazard to cyclists, potential hazard for persons with visual or other impairments, and thus a potential liability.

Figure V-24: Trail intersection on the Martin Goodman Trail in Toronto. The open view and wide design allows users to better navigate around each other at this location where cyclist volumes are often very high.

Figure V-25: Single bollard used for vehicle access control on the Finch Hydro Corridor Trail.

Transit Stops

Waiting, boarding, and alighting passengers can create a conflict zone around transit stops. As recommended by most design guidelines, multi-use trails should be routed around transit stops wherever possible, and be clearly delineated to discourage users from encroaching into each other's space.

Figure V-26: Bus stop with separate loading platform, in Mississauga, on Burnhamthorpe Road East. This design keeps the trail behind the stop, and minimizes pedestrian-cyclist conflicts.

Barrier Crossings

Where off-road trails meet various large barriers—such as highways, railways, and rivers—and a significant detour is required to cross, crossing facilities should be considered. Bridges and tunnels offer different advantages and disadvantages and are appropriate in different contexts. Design guidance including basic dimensional specifications is important to ensure that bridges and tunnels are designed to maximize cyclist safety and comfort, avoiding sharp turns and steep grades whenever possible and including considerations for personal security particularly in tunnel crossings. As noted before, major barrier crossings are critical to implementing a connected cycling network in Mississauga. Locations of barriers and potential crossings should be identified, and crossings prioritized.

Figure V-27: Active transportation crossing of the QEW in Mississauga.

Figure V-28: Active transportation crossing of a highway in the Netherlands.

Multi-Use Trails at Driveways and Intersections

In practice, well-designed driveway crossings of multi-use trails and two-way bike paths follow one of two basic designs: "bend-out" crossings or "bend-in" crossings as illustrated in **Figure V-29**:

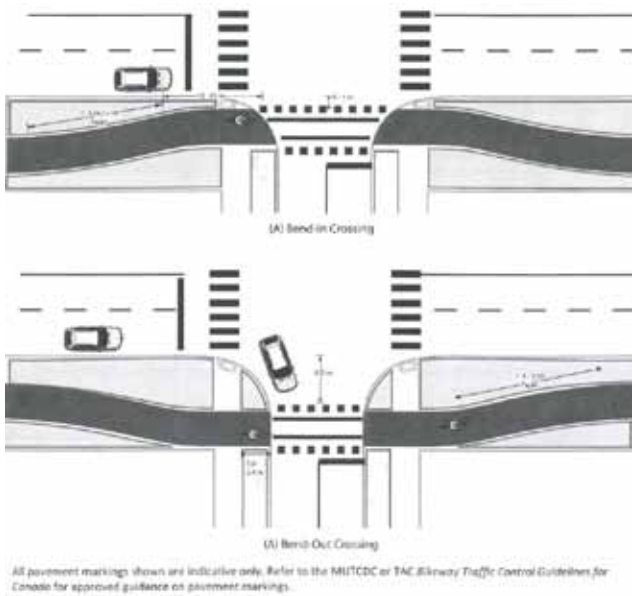


Figure V-29: "Bend-in" and "Bend-out" boulevard trail crossing (Image credit: *TAC Bicycle Integrated Design*, 2017)

Bend-Out Crossing

A bend-out crossing is typically used when there is a high volume of trail users and motor vehicle traffic. This design aims to provide spatial separation between vehicles entering or exiting the driveway and trail users. This increases the visibility of trail users and provides more reaction time to help avoid conflicts. Extra space between the roadway and trail crossing also gives vehicles entering or exiting the driveway a place to stop and wait for traffic to clear without having to block the trail, or hold up traffic on the roadway.

Bend-In Crossing

A bend-in crossing is typically used when bicycle and motor vehicle traffic volumes are lower. It aims to increase visibility of cyclists at intersections by bringing them into the sight lines of vehicles approaching the intersection, and includes elements like smaller curb radii to slow down traffic turning traffic. Wider driveways or intersections may have a median, to stop traffic from making wide turns in front of crossing cyclists.

Pavement markings are an important feature of all multi-use trail crossings and should indicate pedestrian and cyclist paths. Bicycle signals are also needed at signalized intersections and can be used to separate bicycle crossing time from turning motor vehicles where turning volumes are high. Additional design features such as raised crossings and medians may also be incorporated into either of these types of intersection designs where appropriate to provide additional safety benefits.

Multi-Use Trail Design Guidelines Comparison

Table V-1 shows a comparison of multi-use trail design guidance from other jurisdictions.

Table V-1: Comparison of multi-use design guidance from other jurisdictions

	OTM Book 18 2013 & Ontario Bikeways Design Manual 2014	TAC 2017 Design Guide: Chapter 5 Bicycle Design	Toronto Multi-Use Trail Design Guidelines 2015	NACTO 2014 Urban Bikeway Design Guide	Vélo Québec Planning and Design for Cyclists 2010	CROW 2016 Design Manual for Bicycle Traffic
Terminology: MUT in street ROW	Active transportation path In-boulevard multi-use path	Multi-use path	Multi-use trail	No guidance	No guidance	Combined path
Terminology: MUT outside of street ROW	Off-road multi-use trail	Multi-use path	Multi-use trail	No guidance	Multi-use trail	Combined path
Terminology: Cycle track in street ROW	Raised cycle track In-boulevard bicycle facility	Bike path	Segregated-use MUT	Raised cycle tracks	On-road bike path	Segregated cycle path
Terminology: Cycle track/bike path outside of street ROW	No guidance	Segregated multi-use path, bike path	Segregated-use MUT	No guidance	Off-road bike path	Solitary cycle path
Cyclist-pedestrian segregation threshold	Where space permits, separate pedestrian and cycling facilities should be considered	> 20% pedestrians, and total users > 33 persons per hour per metre of path width, or < 20% pedestrians, and total users > 50 persons per hour per metre of path width	Separated configuration should be used rarely, only when significant conflicts between cyclists and pedestrians cannot be resolved	No guidance	In urban settings, parallel pedestrian and bike paths are recommended.	Combined paths for up to 25 pedestrians per hour per metre of pavement width. Use of combined paths discouraged. Only for very restricted sections without residential or storefront usage, or activity by elderly.
Width: Multi-use trail	Minimum: 3.0 m Recommended: 4.0 m Constrained: 2.4 m (over very short distances)	Minimum: 2.7 m Recommended: 3.0–6.0 m	Minimum: 2.7 m Recommended: 3.0–4.1 m	No guidance	Recommended: 3.0 m	Minimum: 2.4 m

	OTM Book 18 2013 & Ontario Bikeways Design Manual 2014	TAC 2017 Design Guide: Chapter 5 Bicycle Design	Toronto Multi-Use Trail Design Guidelines 2015	NACTO 2014 Urban Bikeway Design Guide	Vélo Québec Planning and Design for Cyclists 2010	CROW 2016 Design Manual for Bicycle Traffic
Width: 1-way cycle track	Minimum: 1.5 m Recommended: 2.0 m	Minimum: 1.5 m Recommended: 1.8–2.5 m	No guidance	Minimum: 1.5 m Recommended: 2.0 m	Minimum: 1.5 m Recommended: 2.0–2.5 m	Rush hour bike volume: Width 0–150: 2.0 m 150–750: 2.5–3.0 m > 750: 3.5–4.0 m
Width: 2-way cycle track	Minimum: 3.0 m Recommended: 4.0 m	Minimum: 2.4 m Recommended: 3.0–3.6 m	Minimum: 2.7 m Recommended: 3.6 m	Constrained: 2.4 m Recommended: 3.7 m	Constrained: 2.5 m Recommended: 3.0 m	Per rush hour bike volume: Width 0–50: 2.5 m 50–150: 2.5–3.0 m 150–350: 3.5–4.0 m > 350: 4.5 m
Usage of 1-way vs 2-way cycle tracks	Bidirectional cycle tracks may be cheaper and allow better access to maintenance vehicles. Transitions to unidirectional facilities are problematic, and there are more conflicts at intersections that need to be addressed.	Bidirectional paths can provide cyclists more direct routes in areas with large block lengths and intensive land use. Intersections require special consideration, and unidirectional paths are generally recommended on roadways.	No guidance	Use if: • Few conflicts on one side of street • Not enough room for cycle track on both sides • One-way streets • More destinations on one side • Extra width on one side • To connect with other facility on one side	On-road bike paths should preferably be unidirectional. Bidirectional paths have complications at intersections, though they may be appropriate if there are a lack of intersections along one side of the street.	Built-up areas should use one-way paths. Bidirectional could be used if: • It shortens the route and provides a logical connection • Prevents risky road crossing, though usually bidirectional paths on each side will be necessary • There is insufficient space on one side of the road • Crossings should be raised

	OTM Book 18 2013 & Ontario Bikeways Design Manual 2014	TAC 2017 Design Guide: Chapter 5 Bicycle Design	Toronto Multi-Use Trail Design Guidelines 2015	NACTO 2014 Urban Bikeway Design Guide	Vélo Québec Planning and Design for Cyclists 2010	CROW 2016 Design Manual for Bicycle Traffic
Road buffer	On-street parking: 1.0 m Splash strip: 1.0 m	1.0 m	Minimum: 1.5 m Recommend 3.0 m if no sidewalk, to facilitate future sidewalk installation	Mountable curb (1-way only): 0.3 m Raised curb and/or parking: 0.9 m	Minimum (if parking): 0.5 m	Minimum: 0.35 m Road speed 50 km/h: 1.0 m Road speed 60 km/h: 1.5 m Road speed 80 km/h: 4.5 m
Pedestrian buffer	Varies	No guidance	Minimum: 0.3 m Recommended: 0.6 m	Use color, pavement markings, textured surface, landscaping, or other furnishings	Recommended: 1.0 m	If needed, 0.3 – 0.5 m verge/buffer
Horizontal clearance	Minimum: 0.5 m	0.2 m for obstructions 100–750 mm high, 0.5 m for obstructions greater than 750 mm	Minimum: 0.6 m Recommended: 1.0 m	No guidance	Minimum: 1.0 m	0.25 m for low curbs/verges, 0.5 m for higher curbs, 0.7 m for fixed objects, 1.0 m for closed wall
Vertical clearance	Minimum: 2.5 m	Minimum: 2.7 m Recommended: 3.6 m	Minimum: 2.5 m Recommended: 3.0 m	No guidance	Minimum: 3.0 m	Minimum 2.5 m
Design speed	35 km/h	20–30 km/h recommended. 40–50 km/h for steep downhills, prevailing strong tailwinds, dual (passing) bike lanes.	20–30 km/h	No guidance	20–30 km/h	30 km/h for main network. 20 km/h for secondary network.

	OTM Book 18 2013 & Ontario Bikeways Design Manual 2014	TAC 2017 Design Guide: Chapter 5 Bicycle Design	Toronto Multi-Use Trail Design Guidelines 2015	NACTO 2014 Urban Bikeway Design Guide	Vélo Québec Planning and Design for Cyclists 2010	CROW 2016 Design Manual for Bicycle Traffic
Curve radius	20 km/h: 10 m 30 km/h: 20 m	20 km/h: 10 m 30 km/h: 24 m	Minimum: 10 m Recommended: 20 m	No guidance	20 km/h: 8 m 30 km/h: 17 m	12 km/h: 5 m (minimum) 20 km/h: 10 m 30 km/h: 20 m
Running slope	Maximum: 5%	< 4% ideal, 6%–8% only if necessary	Maximum: 5%	No guidance	Maximum: 6%	Maximum 7.5% for very short sections, formula provided for slope determination.
Vehicle access control	Bollards recommended if needed. Flex bollards cheaper, safer, and accessible by emergency vehicles. (182) P-Gates not recommended	No guidance	Signage with no physical barrier preferred. If needed, use flexi-bollards with 1.5–2.0 m space per direction. P-Gates discouraged	No guidance	Bollards or gates should only be used if there is a significant risk of unauthorized access. Bollards must have at least a 1.0 m opening. Chicanes (p-gates) are not recommended and may pose a hazard to cyclists. Only appropriate locations may be at railway crossings.	Bollards only if necessary, in a contrasting colour. Width 1.6 m between.
Cyclist dismounting	Asking cyclists to dismount should not be relied on in lieu of adequate road design	No guidance	Road crossings designed so that cyclists do not have to dismount	No guidance	No guidance	No guidance

	OTM Book 18 2013 & Ontario Bikeways Design Manual 2014	TAC 2017 Design Guide: Chapter 5 Bicycle Design	Toronto Multi-Use Trail Design Guidelines 2015	NACTO 2014 Urban Bikeway Design Guide	Vélo Québec Planning and Design for Cyclists 2010	CROW 2016 Design Manual for Bicycle Traffic
Surface	Asphalt highest rated overall, granular surface lowest rated	Asphalt, concrete, coloured pavement, and paving stones are appropriate. Granular, timber, and cobblestone are less comfortable and preclude use of some bikes.	Asphalt recommended, granular not recommended	No guidance	Asphalt has the most benefits and fewest drawbacks. Concrete is also ok, though joits can be unpleasant. Stone dust and chip seal are also options, but may preclude other users.	Asphalt recommended, but concrete, tiles, and paving stones may be acceptable.
Markings	(Centreline width: 100 mm (Pedestrian, cyclist, and directional arrows should be used	Centreline width: 100 mm * From TAC Bikeway Traffic Control Guidelines for Canada 2012	Trail centreline to be solid within 10 m of an intersection. Solid lines should be used on curves and approaches to crossings.	Dashed yellow centreline helps distinguish cycle track from pedestrian area	(Bike paths should have markings. Off-road paths should have centrelines on busy stretches and steep curves. Markings on multi-use trails may be detrimental, as it may encourage high-speed cycling to the detriment of other users. Wider trails should have lines to separate bikes and pedestrians.	Centreline width: 0.1 m Normal: 0.3 m line, 2.7 m gap Warning (for curves with restricted sightlines): 2.7 m line, 0.3 m gap If path unlit, use edge markings: 0.05–0.1 m wide

	OTM Book 18 2013 & Ontario Bikeways Design Manual 2014	TAC 2017 Design Guide: Chapter 5 Bicycle Design	Toronto Multi-Use Trail Design Guidelines 2015	NACTO 2014 Urban Bikeway Design Guide	Vélo Québec Planning and Design for Cyclists 2010	CROW 2016 Design Manual for Bicycle Traffic
Lighting	Pedestrian-scale lighting should be used for in-boulevard facilities when lighting from roadway is not sufficient.	Lighting considered important. Priority to intersections, crossings, and where path is more than 5 m from roadway lighting.	Lighting recommended for MUTs, except where lighting would impact sensitive wildlife activities, invite trail users into dangerous situations, or conflict with special requirements.	No guidance	Lighting has significant impact on how safe user feels, and how frequently paths are used at night. Paths should have dedicated lighting if more than 5 m from the roadway. Path light poles should be 3–6m tall.	Lighting desirable, especially on paths in urban areas, but away from roadway lighting. Automatic lighting (triggered when bicycles approach) or animal-friendly lighting may be used on recreation trails, though it may be desirable not to light trails, but to have edge markings instead, which provide contrast.
Maintenance	Maintenance vehicles (such as small street sweepers) typically require 2.0 m unobstructed running width Primary/important bike facilities should get priority year-round maintenance Surface repairs important due to narrow width of bicycle wheels, cracking and potholes a major concern	Year-round maintenance considered important. Priority maintenance network could be used to maintain access to major destinations.	Maintenance should be done on a per-task basis, and different divisions in charge of trails could combine resources for similar tasks. Some activities, such as litter clean-up could be done with volunteers.	Raised cycle tracks should be maintained to be free of pavement damage, broken glass, and other debris. They may be incompatible with regular sweeping and plow equipment. Snow should not be stored on the raised cycle track. Raised cycle tracks receive less wear and tear than travel lanes.	Street sweeping may be required weekly to keep bike paths free of debris. 2 m bike paths can be cleaned by small street sweepers. Snow clearing should be planned for priority cycling routes.	Important for lifecycle costs to be part of initial cost estimates, including winter maintenance, weeding, resurfacing, etc.

	OTM Book 18 2013 & Ontario Bikeways Design Manual 2014	TAC 2017 Design Guide: Chapter 5 Bicycle Design	Toronto Multi-Use Trail Design Guidelines 2015	NACTO 2014 Urban Bikeway Design Guide	Vélo Québec Planning and Design for Cyclists 2010	CROW 2016 Design Manual for Bicycle Traffic
Barrier crossings	Refers to OTM Book 15	Grade-separation may be preferred around high-speed on/off ramps, interchanges, highways, and other barriers. Crossings should conform to same slope and width guidelines for bike paths.	Roads exceeding 35,000 vehicles per day, 60 km/h, and 4 lanes are not appropriate for an at-grade crossing. Grade-separated crossings of rail line is preferred over any at-grade solution.	No guidance	Overpasses and tunnels have their own benefits and drawbacks. For cyclists, there is a higher convenience factor and energy saving with tunnels, as they require less change in elevation.	Grade separation should be used for roads with greater than 70 km/h. It is more desirable to have cycle path level, with roadway going over or under. Otherwise, tunnels are generally more preferred due to the gentler slope, and more efficiency for cycling, provided it is designed with safety in mind.
Transit stops	Bicycle facility should pass behind transit stop. If not feasible, then transit shelter should be as far as possible from bike facility in order to minimize conflicts.	Bikeway should be routed behind transit stop, to create 2.5 m wide transit island. Markings and design should clearly define crossing points for pedestrians.	No guidance	At transit stops, consider wrapping the cycle track behind the stop. At intersections, an extended mixing zone may be provided.	Asphalt bypass bike path should leave 1 m for pedestrians to enter and exit a bus.	Cycle paths should steer away and around transit stop so that cyclists do not experience any nuisance from stopping buses. Path should be at least 0.65 m from bus shelters, and passengers should have 2 m wide waiting area.

On-Road Cycling Facilities

Bicycle Facility Types and Key Considerations for the Mississauga Context

The following section highlights different types of bicycle facilities and some key considerations for implementation. Recommended dimensions and design guidance are available in the most recent TAC guidelines and *OTM Book 18* and are not discussed in detail here.

Shared Roadways

The majority of secondary cycling network routes identified in the 2010 CMP were recommended as shared roadways. In most cases, the signed speed limit on these roadways is 50 km/h or higher and 85th percentile operating speeds where available range from 47–71 km/h.

Figure V-30: Shared bicycle route in Mississauga

Canadian guidance recommends that if a bicycle facility does not include a physical separation (e.g. shared roadway or roadway with a conventional bike lane), the speed differential between cyclists and motor vehicles should not exceed 20–25 km/h (Cyclists typically travel at speeds between 15 and 30 km/h.)[54]

In contrast, Dutch design standards set speed limits on roadways shared between cyclists and motorists at 30 km/h in urban conditions.[55] (The Netherlands has the one of the highest bicycle mode shares—26%—and one of the best bicycle safety records in Europe—1.1 fatalities per 100 million kilometres cycled.)[56]

When examined using Step 1 of the *OTM Book 18* facility selection process, many shared routes identified in the 2010 CMP are on roadways with traffic volumes and speeds that trigger recommendations for designated cycling facilities like separated or conventional bike lanes. Traffic calming would be required in order for many of these locations to meet recommended guidance.

Bicycle Boulevards

Bicycle boulevards create traffic-calmed streets that function as comfortable shared routes to complement routes on busier roadways. This facility type is included in Mississauga's draft Multimodal Street Guidelines as "Bike Friendly Streets" and some cities like Vancouver, Portland and Berkeley have built networks of bike boulevards that offer convenient and low stress cycling routes for relatively low cost. Bicycle boulevards require continuous and direct routes on local streets or where pedestrian/bicycle only connections connect local streets. Cyclists are not typically willing to deviate from the most direct route except for very short

distances. Because most of the local streets in Mississauga are not in a grid pattern, a comprehensive network of bicycle boulevards is not possible. However, there are some locations where bicycle boulevards could create comfortable cycling routes while providing local traffic calming.

Figure V-31: A median refuge island diverter is used in Vancouver, BC to manage volume on this bicycle boulevard. (Photo credit: Richard Drdul)

Guidance for the design of bicycle boulevards[57] includes:

- low speeds (85th percentile speeds of 40 km/h or less);
- low traffic volumes (<3,000 vehicles per day);
- clear wayfinding including signs and pavement markings;
- safe major and minor street crossings with minimal delay to provide for continuous travel;
- connectivity to destinations;
- higher priority for repaving or spot improvements to ensure smooth surfaces;
- speed management measures such as maximum posted speeds of 40 km/h or less, vertical and horizontal deflection such as speed humps and curb extensions; and
- volume management to discourage through traffic.

Mississauga's Traffic Calming Policy states that diverters, barriers and closures should be avoided where possible because of the restrictions they introduce to residents, and emergency and municipal services. However, the policy does support balancing the needs of these services and slowing traffic on local and minor collector roadways through consultation with affected service stakeholders. The importance of providing a safer and more comfortable cycling environment along a bicycle boulevard route would be included in this consideration. Bicycle boulevards may offer an opportunity to improve upon shared routes currently proposed on streets showing higher traffic volumes and speeds than desired.

Conventional Bike Lanes

Conventional bike lanes have become relatively common as a bicycle facility and have been installed in Mississauga. Pilot projects have tested green pavement at some intersection approaches and a double stripe buffered bike lane has been installed by the Region of Peel along a section of Dixie Road between Londonderry Road and Lakeshore Road to create higher visibility in this location where traffic volumes and speeds are high. Other types of conventional bike lanes include contra-flow bike lanes and left-side bike lanes that are applicable only on one-way streets and therefore are not currently planned in Mississauga.

Figure V-32: Through bike lane marked through an intersection (Image credit: NACTO)

Figure V-33: "Floating" transit stops protect cyclists on a buffered bike lane in Seattle, WA (Image credit: NACTO)

Figure V-34: Buffered bike lane in Minneapolis, MN (Image credit: City of Minneapolis)

Figure V-35: Intersection markings, Chicago IL (Image credit: CDOT)

Aspects of conventional bike lane design that have not been installed on Mississauga roadways to date but would improve visibility, legibility and comfort at certain locations include:

- Buffered bike lanes that include a painted, hatched buffer area to provide additional space;
- Intersection and driveway markings to indicate the presence of a bike lane and the expected travel path of cyclists through these areas of conflict; and
- Treatments to integrate with transit, such as green pavement markings at transit stops to increase visibility of mixing zones.

Advisory Bike Lanes

Advisory bike lanes are a relatively new facility and street configuration in North America. This facility uses dashed white lines and bicycle symbols to define the preferred space for motorists and cyclists on narrow streets that would otherwise be a shared roadway treatment. Similar to a shared roadway condition, advisory bike lanes overlap into the motor vehicle travel lanes and motor vehicles are permitted to enter the advisory bike lanes when necessary. These operating conditions are similar to narrow residential roadways with parked cars, where opposing conflicting traffic yields and waits on parking areas until there is sufficient width to pass. Parking is not permitted in advisory bike lanes but could be present in a parking lane separate from the advisory bike lane.

Advisory bike lanes are intended for roadways with low to moderate volumes of two-way traffic where conflicting motor vehicle and bicycle movements will be limited. This creates a more comfortable cycling condition without the need to widen the paved surface of the roadway.

The US Federal Highway Administration report, *Small Town and Rural Multimodal Networks* (2016),[58] provides guidance on the planning and design[59] of this facility type under the terminology "Advisory Shoulder" and "Dashed Bicycle Lane." More recently, Alta Planning has authored a white paper (August 2017)[60] which examines the 12 formal installations of advisory bike lanes in North America as of July 2017. The paper provides important planning and design guidance and concludes that cities who have implemented advisory bike lanes have found them to increase cycling rates, slow motor vehicle speeds, and connect cycling networks. Experience to date has demonstrated that advisory bike lanes work best in these conditions:

- Low-to-moderate traffic volume (≤ 5,000 average daily traffic);
- Low-to-moderate motor vehicle speed (≤ 50 km/h);
- Insufficient roadway width to support dedicated bicycle lanes without widening;
- If parking lanes are present they should be well used.

Figure V-36: Advisory bike lanes in Ottawa, ON (Image credit: Justin Swan, City of Ottawa/Alta Planning)

Public outreach has been included as a component of many advisory bike lane installations. The City of Ottawa created an educational campaign including signage on-site and a video[61] to communicate to community members how the new advisory bike lanes operate. These facilities may be appropriate at some locations in the secondary network and, if applied correctly, could improve comfort and visibility for cyclists.

Protected Bicycle Facilities

There are currently no protected bike lanes in Mississauga but plans for raised cycle tracks have been included in the Hurontario LRT project. Two-way cycle tracks have also been identified in the Downtown Mississauga Movement Plan.

The terminology used to describe protected cycling facilities varies between jurisdictions and can lead to some confusion. For consistency, the 2018 Cycling Master Plan and all of its appendices use the terminology in *OTM Book 18*:

- **Physically separated bicycle lanes**

  Physically separated bicycle lanes are installed on the roadway and provide a physical barrier between cyclists and motor vehicles.

- **Raised cycle tracks**

  Raised cycle tracks are located adjacent to the roadway and are vertically separated from the roadway—either at sidewalk height, or at an intermediate height between the sidewalk and roadway. Cycle tracks can be one-way or two-way, but are for cyclists only and are not shared with pedestrians. There is evidence to support the claim that cycle tracks provide a safer cycling environment, provided there is good intersection design. Some evidence suggests that one-way cycle tracks are safer than two-way,[62] and both types of cycle tracks are safer than cycling on a shared roadway.[63] The means of separation between cycle tracks and sidewalks is an important consideration in order to prevent conflict between pedestrians and cyclists, and must include consideration of pedestrians with visual or other impairments. Special consideration is needed at transit stops to allow for through bicycle traffic while accommodating pedestrians waiting, boarding and alighting transit vehicles.

  The width of cycle tracks must also consider the need for cyclists to pass one another, particularly in areas where bicycle volumes are likely to increase. Intersection treatments are critical to the safe operations of cycle tracks.

Figure V-37: Raised cycle track. In locations where the sidewalk is adjacent to the cycle track tactile pavement is used to separate the two facilities. (Image Credit: MMM, 2012)

Figure V-38: A shared cycle track transit stop may be an appropriate retrofit on constrained transit routes. (Image Credit: Payton Chung)

Figure V-39: A two-way cycle track with floating transit stop. (Image Credit: Dongho Chang)

- **In-boulevard bicycle facilities and boulevard multi-use trails**

  In-boulevard facilities differ from cycle tracks because typically, they are not immediately adjacent to the roadway but are set back with a boulevard or splash strip between the edge of the roadway and the bicycle facility. In-boulevard facilities are implemented where motor vehicle speeds and volumes are high and additional separation is needed to provide a safe and comfortable cycling environment. A setback from the curb also provides space for snow storage. Intersection treatments along these facilities are critical to ensuring safe operation.

  Mississauga has implemented several multi-use trails. Available research has shown that shared multi-use trails introduce higher potential for risk than may be expected by users.[64] Comments from stakeholders have also indicated a lack of comfort for cyclists and pedestrians on in-boulevard multi-use trail facilities at some locations.

  The speed differential between pedestrians and cyclists can be significant and impacts the safety and comfort of all users. Separating pedestrians and cyclists is preferred where space allows and particularly where volumes are expected to increase. If cyclist and pedestrian volumes are low but expected to increase in the long term, it may be preferable to protect for a future sidewalk.

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