LAKEVIEW VILLAGE

INTERSECTION DESIGN REPORT

FEBRUARY 2020

LAKEVIEW
COMMUNITY PARTNERS LIMITED

TMIG
A T·Y·LIN INTERNATIONAL COMPANY

LAKEVIEW
COMMUNITY PARTNERS LIMITED

TACC CONSTRUCTION LTD.

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Lakeview Village

Intersection Design Report

FINAL ▪ FEBRUARY 2020

REPORT PREPARED FOR

LAKEVIEW COMMUNITY PARTNERS LIMITED

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EXECUTIVE SUMMARY

The Municipal Infrastructure Group (TMIG) has prepared the following report to address comments from the City of Mississauga Fire and Emergency Services Group regarding proposed Lakeview Village Right-of-Way (ROW), corner radii treatments, and general intersection design. In particular, this report addresses comments regarding the need for a fire vehicle to navigate proposed Lakeview Village intersections without encroaching upon opposing lanes, thus requiring larger-than-desired corner radii and/or potentially wider-than-necessary travel lanes.

The internal intersections of Lakeview Village have been designed based on the Complete Streets and Vision Zero philosophies to encourage safe, convenient and comfortable travel and access for users of all ages and abilities regardless of their mode of transportation. Designing the internal roadway system of Lakeview Village in this way inherently promotes active forms of transportation through the provision of attractive design alternatives that reduce automobile dependency in support of a vision of a strong, clean, healthy, and more sustainable community.

TMIG acknowledges the critical importance of emergency response times, however, placing emergency access as the over-riding intersection design consideration could very likely cause regular daily safety concerns for vulnerable road users, such as pedestrians and cyclists. This report provides a variety of best practices for the design of safe, inclusive intersections for all road users based on national, provincial, and GTA-specific design guidelines.

A summary of proposed Lakeview intersection design features and their positive influence on pedestrian, cyclist, and driver safety are provided below and are discussed in greater detail in the balance of this report.

- Reducing intersection corner radii shortens pedestrian and cyclist crossing distances across roadways
- Reducing intersection corner radii increases pedestrian visibility (as well as cyclist) – pedestrians are brought closer to the corner where they are better positioned within sightlines of approaching vehicles
- Reducing intersection corner radii decreases vehicular turning speed – vehicles are forced to slow down to maneuver tighter corners, in turn lowering the impact speed of a vehicle-pedestrian collision
- As vulnerable road users, pedestrians and cyclists are highly susceptible to injury in the event of a collision with a vehicle – the probability of severe injury or death increases significantly with impact speed, which would be the unintended result of providing larger corner radii
- City of Toronto Road Engineering Design Guidelines, specifically developed to address the constraints of urban roadway and intersection design, allow for emergency vehicles to encroach upon opposing lanes
- The City of Mississauga's Downtown 21 Master Plan specifies a standard 7.6 metre intersection curb radius for all street types within the downtown area to promote the "reasonable" access of emergency vehicles within downtown and allow for reasonably short pedestrian crossing distances while encouraging motorists to "make turns at reasonably safe speeds". *Note: Lakeview's intersection design proposes 8.0 metre curb radii throughout the development, thus is in excess of the City's own Downtown 21 Master Plan.*
- Existing City of Mississauga Roadway Design Standards specify that several types of residential intersections are to be designed with 8 metre curb radii, which implies many residential intersections across the City have already been constructed with 8 metre curb radii (which aligns with the 8 metre curb radii proposed by Lakeview Village). In theory, fire trucks must already be navigating these existing intersections by encroaching upon opposing lanes (i.e. crossing the centreline) in order to navigate turning through these residential intersections.

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Rendering of Lakeview Square and the water entry feature

INTRODUCTION

Lakeview Village is envisioned to be a highly connected community of the future that embraces a diverse and close-knit mix of residential, institutional, cultural, office and retail spaces. With a primary focus on sustainability, the Lakeview Village transportation framework has been designed to promote attractive alternatives to reduce automobile dependency to support the vision of a strong, clean and healthy community.

The internal intersections of Lakeview Village have been designed based on the Complete Streets philosophy to encourage safe, convenient and comfortable travel and access for users of all ages and abilities regardless of their mode of transportation. With this in mind, intersection design throughout the Lakeview Village community has proposed 8 metre curb radii at all internal intersections to enhance public realm space, slow vehicular traffic, and to reduce pedestrian and cyclist crossing distances across active vehicular lanes.

Many municipalities in Ontario have adopted Vision Zero, including the City of Mississauga and the Region of Peel. Vision Zero is a road safety program developed in Sweden that refuses to accept that fatalities and serious injuries are inevitable consequences of mobility on our roads. Vision Zero aims to create a worldwide road traffic system where no human being is killed or seriously injured.

As long as people are responsible for operating vehicles we will never prevent all crashes. This is because people make mistakes. One way that Vision Zero attempts to accommodate human error is by ensuring crash impact energy remains below the thresholds likely to result in death or serious injury. It goes beyond establishing speed limits to managing interactions between the environment, infrastructure and physical vulnerability. Effective speed mitigation strategies create safer roads, roadsides and vehicles to accommodate driver error.

The Lakeview Community has been designed with Vision Zero in mind. This is achieved in part through a speed mitigation strategy of road narrowing and the reduction of curb radii at intersections. This design also has the secondary benefit of improving sightlines and shortening the turning radii of left and right turning vehicles to better protect pedestrians and cyclists. This is important given that a significant portion of road deaths (up to 20% in urban areas) have been attributed to pedestrians being struck by turning vehicles when legally crossing within intersections.


Rendering of Townhomes at Aviator Park

Lakeview Village supports reducing speed limits on its internal roadways as a speed mitigation measure in conjunction with providing appropriately scaled intersection curb radii. These two speed mitigation measures in particular are a strong combination, as vehicles traveling at slower speeds are able to better navigate smaller curb radii, and thus would not require larger (oversized) curb radii based on reduced speed limits.

In addition to slowing traffic, the proposed 8 metre curb radii at all internal intersections throughout Lakeview Village will aid in creating a compact, urban environment within the new development. Should intersections be required to accommodate unfettered movement of large fire services vehicles throughout the site, larger curb radii and enlarged intersections will be necessary, representing a significant departure from the desired urban design.

LAKEVIEW URBAN DESIGN CONSIDERATIONS

2

Rendering of a Mid-rise Community

LAKEVIEW URBAN DESIGN CONSIDERATIONS

Lakeview Village is designated as one of Mississauga's major nodes, and aims to become a major urban-scaled development on the City's waterfront. An important component of designing Lakeview Village to an urban scale is creating roadways that promote active transportation as a viable, safe, and enjoyable mode of transportation.

Creating a pedestrian-friendly, urban-scaled development is of utmost importance to achieve Lakeview Village's goal of being an innovative, sustainable, and highly connected waterfront community. Designing urban roadways throughout the Lakeview Community to be safe and accessible for all road users, with a particular focus on pedestrian safety, will aid in providing attractive transportation alternatives to reduce automobile dependency within Lakeview Village and beyond.

The choice of curb radii impacts many components of intersection design such as vehicle turning speed, pedestrian crossing distance and directness, sight lines, and road surface area. The curb radii required at an intersection can also impact the developable area of the land abutting the intersection. These aspects of intersection design, in addition to existing City of Mississauga standards, were taken into consideration while developing the urban-scaled, pedestrian-friendly intersections of Lakeview Village.

2.1 City of Mississauga Intersection Design Standards

The City of Mississauga's Roadway Design Standards provide standard drawings for the design of various sizes of intersections and provide examples of intersections between roads of the same or differing road classifications. City of Mississauga Design Standards drawings for the design of intersections involving residential roads are provided in **Appendix A** for reference purposes.

The current City design standards specify 8, 12, or 15 metre curb radii between roadways, dependent upon the classification of the roads that intersect with each other. The majority of the roads within Lakeview Village are proposed as the equivalent to the City's definition of minor residential, residential, or minor residential collector roads. Three roads within Lakeview Village are identified as major collectors (26 metre Right-of-Way (ROW)), providing one lane in each direction for vehicular traffic. **Figure 2-1** provides a summary of the proposed Lakeview Village road classifications and their associated ROW widths.

Any intersection made up of a combination of roads from any of Mississauga's three residential roadway classifications requires a minimum curb radius of 8 metres between intersecting roads (with the exception of the intersection of two minor collector roads requiring 12 metre curb radii). Examples of minor residential, residential, and minor residential collector road intersections are provided in **Figure 2-2**.

The intersection of two collector roads requires the intersection to be designed with 15 metre curb radii based on current City of Mississauga design standards. Based on their standard intersection design drawings, a collector road designation assumes a 26 metre ROW, and collector roads presented in the design drawings have two vehicular travel lanes in both directions. Although the three Lakeview Village major collector roads are designed with a 26 metre ROW, they are designed with only one lane of vehicular traffic in each direction and provide robust active transportation infrastructure (a cycle lane and sidewalk on both sides of the road) in place of an additional lane of vehicular travel.

Figure 2-1 Lakeview Village Street Hierarchy

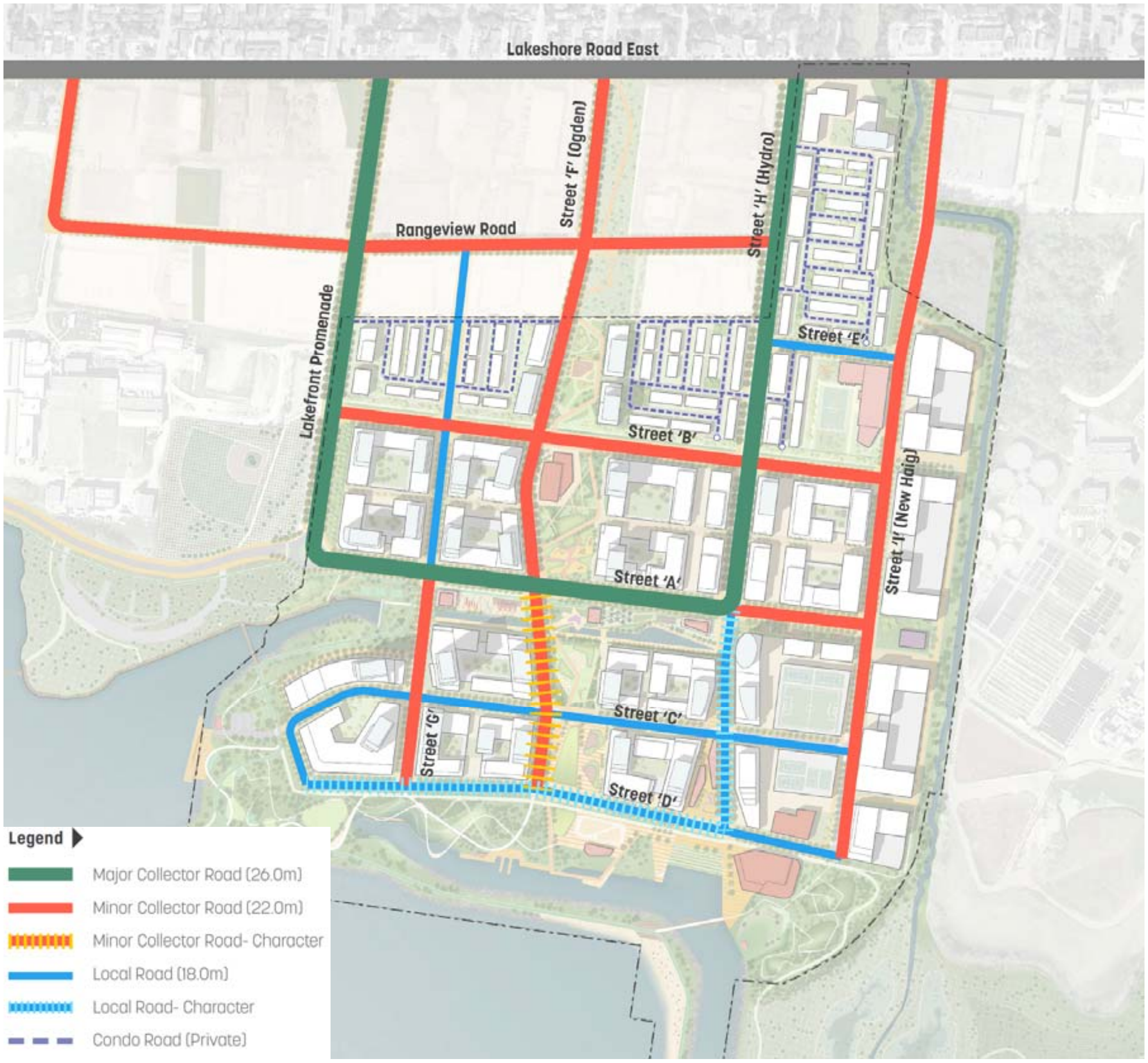
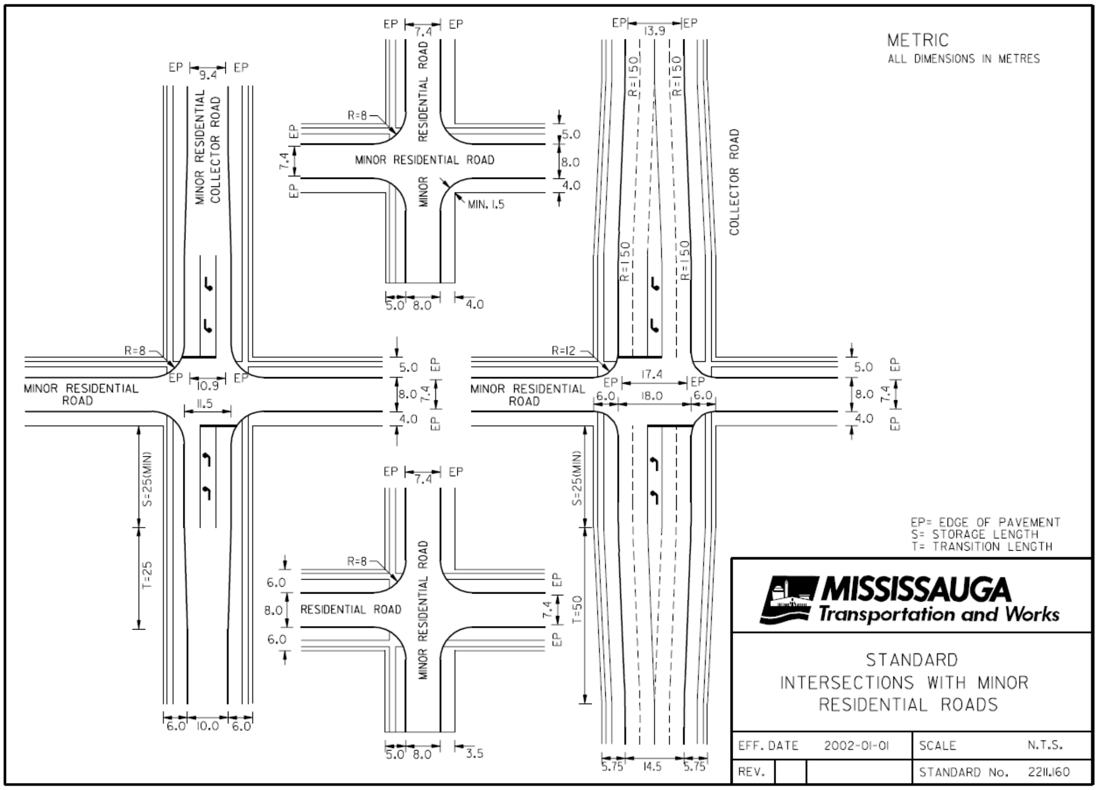
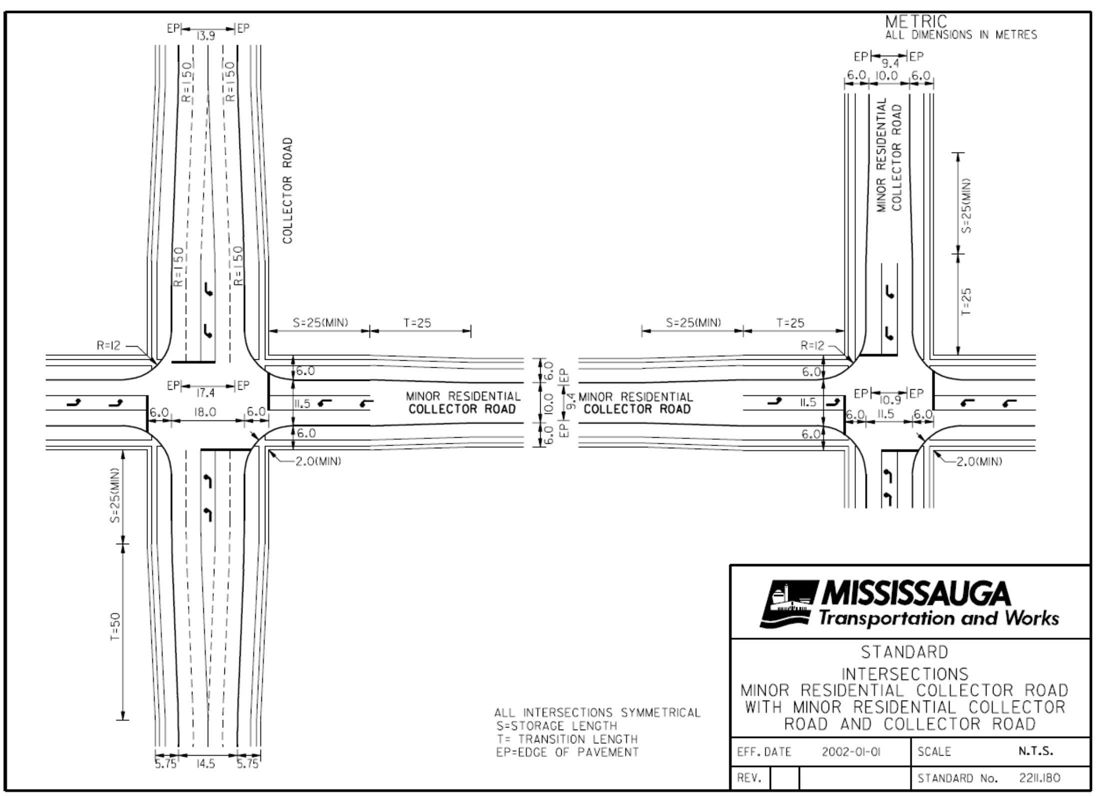


Figure 2-2 Examples of City of Mississauga Intersection Design Standards





2.2 Urban Design and Street Scale

Incorporating current urban design best practices is of high importance for Lakeview Village in order to create an environment that is safe and welcoming to all road users, in keeping with the Complete Streets philosophy. In addition to TMIG's design expertise and approach, NAK Design Strategies was consulted to provide input for this report regarding urban design best practices and the incorporation of all road users in a safe, urban environment. The following is an excerpt from the information that was provided by NAK Design Strategies.

> *We can also think of this issue from the standpoint of street scale and the manner drivers, cyclists and pedestrians perceive space. Simply put, where there are wide streets and travel lanes with little to frame the street (ineffective tree planting, undersized building massing, oversized building setbacks, lack of on-street parking, etc.), drivers tend to drive significantly faster, often without realizing they are doing so. The wider street expanse and increased vehicular speeds also results in a more hostile environment for pedestrians and cyclists. In more compact street environments (narrower streets and travel lanes, robust street tree planting, on-street parking, strong building relationship, etc.) drivers proceed more cautiously and slower and pedestrians and cyclists feel more comfortable. This is important to keep in mind when considering that the greater the corner radii, the longer the pedestrian crossing distances, the further buildings are pulled away from the corner and the more expansive the intersection, resulting in the ability of cars to navigate turns at a greater speed, thereby increasing the likelihood of accidents and reducing the sense of comfort for the pedestrians and cyclists.*
>
> *There are several recent local development masterplan examples, including Regent Park and Canary District in Toronto, where the tightening of guidelines around corner radii and lane widths have effectively slowed traffic and reduced the number of vehicular-pedestrian incidences. This is further reinforced by the older residential streets in Toronto that have significantly reduced dimensions when compared with the current suburban standards put forward by Mississauga.*

As highlighted by NAK Design Strategies, curb radii can have a significant impact on the scale and feel of an intersection and the resulting safety for all road users. By implementing “compact street environments”, vehicles are less prone to speeding, which provides increased safety for all road users, but in particular pedestrians and cyclists. Reduced curb radii allow for improved street scaling and framing at intersections to promote all road users to travel through the intersection at an appropriate speed and awareness of other road users, further reducing the risk and severity of collisions between road users.

Reducing corner radii also aids in minimizing the required offset of buildings on land adjacent to intersections. The proximity of buildings to an intersection affects the framing of an intersection, thus, larger curb radii will push buildings further away from intersections and give drivers the impression of an open, suburban-sized intersection, leading to higher automobile speeds and increased danger to vulnerable road users.

Another possible side-effect of increasing curb radii and placing buildings further away from intersections is a loss in the developable area of a piece of land abutting an intersection. This apparent loss in developable area will reduce a building's footprint and could lead to increasing the height of the building in order to compensate for the gross floor area (GFA) lost to the reduced building footprint. Given that the height of buildings can be a contentious issue for existing residents near a new development, reduced curb radii can indirectly allow for shorter buildings (with equivalent GFA) by providing a larger amount of developable area for lands abutting intersections.

2.3 Pedestrian Design Considerations

Lakeview Village is envisioned as a highly connected and accessible community for all road users. Given that pedestrians are the most vulnerable road user in terms of serious injuries and fatalities from collisions, a particular focus on the safety of pedestrians is appropriate when designing intersections. As has already been stated in this report, the curb radii at intersections have a direct impact on pedestrian crossing distances and walking times.

Figure 2-3 provides a comparison between applying an 8 metre and a 15 metre curb radius to a proposed Lakeview Village intersection. Of particular interest, the impact curb radii has on crossing distance for pedestrians and cyclists is clearly illustrated. Increasing the curb radii from 8 metres to 15 metres results in a 50% to 85% increase in crossing distance at the intersection displayed in **Figure 2-3**.

As pedestrian crossing distances increase with larger curb radii at an intersection, the time it takes a pedestrian to cross the intersection will also increase. **Table 2-1** compares the pedestrian crossing times for the crossing distances provided in **Figure 2-3** for 8 and 15 metre curb radii. Three different walking speeds were selected from Chapter 9 of the City of Toronto's Compete Streets Guidelines to compare a variety of pedestrians at different stages of life. Crossing distances corresponding to an average pedestrian (1.0 m/s), an aging pedestrian (0.9 m/s), and an elementary school-aged pedestrian (0.6 m/s) are provided in **Table 2-1.**

Table 2-1 Example Pedestrian Crossing Times – 8.0 vs. 15.0 metre Curb Radii

Intersection Leg / Type of Road	Crossing Distance[1] (m)		Crossing Time (m)					
			1.0 m/s Average Pedestrian Walking Speed[2]		0.9 m/s Older Pedestrian Walking Speed[2]		0.6 m/s Elementary School Student Walking Speed[2]	
	8.0 m radii	15.0 m radii	8.0 m radii	15.0 m radii	8.0 m radii	15.0 m radii	8.0 m radii	15.0 m radii
North Leg Major Collector (26.0m ROW)	9.0	16.7	9.0	16.7	10.0	18.6	15.0	27.8
South Leg Local (18.0m ROW)	7.5	13.7	7.5	13.7	8.3	15.2	12.5	22.8
East Leg Minor Collector (22.0m ROW)	10.4	15.7	10.4	15.7	11.6	17.4	17.3	26.2
West Leg Major Collector (26.0m ROW)	10.4	15.6	10.4	15.6	11.6	17.3	17.3	26.0

1. *Crossing distances are based on dimensions provided in Figure 2-3*
2. *Walking speeds based speeds presented in Toronto's Complete Street Guidelines*

For all pedestrians crossing the intersection, regardless of walking speed, the crossing time will increase proportional to the increase in crossing distance. For example, an elementary school student crossing the north leg of the intersection will take 15 seconds when the intersection is designed with 8 metre curb radii, but will take 27.8 seconds to cross the same leg when the intersection is designed with 15 metre curb radii. This 85% increase in crossing time corresponds to the 85% increase in crossing distance (9.0 metres to 16.7 metres).

Accordingly, if increasing the curb radii from 8 metres to 15 metres at the example intersection in **Figure 2-3** results in a 50% to 85% increase in crossing distance, the pedestrian crossing times will also increase by 50% to 85%, resulting in a longer amount of time a pedestrian is required to cross live lanes of traffic. In summary, shorter crossing distances (due to smaller curb radii) provide shorter crossing times for pedestrians, which results in pedestrians being removed from live lanes of traffic more promptly.

Minimizing pedestrian crossing times can also be strategic at signalized intersections, as the shorter the pedestrian walk time is, the sooner the pedestrian phase can be completed and a green phase can be provided to the opposing flow of traffic. This can be particularly important at an intersection that has a high volume of vehicles and pedestrians traveling in opposing directions.

Pedestrian crossing times at signalized Lakeview Village intersections may also need to be increased beyond the City's current standards in order to accommodate the anticipated higher than average pedestrian activity within the development compared to other areas of the City. Shortening pedestrian crossing distances will also help to offset this need for increased pedestrian crossing times at signalized intersections.

2.4 General Design Considerations

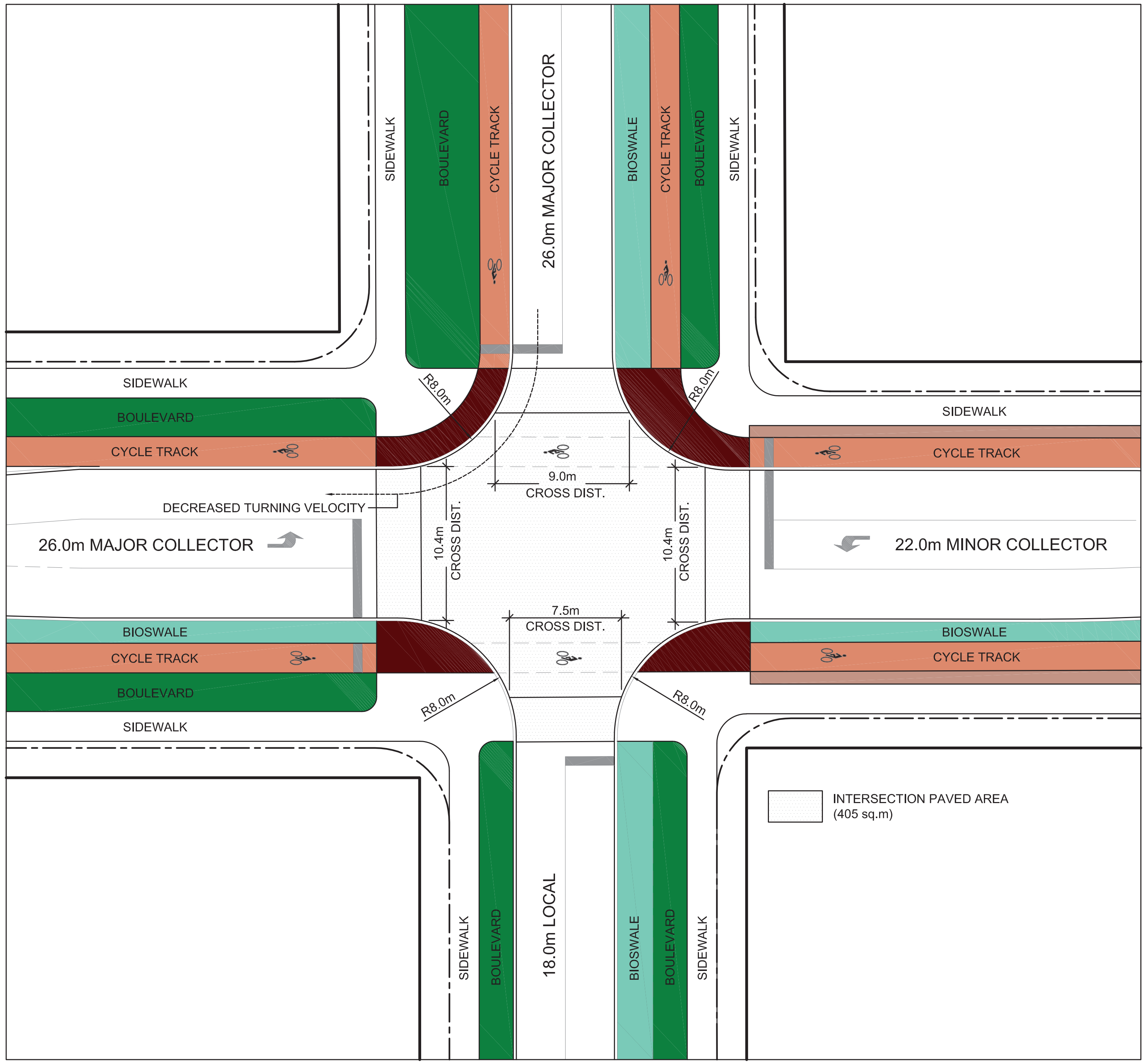
The reduction of curb radii at an intersection also has the potential to impact other areas of roadway design, and the benefit of smaller curb radii is not limited to the safety of road users.

For example, reduced curb radii results in an overall reduction in the surface area of the paved roadway of an intersection. This minimized paved area can lead to maintenance benefits such as reduced snowfall volume to clear from the intersection during the winter, which can also result in lower snowbanks at the intersection. Reducing the height of snowbanks at an intersection provides better sightlines for all road users (increasing safety) and limits discomfort to pedestrians traversing the snowbank between the time it is left behind by a road plough and a sidewalk plough later clears the snowbank.

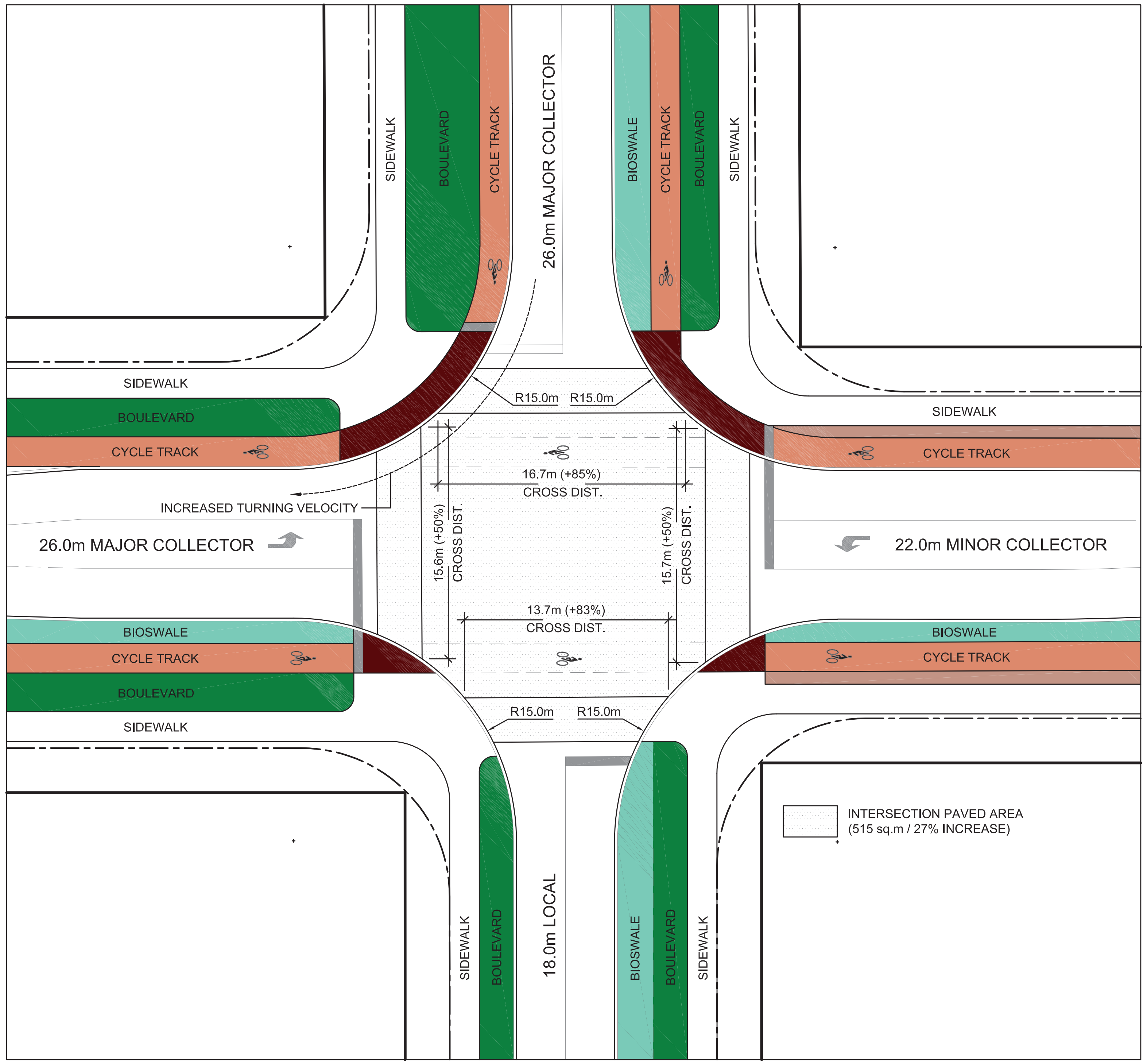
Increasing curb radii at an intersection also increases the overall length of the intersection, which in turn will reduce the length of a road between two intersections. This shortening of roads between intersections in Lakeview Village could lead to a potential loss of bio-retention areas in the boulevard and a loss of on-street parking.

A recent example of innovative intersection design is not improving an intersection to accommodate a large design vehicle, such as a fire truck, but to design the vehicle to fit the intersection (so as not to overdesign the intersection for its day-to-day users). The City of Hamilton added an "urban pumper" to its Fire Department vehicle fleet in 2019. The pumper is designed with a shorter wheelbase and an overall shorter length in order to navigate tighter turns that are common in an urban environment.

As the City of Mississauga moves forward with its commitment to Vision Zero, it may be time for the City to start investigating ways that technology can allow vehicles to adapt to "Vision Zero road designs" instead of maintaining the status quo of oversizing roads to ensure efficient vehicle movement at the cost of safety for all road users.



A. INTERSECTION WITH 8.0m RADIUS CORNERS



B. INTERSECTION WITH 15.0m RADIUS CORNERS

FIGURE 2-3

LAKEVIEW VILLAGE - CORNER RADIUS COMPARISON

January 6, 2020

NAK design strategies

3 CHANGES IN APPROACH TO CANADIAN ROAD DESIGN

Rendering of the Cultural Hub

CHANGES IN APPROACH TO CANADIAN ROAD DESIGN

Historically, roads were designed to prioritize cars and trucks over other users to ensure quick and efficient movement. They were built with wide lanes and large intersection turning radii to ensure maximum efficiency. This thinking led to the unintended consequence of increased serious collisions and speeding and required vulnerable road users (pedestrians and cyclists) to be allocated to the periphery of the right-of-way. Over the last few decades new approaches have been adopted by road authorities intending to slow traffic and provide safer spaces for cyclists, pedestrians and other active modes.

Evidence of this can be found in the guiding standards used throughout the province and country. These standards include the Transportation Association of Canada's (TAC) Geometric Design Guide for Canadian Roads and the Ontario Ministry of Transportation's (MTO) Ontario Traffic Manual (OTM). Engineering Guidelines developed by the City of Toronto and two of the City of Mississauga's Master Plans were also reviewed, as they provide GTA-specific commentary on fire truck movements through intersections and the impact of curb radii on all road users.

3.1 TAC Geometric Design Guide

The TAC Geometric Design Guide discusses the interaction between pedestrians, cyclists, and vehicles at intersections in multiple sections and gives consideration to safety for all road users while maintaining acceptable intersection operations. Topics such as curb radii design, pedestrian crossing distances, the influence of vehicle speed in vehicle-pedestrian collisions, and driver expectations are included in the TAC Design Guide to provide intersection design guidance to benefit all road users.

The TAC Geometric Design Guide sections referenced in this report are provided in **Appendix B** in their original format.

3.1.1 Impacts of Intersection Curb Radii on Pedestrian Safety

Specifically, Chapter 6 of the TAC Design Guide provides guidance for the design of roads and intersections with a particular focus on the pedestrian realm and its interaction with roadways and intersections. When considering the design of a pedestrian crossing at an intersection, Section 6.4 of the TAC Guide states the following.

> *"Since pedestrians are the most vulnerable road user group, their design needs should promote safety and comfort by managing motor vehicle speeds, improving visibility and sightlines, reducing pedestrian crossing distance, increasing crossing directness and providing accessible spaces."*

Many of the pedestrian design needs listed in the TAC Guide are impacted by the curb radii selected for intersection design. In particular, "the size of the corner radius can significantly affect pedestrian comfort and safety". The following items are listed in Section 6.4.4 of the TAC Design Guide and are influenced by the radius of a curb:

- Available pedestrian queueing space
- Pedestrian crossing distance
- Pedestrian crossing directness
- Pedestrian and motorist sightlines and visibility
- Speed of turning motor vehicles

3.1.2 Pedestrian Crossing Distance and Directness

The effects of curb radius on pedestrian crossing distance and crossing directness is illustrated in **Figure 3-1** of the TAC Guide, emphasizing the potential increase in crossing distance and decrease in crossing directness as the curb radii of an intersection increases.

Figure 3-1 Effect of Corner Radius on Pedestrian Crossing Distance and Directness

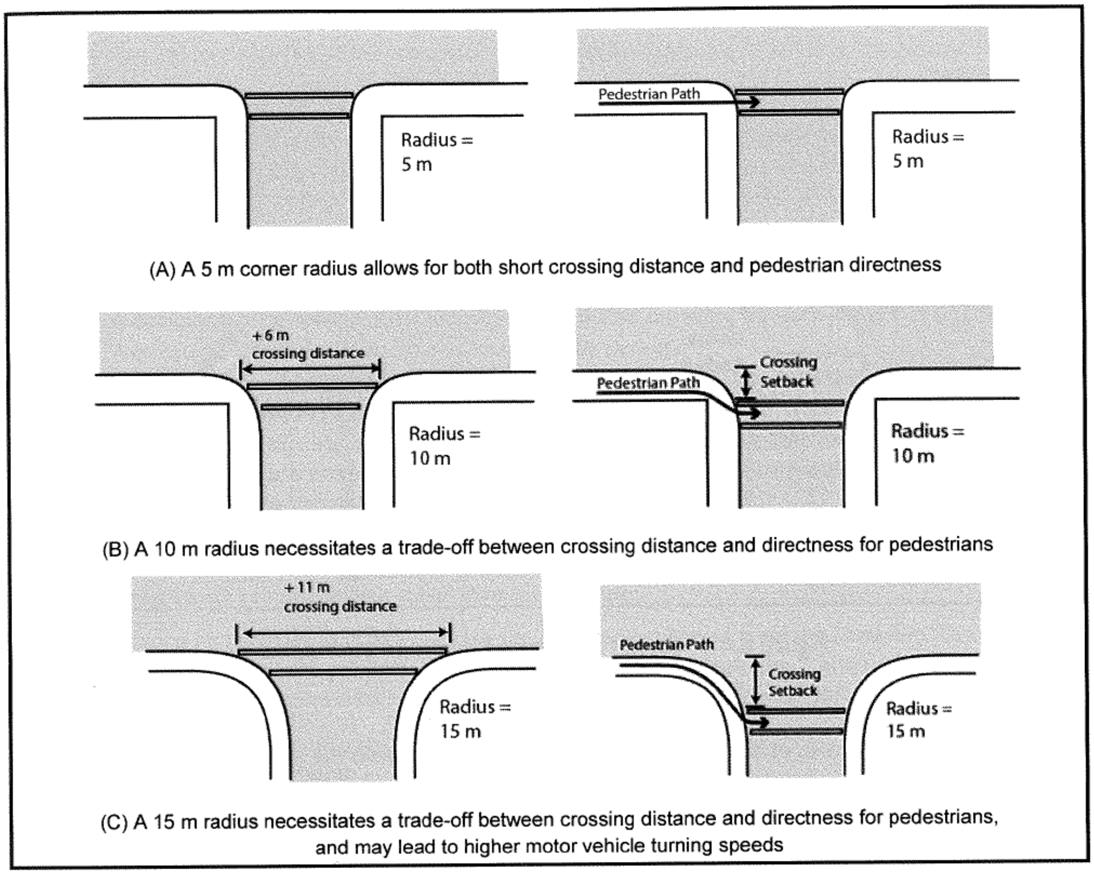


Figure Source: TAC Geometric Design Guide, Chapter 6, Figure 6.4.5

The TAC Design Guide provides the following description of **Figure 3-1**:

> *"With larger corner radii (above 5m), the location of the crosswalk necessitates consideration of trade-offs between pedestrian crossing distance, crossing directness and visibility. Increased corner radius increases the pedestrian crossing distance unless the crosswalk location is set back further from the intersection, which affects crossing directness and visibility as shown in Figure 3-1."*

3.1.3 Vehicle Speed and Severity of Collisions with Pedestrians

In addition to the impacts increasing the intersection curb radii has on pedestrian crossing distance and directness, an increase in a curb's radius can lead to vehicles performing turning movements at higher speeds. Section 9.13.2 in Chapter 9 of the TAC Design Guide discusses the need to reduce curb radii at intersections to address both vehicular speeds and pedestrian crossing needs.

> *"Large corner radii encourage higher speeds by turning vehicles and increase the distance pedestrians must travel to cross the roadway at an intersection. Where pedestrian crossing volumes*

*are significant, it is desirable to design the curb radii to conform to the **minimum design vehicle turning path**, thereby reducing vehicular turning speeds and minimizing the pedestrian crossing distance."*

The TAC Design Guide also identifies the contribution of vehicle speed in the severity of vehicle-pedestrian collisions. **Figure 3-2** in the Guide summarizes historical vehicle-pedestrian collision data and comments that, "collisions at 30 km/h or less correlate with a lower probability of death, whereas at motor vehicle speeds above 40 km/h, the probability of death increases significantly".

Figure 3-2 Relationship between Vehicle Speed and Risk of Pedestrian Death in a Collision

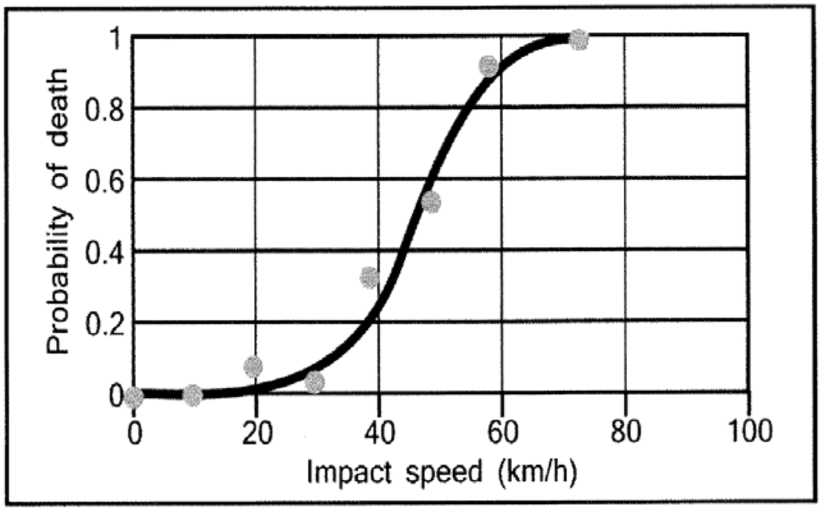


Figure Source: TAC Geometric Design Guide, Chapter 6, Figure 6.2.4

Any effort made to reduce vehicle speed and vehicle-pedestrian conflicts will help to protect pedestrians from potential injury and death.

3.1.4 Intersection Design and Driver Expectations

Both Chapters 2 and 9 of the TAC Design Guide identify the importance of designing roadways and intersections in such a way that driver expectations will be met. A roadway that meets driver's expectations (it has been designed in the "usual way") is of particular importance when drivers are visitors to the area and are unfamiliar with the roadway or intersection. According to Section 2.2.5.4, if an intersection or roadway has an abnormal design compared to what a driver expects or is used to from their previous driving experiences, "the potential for driver error and an inappropriate driver reaction increases substantially."

Driver expectations can also be applied to pedestrian traffic – if pedestrians cross an intersection at a location a driver does not expect or is used to, there is a higher likelihood of collision if a driver is not expecting to interact with pedestrians at a certain location of an intersection or roadway.

As discussed previously, the radius of a curb can have a significant impact on the location, length, and directness of a pedestrian crossing at an intersection. Of particular concern is if the crossing location is not in line with a pedestrian desire line, and a pedestrian crosses the road outside of the designated pedestrian crossing area, causing a driver's expectations of pedestrian crossing location to be violated (see **Figure 3-1**(c)).

3.2 MTO – Ontario Traffic Manual

The Ontario Traffic Manual is a collection of 18 books that guide the implementation of traffic signs, signals, pavement markings and more throughout the province. They are updated regularly to reflect changes throughout our road system. Much of what is outlined in the TAC guide is repeated in the OTM, but we have provided the following excerpts illustrating the need for smaller radii in highly urban areas.

The OTM sections referenced in this report are provided in **Appendix C** in their original format.

3.2.1 OTM Book 15 – Pedestrian Crossing Treatments

Book 15 – Pedestrian Crossing Treatments, 3.3.2 Walking Considerations

"The potential for conflicts and collisions is directly affected by the level of interaction between road users. A higher exposure of pedestrians interacting with vehicles (from higher vehicle and/or pedestrian volumes, or a higher number of potential conflict points) will generally result in a higher potential for pedestrian collisions."

"The higher the vehicular speed at the time of impact, the higher the probability of fatality of pedestrians. Relatively small changes in speed can have a large impact on the severity of a pedestrian collision (particularly between 40 km/h and 60 km/h)."

"Expectancy influences the speed and accuracy of information processing; and conditions that meet or reinforce expectancies help drivers and pedestrians to respond quickly, efficiently and without error. Violations of expectancy increase the chance of inappropriate decisions that lead to conflicts or inability to control vehicles safely."

"Pedestrians differ in terms of their mobility, their speed, and their ability to perceive and react to potential conflicts.... Designs for crossing devices should have regard for the needs of all pedestrians (i.e., the elderly, the young, and persons with a disability)."

"Pedestrian crossings are a critical element among the many factors that influence the overall walkability of an environment. The factors that can affect walkability… include, but are not limited to, distance of the trip, perceived safety and security of the route, and the comfort and convenience of walking versus the alternative modes of transportation."

"Examples of elements that directly impact the perceived and actual safety of pedestrians:

- *Pedestrian crossings that have excessive crossing distances*
- *Pedestrian crossings with fast-turning vehicles*
- *Lack of crossing facilities at a convenient location"*

"Some factors that create a … environment that is conducive to walking include:

- *Ample separation of pedestrian facilities from high-speed vehicular traffic*
- *Safe, convenient and unambiguous street crossings"*

Book 15 – Pedestrian Crossing Treatments, 5.1.2 Pedestrian Crossover Assessment

"Crossing distance has an impact on the likelihood of a pedestrian collision, particularly on roads with higher traffic volumes (i.e., the wider the crossing distance, the more difficult it is for pedestrians to safely cross the street)."

Book 15 – Pedestrian Crossing Treatments, 6.2.1.1 Crosswalk

"Crosswalks should be as short as possible without compromising other design factors."

3.2.2 OTM Book 18 – Cycling Facilities

Book 18 – Cycling Facilities, 2.4.5 Safety and Comfort

"The factors that influence the level of safety and risk exposure for a particular bikeway include: user conflicts, traffic volume and speed, truck and bus volumes, on-street parking, surface quality, sightlines, maintenance considerations and human factors."

Book 18 – Cycling Facilities, 2.5 Bicycle Design Supporting Complete Streets

"Complete Streets are roadways which have been designed to be a safe, attractive, accessible and integrated environment for all road users across all modes… Cycling infrastructure is a key element of the Complete Streets mix."

Book 18 – Cycling Facilities, 3.2.2.2 Step 2: A More Detailed Look

"Heavy vehicles, such as transport trucks and buses have a greater influence on cyclists than passenger vehicles. This is partly due to the larger difference in mass between cyclists and heavy commercial vehicles, and the increased severity of any resulting collision."

Book 18 – Cycling Facilities, 4.2.1.4 Design Applications - Pavement Markings at Intersections / Conflict Zones for Through Moving Cyclists

"Intersections are shared space zones. The entirety of the area where two streets intersect can be used by all vehicles, including cyclists. At certain locations, there may be a benefit to providing pavement markings or treatment through the intersection. Such markings may help to guide cyclists between facilities on either side of the intersection. They also highlight conflict areas where cyclists and motor vehicles will cross paths so that each user group is more aware of the other."

Book 18 – Cycling Facilities, 5.4 Conflict Zones

"A conflict zone is an area where different types of road user cross travel paths and, therefore, the risk of collisions is higher."

"These conflicts generally occur where a cyclist is making a through movement and a motorist is turning. They can occur within the roadway, particularly through intersections…"

3.3 City of Toronto Road Engineering Design Guidelines

The City of Toronto has been developing City-specific engineering design guidelines for road works, as City staff has acknowledged that national and provincial design guidelines do not necessarily reflect the geometric design constraints unique to highly urban environments. For example, Part 6 of the City of Toronto's Road Engineering Design Guidelines focuses on how to determine the curb radii required at a given intersection. The guidelines include instructions as to how specific design vehicles are allowed to travel through an intersection, including their starting position lane, if they can encroach upon other lanes or turning movements, and their minimum distance from a curb when performing a turning movement. One such design vehicle is a City of Toronto Aerial fire truck.

Based on Section 6.3.1 of the Curb Radii Design Guidelines, a fire truck can be assumed to start a right turn movement from outside of its lane of travel, so long as it maintains a 300mm offset from the curb, as described below.

"Fire trucks shall be assumed to initiate a right turn from anywhere on the roadway in order to be able to manoeuvre a turn. Vehicles shall maintain a minimum 300mm offset from the face of curb."

As described in Section 6.3.2 of the Curb Radii Design Guidelines, a fire truck can be assumed to complete a right turn movement using any lane of travel, so long as it maintains a 300mm offset from the curb, as described below.

> *"Fire trucks shall be assumed to manoeuvre right turns using the entire roadway. Vehicles shall maintain a minimum 300mm offset from the face of curb."*

Based on City of Toronto engineering guidelines, a fire truck is not required to remain within its own lane and is allowed to encroach upon opposing traffic lanes when performing a right turn movement under urban conditions.

The sections of the City of Toronto Road Engineering Design Guidelines referenced in this report are provided in **Appendix D** in their original format.

3.4 Mississauga Cycling Master Plan

Within the Bicycle Facility Design Best Practices section of Appendix V of the Mississauga Cycling Master Plan, key intersection design components are identified that relate to the safety of all road users, including vulnerable users such as cyclists and pedestrians. The following excerpts are provided from Appendix V of the City's Cycling Master Plan:

3.4.1 Intersection Design

"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 15km/hr and 30 km/hr and up to 50km/hr on a downhill) 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."

3.4.2 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."

"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."

"Cities are setting clear policies around roadway design with an effort to control traffic speeds and improve safety for all road users.... For example, City of Toronto roadway design guidelines call for a minimum curb radius of 4.0m and a maximum curb radius of 15.0m."

"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."

The sections of the Mississauga Cycling Master Plan referenced in this report are provided in **Appendix E** in their original format.

3.5 Downtown 21 Master Plan

Section 6.4 of the City of Mississauga's Downtown 21 Master Plan (April 2010) provides street and building design standards as a part of the urban design guidelines for the City's Downtown area. Section 6.4 of the Master Plan details intersection design guidelines, including a standard corner radius to be applied to intersections in the Downtown area to promote safer road crossings for pedestrians. The following are excerpts from Section 6.4 of the Downtown 21 Master Plan:

3.5.1 Intersection Design

"The design and scale of intersections in the Downtown should strive to minimize the width of pedestrian crossings while providing safe, traffic-calmed turning movements.

- *The standard corner radius, for all non-roundabout intersections, for all street types, in the downtown, is 7.6m (25'). The design vehicle for downtown is the WB12m (WB40') tractor trailer. In this way, delivery trucks, busses, and emergency vehicles will be able to reasonably access the downtown; motorists will be encouraged to make turns at reasonably safe speeds, and pedestrians will have reasonably short crossing distances.*
- *Intersections, involving one or more streets, with two or more lanes in one direction, may use smaller corner radii than 7.6m (25').*
- *Intersections involving streets with medians and one lane on each side of the median, will use the smallest corner radius that permits the WB12m (WB40') tractor trailer to turn."*

The sections of the City of Mississauga's Downtown 21 Master Plan referenced in this report are provided in **Appendix F** in their original format.

3.6 City of Mississauga Vision Zero Goals

Mississauga council endorsed the framework of Vision Zero in February of 2018 and later provided more specific Vision Zero goals and action items in its 2019 Transportation Master Plan. The Transportation Master Plan (TMP) outlines six goals for transportation that will advance Mississauga resident's freedom to move "safely, easily, and efficiently to anywhere at any time". The first of the six goals listed in the TMP is "Safety: Freedom from Harm", and speaks to Vision Zero specifically; "Safe conditions for all travellers, advancing Vision Zero by supporting hazard-free travel and striving for zero fatalities."

Figure 3-3, extracted from the City's TMP, states that the City intends to mitigate the risk of injury and death on City roadways by enhancing road safety through engineering, education, enforcement, empathy, and evaluation. The first mitigation method, engineering, is particularly applicable to Lakeview Village, as the internal transportation network has yet to be constructed and is in the final stages of conceptual design. Accordingly, significant opportunities are available to design the Lakeview Village road network in a way that aligns with the City's Vision Zero goals.

From its inception, a goal of the Lakeview Village development has been to be a future-thinking, sustainable community that will become an icon along the Mississauga waterfront. By designing the Lakeview Village road network in a way that promotes safety for all road users, conforming to Vision Zero goals, the new development will create a precedent for other developments in the City and across the GTA to prioritize the safety of its road users.

As stated previously in this section, designing roads and intersections to mitigate the danger of high-speed collisions is a key component of achieving the goals of Vision Zero. Reducing corner radii and forcing vehicles to slow down to navigate a turn is an important intersection design element that can decrease the rate of pedestrian collisions and their severity. As stated in the City's TMP, a Mississauga Vision Zero safety objective is that “roads, sidewalks, and trails are designed to prioritize the safety of pedestrians, cyclists, and other vulnerable road users.”

Figure 3-3 City of Mississauga Vision Zero Risk Mitigation Strategies

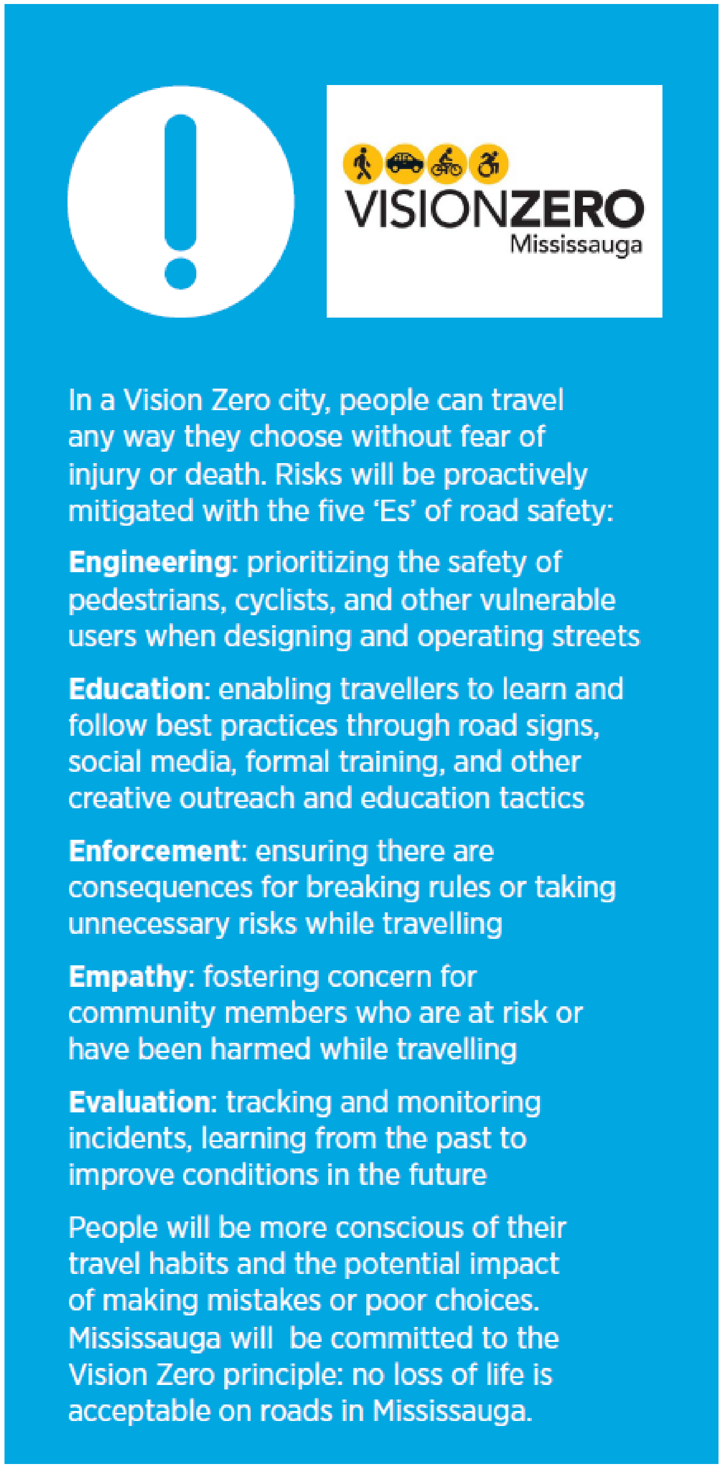


Figure Source: City of Mississauga Transportation Master Plan, 2019

Prior to the City of Mississauga adopting Vision Zero in 2018, the Region of Peel committed to adopting Vision Zero in 2017 and later published their Vision Zero Road Safety Strategic Plan in 2018 outlining the road safety programs to be implemented from 2018 – 2022 to achieve an “overall objective of reducing fatal and injury collisions by 10% within five years (by 2022), and advance the Region towards its ultimate long term vision of zero fatal injury collisions.” In this way, the management and design of all existing and future Regional and City roads within Mississauga are progressing towards the ultimate goal of Vision Zero.

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CONCLUSION

4

Rendering of Lakeview Square

CONCLUSION

The report herein has been prepared by The Municipal Infrastructure Group (TMIG) to address comments from the City of Mississauga Fire and Emergency Services group regarding proposed Lakeview Village Right-of-Way (ROW) and intersection treatment designs. The impact of intersection curb radii on both emergency vehicle access and daily road user safety was discussed in detail based on national, provincial, and GTA-specific road design guidelines and urban design best practices.

Lakeview Village embraces a vision of a strong, clean and healthy community with a transportation framework that has been designed to promote active transportation, such as walking and cycling, as attractive alternatives to our GTA culture's prominent dependency on automobiles. The internal intersections of Lakeview Village have been designed with 8.0 metre curb radii to enhance public realm space, slow vehicular turning traffic, and to reduce pedestrian and cyclist crossing distances across active vehicular lanes.

Although TMIG acknowledges the need to minimize emergency vehicle response time, we feel that consideration must also be given to the everyday safety of vulnerable road users, and that intersection design should not be based solely upon rare instances of a fire within Lakeview Village, but also on overall public safety in the general and regular experience. The negative impacts of the large curb radii required to allow emergency vehicles to navigate a right-turn through an intersection unimpeded by opposing lanes include increased vehicle turning speeds (which can lead to a higher probability of severe injury to vulnerable road users), decreased visibility of pedestrians and cyclists, and longer, less direct crossings across active vehicular lanes.

Overall, the internal intersection design of Lakeview Village aims to reflect Complete Streets and Vision Zero philosophies to promote the safe, convenient and comfortable travel and access for users of all ages and abilities regardless of their mode of transportation.

Therefore, it is our opinion that City of Mississauga Fire and Emergency Services requirement for larger curb radii to accommodate the swept paths of vehicles without encroaching upon opposing lanes is contrary to the Complete Streets philosophy, guiding standards used within the City and throughout the province and country, and does not take into consideration the overall safety of the public.

Rendering of Waterway Common

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REFERENCES

Rendering of Ogden Park

REFERENCES

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Ontario Traffic Manual (2016). ‘*Pedestrian Crossing Treatments’.* Queen’s Printer for Ontario.

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Transportation Association of Canada (TAC) (2017). ‘*Geometric Design Guide for Canadian Roads’.*

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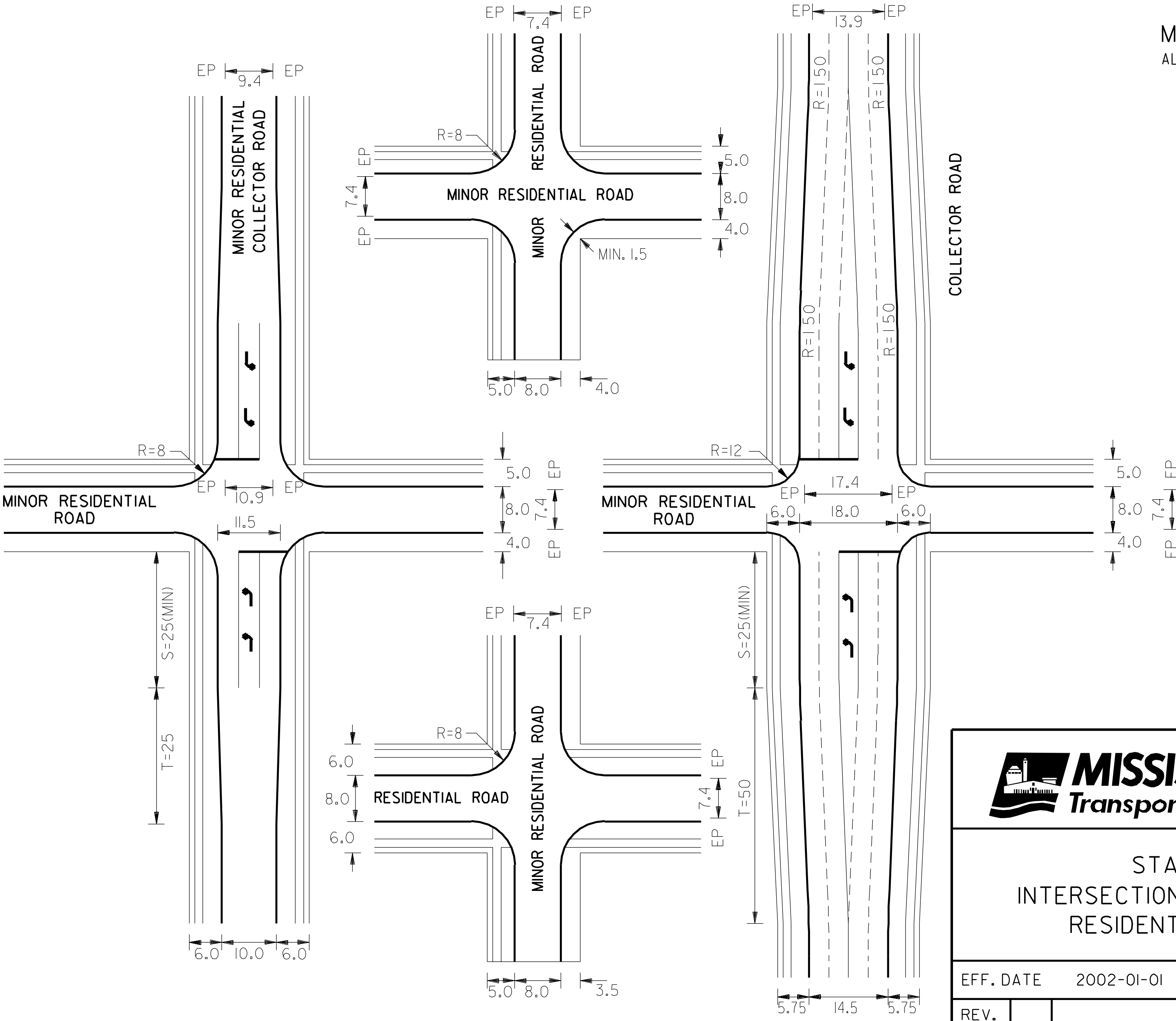
APPENDIX A

City of Mississauga Roadway Design Standards Drawings

METRIC

ALL DIMENSIONS IN METRES



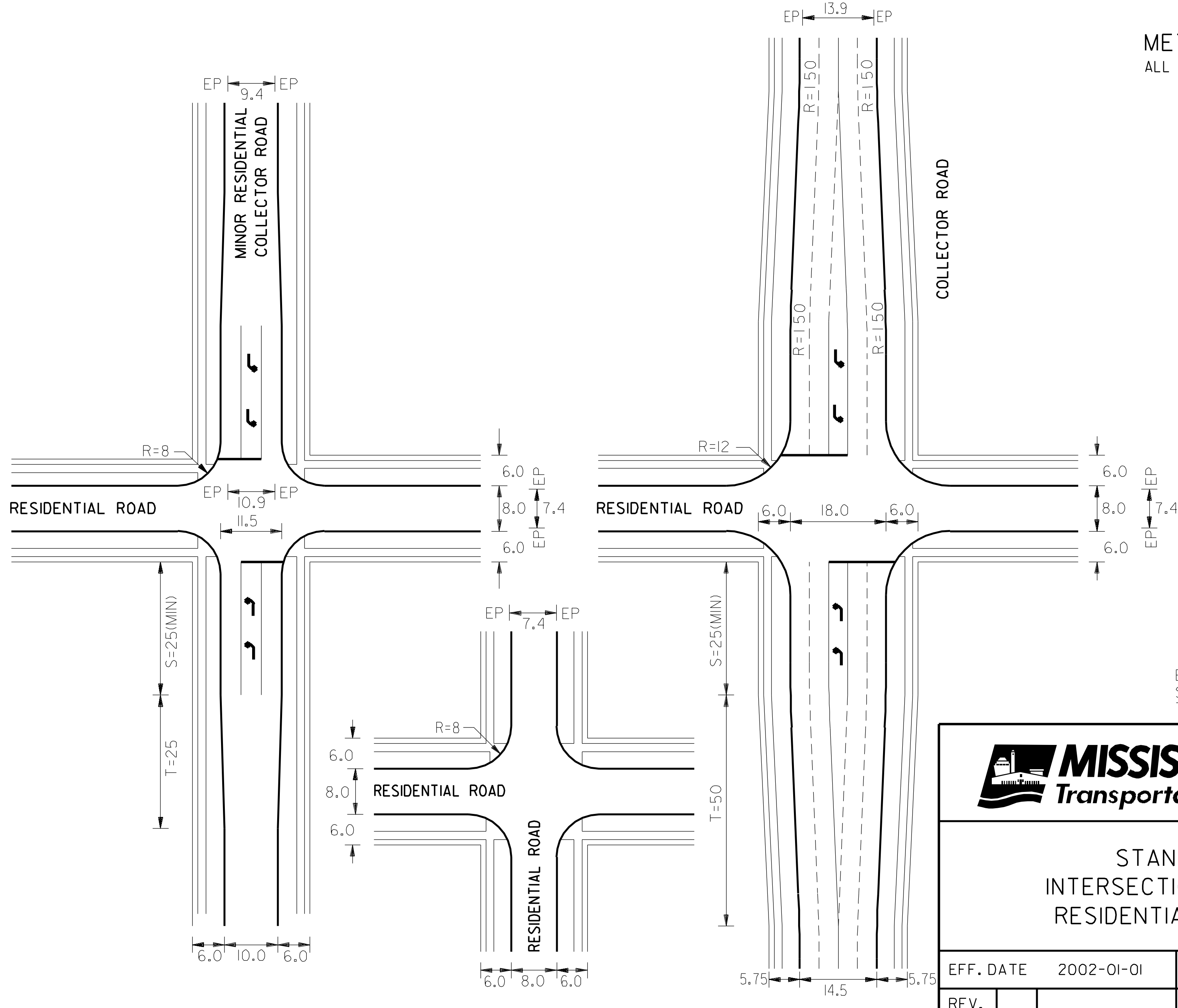
EP= EDGE OF PAVEMENT
S= STORAGE LENGTH
T= TRANSITION LENGTH

MISSISSAUGA
Transportation and Works

STANDARD
INTERSECTIONS WITH MINOR
RESIDENTIAL ROADS

EFF. DATE	2002-01-01	SCALE	N.T.S.
REV.		STANDARD No.	2211.160

METRIC
ALL DIMENSIONS IN METRES



EP=EDGE OF PAVEMENT
S=STORAGE LENGTH
T= TRANSITION LENGTH

MISSISSAUGA
Transportation and Works

STANDARD INTERSECTIONS WITH RESIDENTIAL ROADS

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REV.		STANDARD No.	2211.170

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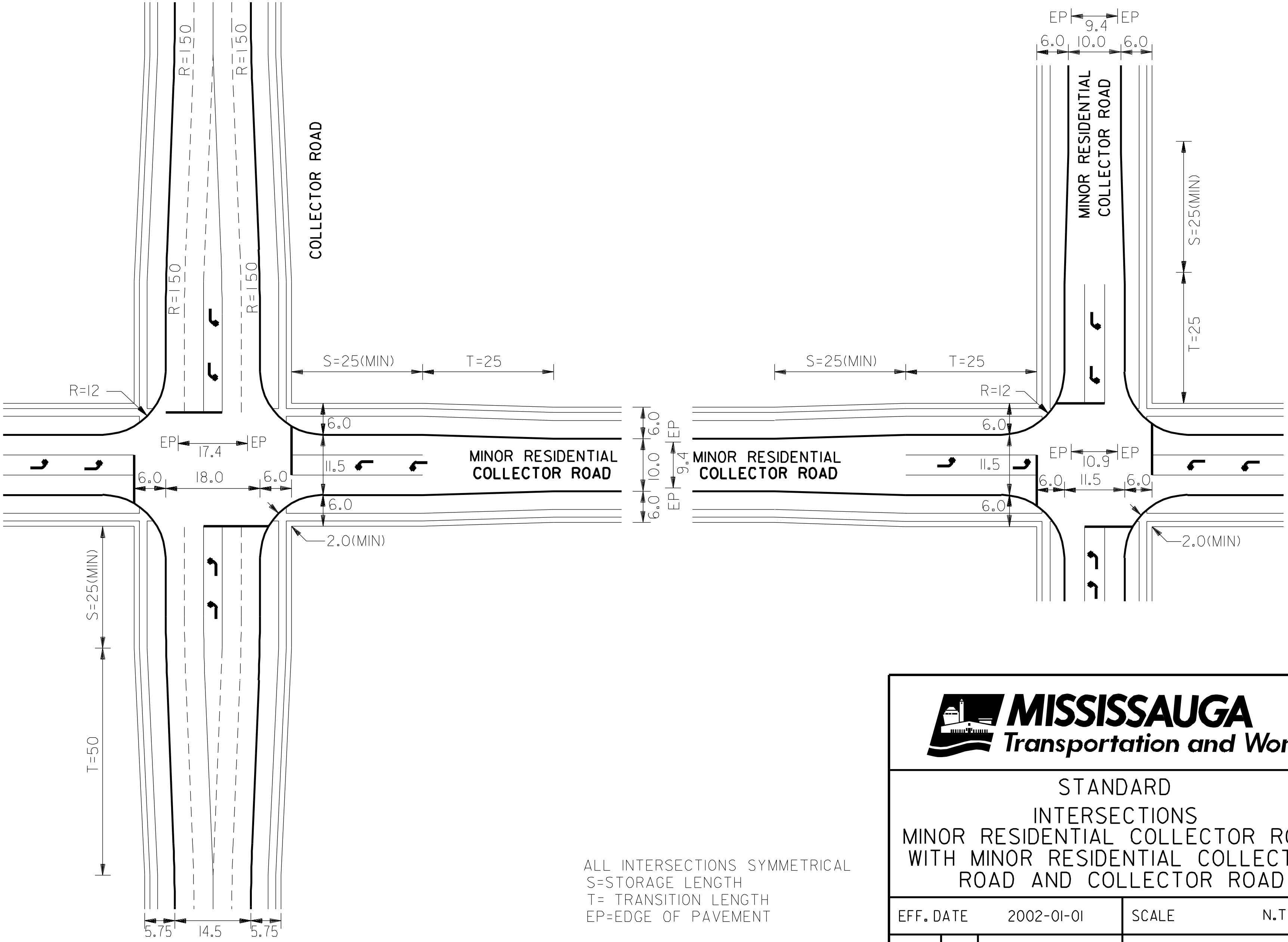
ALL DIMENSIONS IN METRES



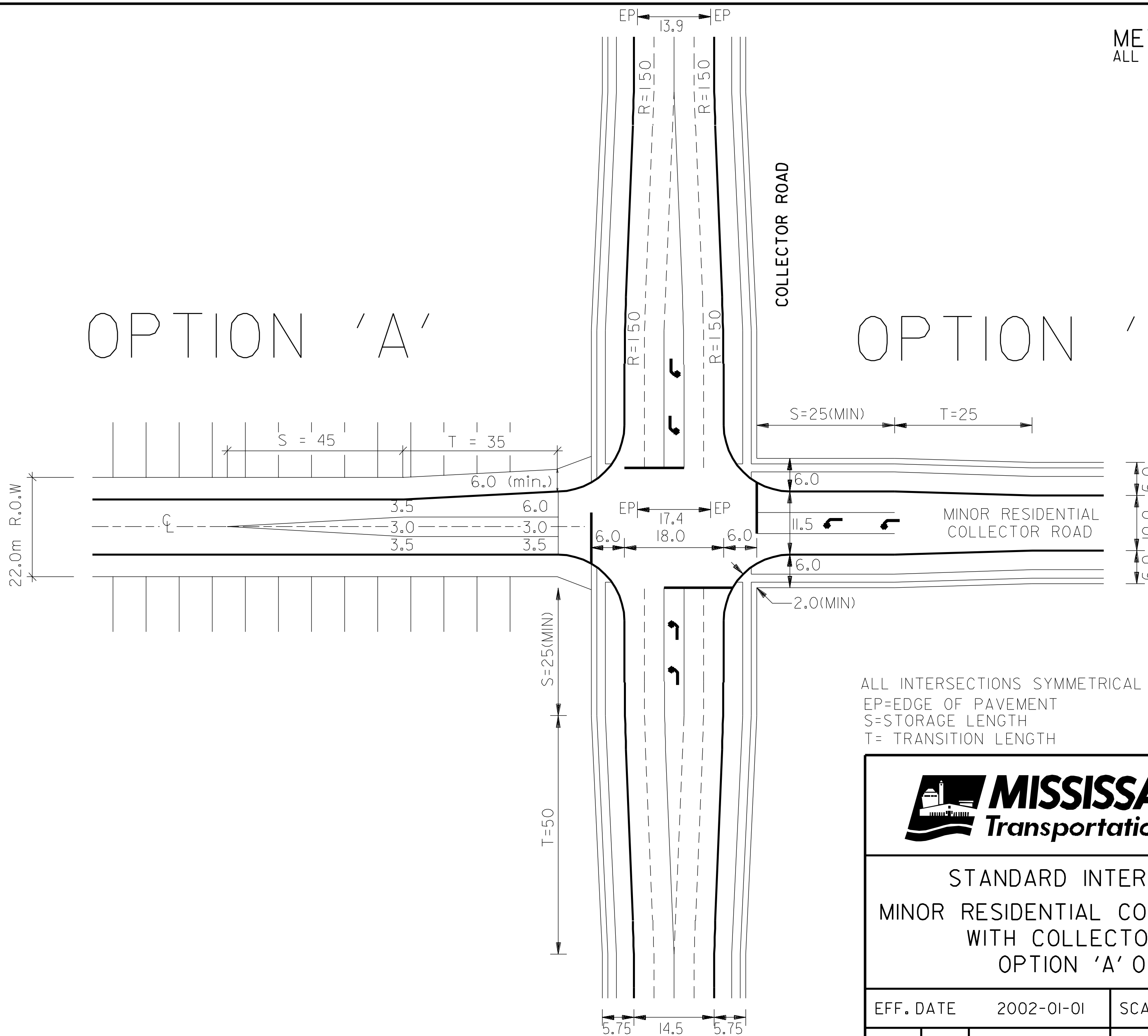
ALL INTERSECTIONS SYMMETRICAL
S=STORAGE LENGTH
T= TRANSITION LENGTH
EP=EDGE OF PAVEMENT

MISSISSAUGA
Transportation and Works

STANDARD

INTERSECTIONS
MINOR RESIDENTIAL COLLECTOR ROAD
WITH MINOR RESIDENTIAL COLLECTOR
ROAD AND COLLECTOR ROAD

EFF. DATE	2002-01-01	SCALE	N.T.S.
REV.		STANDARD No.	2211.180



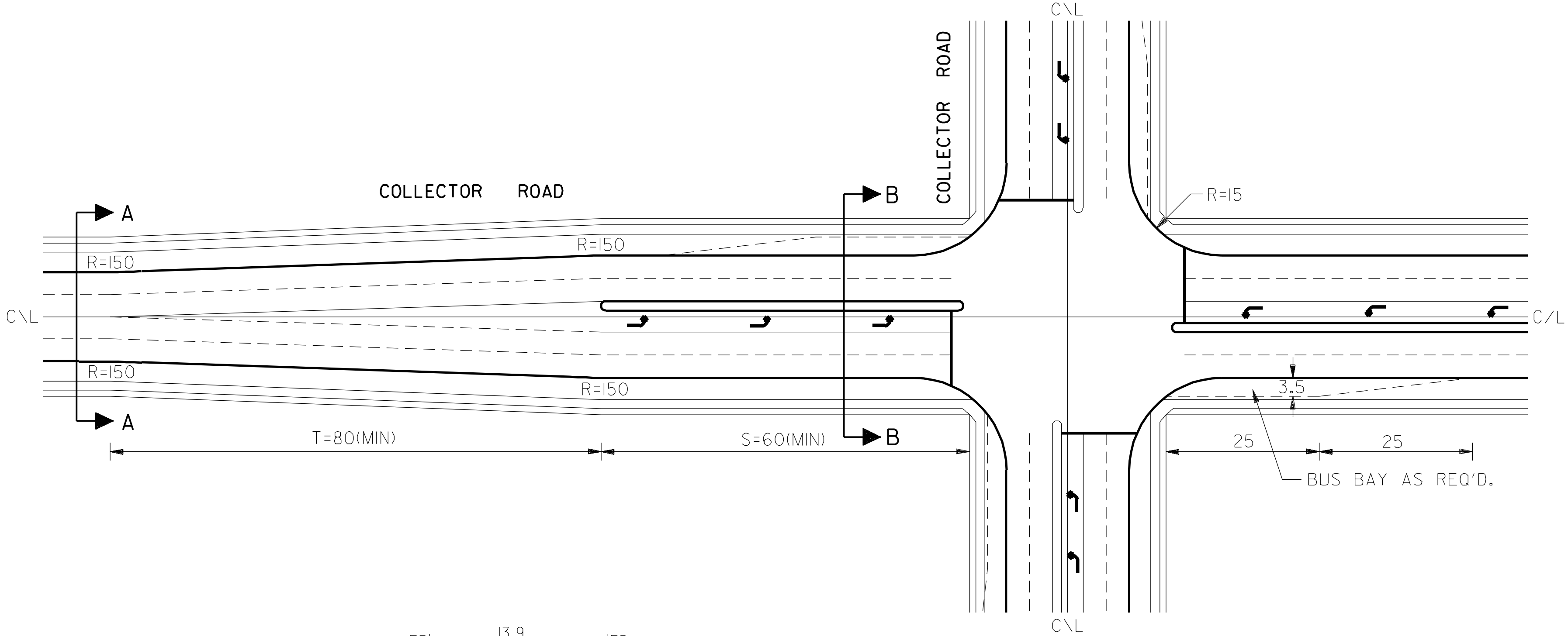
ALL INTERSECTIONS SYMMETRICAL
EP=EDGE OF PAVEMENT
S=STORAGE LENGTH
T= TRANSITION LENGTH

MISSISSAUGA
Transportation and Works

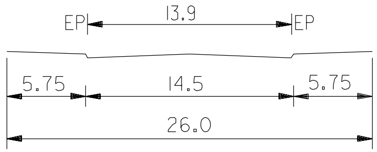
STANDARD INTERSECTIONS
MINOR RESIDENTIAL COLLECTOR ROAD
WITH COLLECTOR ROAD
OPTION 'A' OR 'B'

EFF. DATE	2002-01-01	SCALE	N.T.S.
REV.		STANDARD No.	2211.181

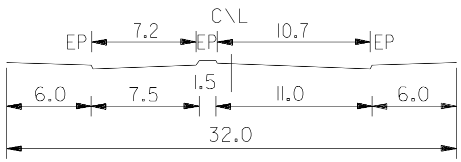
METRIC
ALL DIMENSIONS IN METRES



DESIGN SPEED 70km/h
EP=EDGE OF PAVEMENT
S=STORAGE LENGTH
T= TRANSITION LENGTH



SECTION A-A



SECTION B-B

MISSISSAUGA
Transportation and Works

STANDARD
INTERSECTION
COLLECTOR ROAD TO
COLLECTOR ROAD

EFF. DATE	2002-01-01	SCALE	N.T.S.
REV.		STANDARD No.	2211.190

APPENDIX B

TAC Geometric Design Guide Excerpts

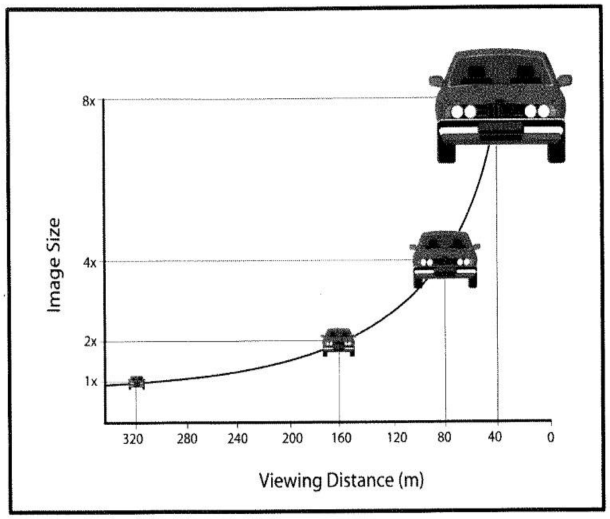


Figure 2.2.3: The Relationship Between Viewing Distance and Image Size

2.2.5.4 Cognitive Abilities

The phrase "cognitive abilities" refers to our abilities as human beings to process visual and other information that we are receiving, understand the data received, and take appropriate action. This section deals with three topics:

- Attention and information processing
- Driver mental workload
- Driver expectations

These are discussed below.

- **Attention and Information Processing**

Driving can be a challenging task because our visual and information processing capacities are easily over-extended. These capacities evolved in the context of walking and running speeds, which typically do not exceed on the order of 5 m/s. With the advent of automobiles, drivers are moving through space at speeds up to 20 m/s in urban areas and 35 m/s or more on highways.

Human attention and abilities in information processing are limited. These limitations can create difficulties because driving requires the division of attention between control tasks (e.g., staying in the lane), guidance tasks (e.g., obeying traffic signals, avoiding other road users), and navigational tasks (e.g., looking for landmarks and street name signs). In addition to these tasks, drivers may also be exposed to internal vehicle distractions such as cell phones, computers and GPS devices. While attention can be switched rapidly from one task to another, humans only attend well to one task at a time, especially if that task requires conscious attention. This is why it is important to design roads so that drivers are not overloaded in more than one task at a time, for example having to change lanes due to a lane drop while negotiating a curve.

Furthermore, humans can only extract a small proportion of the available information from the road scene. It has been estimated that out of over 1 billion bits per second of information directed at the sensory system, only 16 bits per second are consciously recognized (the answer to a single yes/no question provides 1 bit of information). In short, the human information processing system is essentially a single channel system with limited capacity.[10] Given the limitations in driver information processing, drivers only notice a limited number of the available items to be seen. Designs should provide positive guidance and be self-reinforcing and not rely on single features, such as signage or pavement markings, to be the only source of information for drivers. For example, a single STOP sign is not a sufficient cue to the need to stop at a rural intersection when the driver has travelled a long distance without the need to stop. In addition to a STOP sign, good sight distance to the intersection pavement and cross traffic, a STOP Ahead sign or an overhead flasher will assist the driver in detecting the need to stop.

- **Driver Mental Workload**

Because our attentional and information processing resources are limited, designers should consider how driver mental workload changes along a section of roadway. Workload depends on the resources the driver brings to the driving task as well as the resources demanded. A task, such as changing lanes to get to an exit in a short weaving section, will be easier for a familiar and experienced driver, who is prepared for it, than for an unfamiliar or inexperienced driver. Mental workload is increased when the task is difficult (such as negotiating a sharp curve), there is time pressure (merging onto a freeway using a short acceleration lane), or there is a high information load (reading guide signs with many destinations). Designers should avoid designs that result in high workload with more than one task at a time (an intersection on a curve, a lane drop on a curve, lane changes while reading guide signs, or a railroad crossing near a stop sign).

- **Driver Expectations**

Expectation is a powerful determinant of accuracy and reaction time. For example, as we enter a dark room that we have never entered before, we expect the light switch to be about shoulder height and near the edge of the door. We also expect to move it up to turn it on. If it is placed as expected, and operates as expected, we can locate it and turn the light on quickly. If it is not placed as expected – say at waist height — and operates differently than expected, our response time will be considerably longer and there will be an error in our initial movements. Similarly, drivers will respond quickly and accurately when the road environment corresponds to their expectations. When drivers are surprised because their expectations are violated, slowed responses and errors occur.

Designing in a manner that meets driver expectations is particularly important when drivers are unfamiliar with the roadway. This is because drivers expect that common driving situations will be designed in the "usual way". When this expectancy is violated, the potential for driver error and an inappropriate driver reaction increases substantially.

For example, based on experience, drivers expect freeway exits to be on the right. As a result, drivers may anticipate their exit on the right, and move into that lane. If the exit is on the left, the driver may suddenly slow, stop, or make a series of rapid lane changes to the left in order to avoid going past their exit. Such actions have a significant potential to cause a collision, or result in inappropriate evasive maneuvers by other vehicles.

Expectations can include both short-term and long-term expectancies. Short-term expectations arise over the course of a journey, for example, curves on this road are gentle. Long-term expectations arise over years of experience, for example, that freeway exits are on the right.

We can process information faster and more accurately if it corresponds with previous experience and expectations. When road designers adhere to driver expectations, drivers know what to expect and how to respond rapidly. Violations of driver expectations should be avoided as they can lead to increased reaction times and a greater likelihood of driver errors. These, in turn, may lead to a higher risk of collisions.

2.2.5.5 Perception-Reaction Time

Driver perception-reaction time refers to the process of detecting the presence of a target, recognizing it as something requiring action, and then doing what is necessary to initiate appropriate action: for instance, in the case of a need to stop, moving the foot from the accelerator to the brake. There are four stages of perception-reaction time: detection, identification, decision, and response. The detection period starts when a hazard enters the driver's field of view and ends when the driver becomes consciously aware that something is present. Identification refers to the process of acquiring enough information to inform the decision-making process. Next the driver must decide what action, if any, is appropriate. Finally, in the response phase the driver initiates the intended action.[11]

The figure often used for driver perception-reaction time in accident reconstruction is 1.5 seconds, while the figure typically used in design is 2.5 seconds. In fact, perception-reaction time is dependent on many factors including stimulus salience (e.g., size, contrast, motion, and exposure time), background complexity, number of response choices, expectancy, and more. In choosing an appropriate perception-reaction time, it is important to consider these features.

The value of 1.5 seconds is the 90th percentile perception-reaction time for young subjects, measured as they drove over the crest of a hill during the daytime and braked to avoid an obstacle partially blocking their lane.[12] This value is an appropriate estimate for the perception-reaction time to a clearly seen hazard in the direct line of sight for a reasonably alert and attentive driver. Hazards may be in the line of sight, but too small or too poorly contrasted with the background to be detected. This is especially true at night. Until the hazard is detectable to the driver, the perception-response time interval cannot be considered to have started. When hazards are seen off the line of sight by more than about 15 degrees, drivers take longer to respond and are more likely to fail to detect them.[13]

Drivers in experiments are likely unusually alert. Drivers on the road may not always be so. Olson reviewed the impacts of alcohol, other drugs and fatigue on perception-reaction time. The largest increases noted in mean values were 45-65%. A 50% increase in the 90th percentile perception-response time is 2.3 seconds, very close to the present value used for design of 2.5 seconds. Given the long experience of highway designers with the 2.5 second value, it was recommended that it be retained.[14] While the 1.5 perception-reaction time is used in accident reconstruction to judge driver fault, 2.5 seconds is a more appropriate value to assume by designers who wish to include a wide range of typical drivers.

The perception-reaction times discussed above are relevant to emergency stops in a stopping sight distance scenario. Perception-reaction times to initiate other actions, where there is less urgency, and where geometry is complex, are longer. An example is perception-reaction time in a decision sight scenario where drivers must respond to complex situations involving signs and markings warning of lane drops or splits ahead.[15] In an on-road study perception-reaction time was measured between the point that the physical gore was in view to the experimenter and the point that drivers initiated a lane change. Based only on subjects (approximately 50%) who signaled their detection of the need to change lanes only after the gore became visible (i.e. not in response to advance signs or markings), mean perception-reaction time was 10.5 sec. The 85th percentile perception-reaction time was estimated to be about

6.2.5 SPEED AND VOLUME MANAGEMENT

Speed and volume management (collectively referred to as "traffic calming") tends to improve pedestrian comfort and safety. Design guidance for traffic calming measures is available in various relevant publications.[5]

In the event of a collision involving a motor vehicle and a pedestrian, lower motor vehicle speeds correlate with increased pedestrian survival rates, as shown in **Figure 6.2.4**, which summarizes data from collision studies undertaken over the last 30 years. Collisions at 30 km/h or less correlate with a lower probability of death, whereas at motor vehicle speeds above 40 km/h, the probability of death increases significantly.

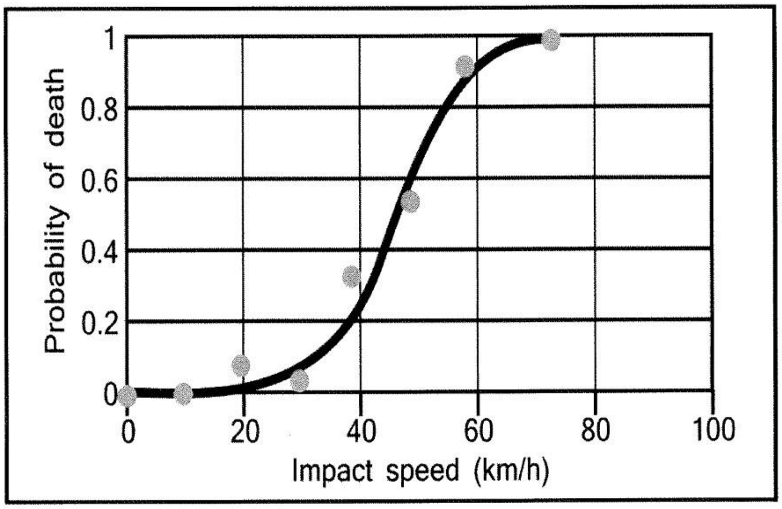


Figure 6.2.4: Relationship between Vehicle Speed and Risk of Pedestrian Death in a Collision[6]

Lower volumes of motor vehicles tend to improve pedestrian comfort by reducing exposure to motor vehicles and associated noise/exhaust.

Figure 6.2.5 illustrates some example speed and volume management measures, which may impact the horizontal and/or vertical movement of motor vehicles. Selection of appropriate measures should consider the road classification and function, as not all measures are appropriate in all contexts.

Some example speed management measures include speed tables/humps, raised crosswalks, neighbourhood traffic circles, pinch-points, neck-downs, raised centre islands, reallocating or removing general purpose lanes, narrowing lane widths, adding curb extensions, and reducing corner radii.

Volume management measures control access into and out of streets at intersections. Example volume management measures include right-in/right-out control, partial street closures, diagonal diverters, and median diverters. These techniques are designed to apply to motor vehicles only—not bicycles or pedestrians.

The width of the ancillary space depends on the context of the street and the desired street elements within the space; a width sufficient for a parking lane is suggested, since most or all other elements can be accommodated within that dimension.

Roadsides lacking both ancillary space and a furnishing zone will position the pedestrian through zone adjacent to moving motor vehicles, which negatively affects the safety and comfort of pedestrian travel. On commercial streets, or where adjacent traffic speeds are 50 km/h or higher, provision of ancillary space and/or a furnishing zone is recommended.

6.3.3 CONTEXT CONSIDERATIONS AND TRADE-OFFS

The design of roadways and evaluation of trade-offs, particularly in retrofit situations, requires the designer's judgement and consideration of the needs of the design user group. In all cases, context considerations and trade-offs will be affected by jurisdictional policy and modal priorities.

The designer should take care to ensure that pedestrian needs are integrated and not unduly hindered by the design of other roadway elements. For example, where cross-sectional space is limited, the following application heuristics could be considered for urban roadways.

- General purpose travel lanes or turn bays could be narrowed or removed, taking into consideration the recommended lane widths for passenger vehicles, freight, and transit movement.
- If available width is insufficient to accommodate all three zones of the roadside, the pedestrian through zone width should be preserved and the width of the frontage zone or furnishing zone, in that order, reduced.
- Ancillary space could be left out of the design so the pedestrian through zone is preserved and the furnishing zone increased.

In urban areas, these trade-offs often involve incremental adjustments to street elements rather than removal of entire zones. The width of each functional zone should generally be selected from the recommended range outlined in **Section 6.3.3** based on contextual factors. If the width of a roadside zone is too low to provide the functionality of that zone, it may be preferable to leave it out in order to provide suitable functionality of other design elements.

6.4 PEDESTRIAN DESIGN: PEDESTRIAN CROSSINGS

The management and integration of pedestrian spaces that intersect with the roadway network is of particular importance to pedestrian design. At these locations, pedestrians are required to cross the path of other road users and vice versa, creating conflict points that must be mitigated to provide a comfortable and safe pedestrian environment. These conflict points occur:

- On the roadway, at intersection and mid-block crosswalks and
- On the sidewalk, where driveways and alleys cross the sidewalk.

Since pedestrians are the most vulnerable road user group, their design needs should promote safety and comfort by managing motor vehicle speeds, improving visibility and sightlines, reducing pedestrian crossing distance, increasing crossing directness and providing accessible spaces.

Design principles for safe and attractive pedestrian crossings include:

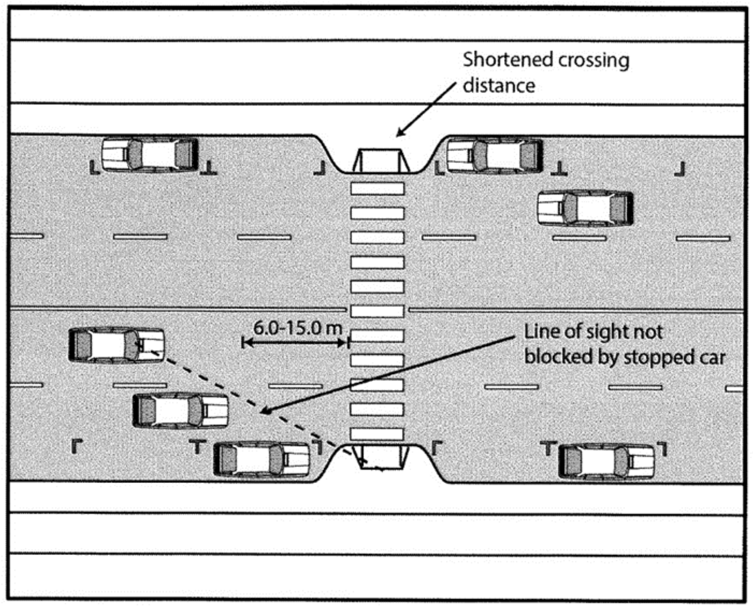


Figure 6.4.4: Pedestrian-Motorist Sightlines at Multi-Lane Mid-Block Crossings

6.4.4 CORNER RADII

The corner radius is constructed to connect the curbs of two intersecting streets. The size of the corner radius can significantly affect pedestrian comfort and safety. Corner radius influences:

- Available pedestrian queuing space
- Pedestrian crossing distance
- Pedestrian crossing directness
- Pedestrian and motorist sightlines and visibility
- Speed of turning motor vehicles.

In general, a smaller corner radius provides more pedestrian queuing space, facilitates a shorter crossing distance, enables straight and direct connections between the sidewalk, curb ramp and crosswalk, and increases the visibility of pedestrians. A small corner radius may also encourage slower motor vehicle turning speeds. **Figure 6.4.5** illustrates the effect of corner radius on pedestrian crossing distance and directness. As corner radius increases, the pedestrian crossing distance increases or directness is reduced to minimize crossing distance. Changes in directness of crossing can impact visibility and likelihood of pedestrians crossing within the marked crosswalk.

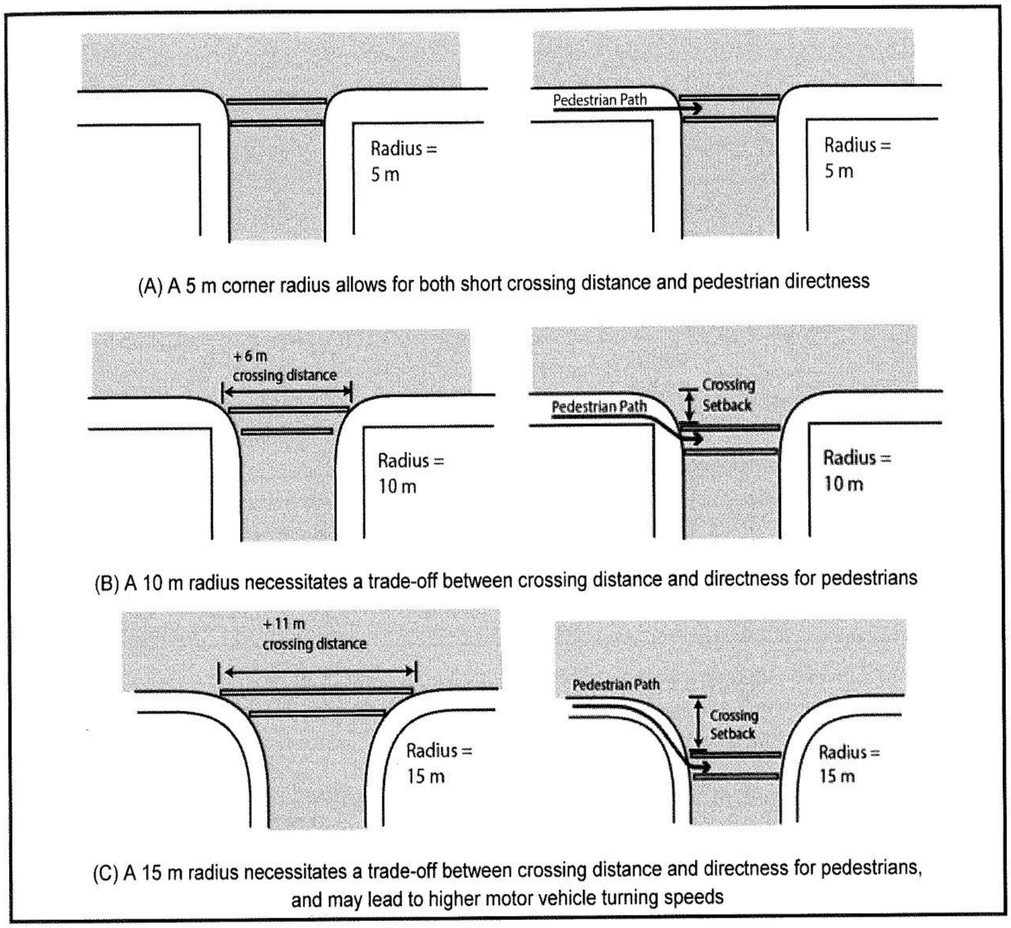


Figure 6.4.5: Effect of Corner Radius on Pedestrian Crossing Distance and Directness

During the design phase, the chosen radius should be the smallest possible for the design vehicle and circumstances. Mitigation techniques for freight, transit, and emergency vehicles around small-radius corners should be considered and can be accommodated by considering the effective turning radius.

Corner radii at intersections should be designed based on analysis of effective turning radii. The effective turning radius (**Figure 6.4.6**) is based on the travel path typically used by a motor vehicle to navigate around a corner, and is larger than the constructed corner radius. Wide curbside travel lanes and on-street parking or bicycle lanes contribute to a larger effective turning radius as does the availability of multiple receiving lanes. Recognizing the effective turning radius allows the designer to select a corner radius that is substantially smaller than selecting a corner radius to match the turning radius required by the design vehicle. This means that the pedestrian benefits of a small corner radius may be realized without affecting motor vehicle movements.

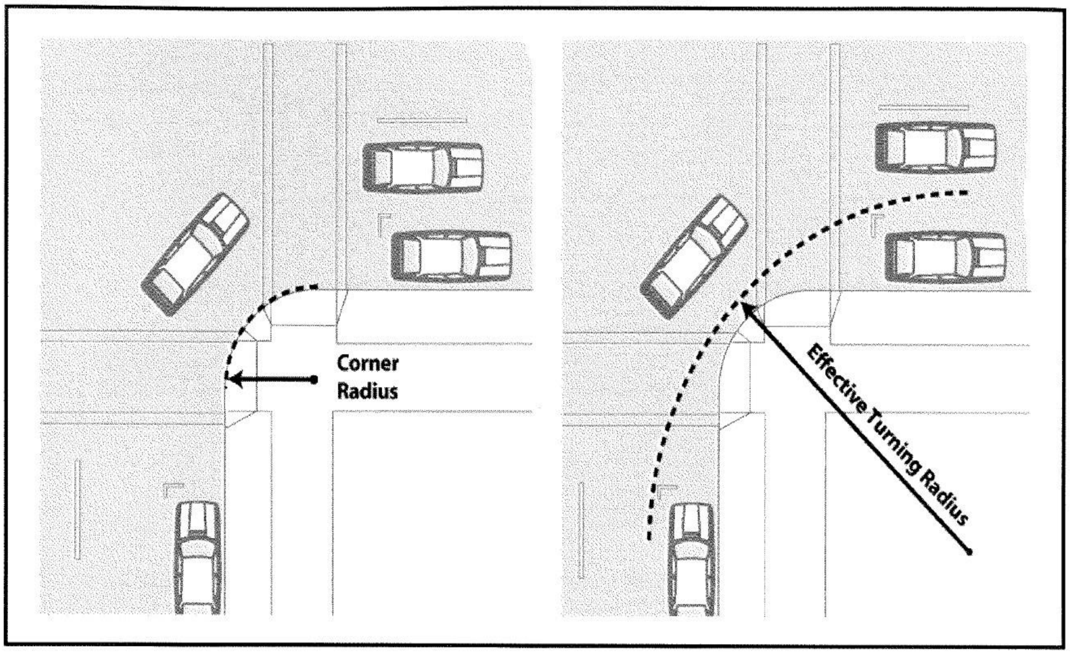


Figure 6.4.6: Corner Radii and Effective Turning Radius

6.4.5 CROSSWALK LOCATION

One of the design features of integrating pedestrians at intersections is the location of any crosswalk markings. The location of crosswalk markings is impacted by corner radii (**Section 6.4.4**) and the width of the crosswalk which subsequently affects the type and placement of curb ramps (**Section 6.4.6**).

Smaller corner radii (5 m or less) benefit pedestrians by allowing for the selection of a crosswalk location that maintains the shortest practicable crossing distance, typically provides a direct trajectory from sidewalk to crosswalk, and maintains good visibility of pedestrians.

With larger corner radii (above 5 m), the location of the crosswalk necessitates consideration of trade-offs between pedestrian crossing distance, crossing directness and visibility. Increased corner radius increases the pedestrian crossing distance unless the crosswalk location is set back further from the intersection, which affects crossing directness and visibility as shown in **Figure 6.4.5**.

In balancing the crossing distance and directness, the intersection side of a typical 2.5 m wide crosswalk should initially be offset a minimum of 0.6 m from the face of the parallel roadway curbline. The crosswalk can then be moved around the curb return as necessary to achieve a balance of crossing distance and directness. The amount of adjustment will depend on the radius of the curb return. In addition to balancing crossing distance and directness, it is desirable to provide adequate distance between the curb ramps to allow for development for the full height of a 150 mm between the curb ramps on that corner. A minimum distance of 3 m for the tapers down to the curb ramps is typically desired.

The curb ramp should be centred in the crosswalk. Where pedestrian crossing volumes are more than 600 pedestrians per hour, a crosswalk wider than the typical 2.5 m minimum width may be warranted. If

9.13.2 CORNER RADIUS CONSIDERATIONS AND DESIGN

9.13.2.1 Overview

The design of the corner radii at intersections is affected by the location of the vehicle travel path as it approaches and departs from the intersection. For instance, in urban areas where parking is allowed adjacent to the curb, a vehicle typically makes the turn at an appreciable offset from the curb line. In other situations, it is desirable to have the turning movement made totally within a curb lane on both the approach and departure legs. Corner radii are designed in a different manner for each situation. An appropriate curb radius design may be accomplished using vehicle turning path software.

Large corner radii encourage higher speeds by turning vehicles and increase the distance pedestrians must travel to cross the roadway at an intersection. Where pedestrian crossing volumes are significant, it is desirable to design the curb radii to conform to the minimum design vehicle turning path, thereby reducing vehicular turning speeds and minimizing the pedestrian crossing distance. Refer to **Section 6.4.4** in **Chapter 6** for guidance on intersection curb/corner radii for accommodation of pedestrians.

The design of at-grade intersections are site-specific and depend on many influencing factors, such as traffic, design vehicles, lane widths, pavement widths, angle of intersection, and degree of pedestrian activity. In retrofit situations, the corner radii design may also be influenced by physical constraints and right-of-way restrictions.

Typically, three types of curves are used in intersection design:

- Circular curve
- Two-centred compound curve and
- Three-centred compound curve.

9.13.2.2 Circular Curve

The circular curve is most commonly used at urban intersections, often with restricted rights-of-way. It facilitates the passenger vehicle, single-unit truck, and single-unit inter-city bus turning maneuvers. The size of the radius is dependent on the minimum turning radius of the selected design vehicle and turning condition (either stop or yield).

For appropriate turning radii for a stopped turning condition, refer to **Chapter 2**. For a yield condition, turning speed is typically assumed to be 20 km/h in an urban environment and up to 30 or 40 km/h in a rural environment. The turning radii should be determined based on the desired turning speed.

The circular curve design can also be used where a right-turning tractor trailer approaching on a single lane can turn into a four-lane roadway section, with the truck using more than one lane in making the turn. Where it becomes necessary to ensure that large trucks turn into the right lane of a multilane roadway section, a two- or three-centred compound curve design is appropriate.

Figure 9.13.4 illustrates simple curve geometric elements.[75] The turning radius (R) can be determined from **Chapter 2**. The angle of turn (Δ) varies from 70° to 110° as per the intersection angle.

APPENDIX C

MTO Ontario Traffic Manual Excerpts

facility, such as an intersection, pedestrian crossing or roadway section can be measured by comparing the average collision frequency to the statistically estimated collision frequency for that type of facility for a given time period. In simple terms, an existing facility is considered to have a lower potential for safety improvement if the average number of collisions is lower or equal to the expected frequency. Because collisions are relatively unpredictable events, proxy measures of safety may be used, such as the number of conflicts observed during a fixed period of time. A conflict is defined as a traffic event involving the interaction of two or more road users where an evasive action such as braking or swerving occurs to avoid a collision.[10]

Qualifying Security: Security is the perception of how safe a road user feels in the road environment, as opposed to the actual level of safety. Road users' perception that a facility is "safe" or "safer" is based on their experience and knowledge. For a given state, the road environment and vehicle generally behave in a repeatable, predictable fashion. However, for a given situation, the human element in the system has a wide range of responses, some unexpected. Driver and pedestrian behaviour is at least partly based on their perception of risk, and road users do not always evaluate risk consistently. Therefore, road users' actions can be attributed to their acceptance of perceived level of risk.

Influencing Safety and Security: The installation or modification of a transportation facility may or may not yield the desired change in either safety or security. It is up to practitioners to use their best engineering judgment to understand the environment and the road users and to predict as accurately as possible the effects of the modification. Practitioners should also consider that improving safety may still not improve the sense of security for the users and vice versa.

Higher levels of safety occur where there is the proper level of right-of-way control for the road type, roadside environment, volume of pedestrians, age / type of pedestrians, volume of vehicles, and related factors. It also occurs when pedestrians and drivers have a clear understanding of what they are supposed to do and what other road users are likely to do, enough information (including clear sight lines and appropriate guidance) to make safe decisions, and the ability to make those decisions and execute them.

It is imperative that practitioners have a full understanding of the details of available research in order to assess the applicability of research findings to their roadway environment. Alternatively, jurisdictions can develop their own quantifiable before and after study processes to quantify safety impacts.

3.3.1 Factors Influencing Safety

Contributing factors that influence the level of safety within the context of pedestrian roadway operations may include:

- The degree of pedestrian-vehicle interaction
- Vehicle speeds
- Road users' expectancy
- Road users' perception
- Road users' awareness
- Pedestrian's ability (mobility, vision, hearing and cognition)
- Road users' understanding of the rules of the road

These factors are shown in Table 3.

3.3.2 Walking Considerations

Walkability is a measure of the level of integration of pedestrian facilities (such as sidewalks, trails and crossings). It considers the ease in which pedestrians can move through the transportation network efficiently, conveniently, enjoyably and safely. A walkable environment serves to encourage a healthier lifestyle by promoting walking or the use of non-motorized means of transportation.

Table 3: Factors Influencing Safety

Factors Influencing Safety	Related Impacts and Considerations for Treatment of Pedestrian Crossings
Degree of pedestrian-vehicle interaction	The potential for conflicts and collisions is directly affected by the level of interaction between road users. A higher exposure of pedestrians interacting with vehicles (from higher vehicle and/or pedestrian volumes, or a higher number of potential conflict points) will generally result in a higher potential for pedestrian collisions.
Vehicular speed	The higher the vehicular speed at the time of impact, the higher the probability of fatality of pedestrians. Relatively small changes in speed can have a large impact on the severity of a pedestrian collision (particularly between 40 km/h and 60 km/h). [11]
Driver and pedestrian expectancy	Expectancy influences the speed and accuracy of information processing; and conditions that meet or reinforce expectancies help drivers and pedestrians to respond quickly, efficiently and without error. Violations of expectancy increase the chance of inappropriate decisions that lead to conflicts or inability to control vehicles safely.
Perception (visual acuity and visual contrast)	There is an inherent limitation in drivers' or pedestrians' ability to detect objects, especially under low visibility conditions. Furthermore, the difference between visual acuity and visual contrast should also be considered. Visual acuity is a measure of the ability to identify black symbols on a white background at a standardized distance. Visual contrast is the ability to distinguish between various shades of gray. At night, a driver's visual contrast is much more important for detecting pedestrians than visual acuity. Both visual acuity and visual contrast decline continuously with age.
Level of awareness (positive guidance and driver workload)	Humans behave as a single channel processor, which means they are able to conduct one task consciously at a time. A more complex driving environment will therefore require a higher level of mental effort and reduce one's ability to focus upon the driving tasks. Positive guidance considers a driver's workload and reduces the occurrence of multiple potential conflicts. As defined in OTM Book 1C, "Positive Guidance is provided when that information is presented unequivocally, unambiguously and conspicuously enough to meet decision sight distance criteria and enhances the probability of drivers making appropriate speed and path decisions."
Pedestrian ability	Pedestrians differ in terms of their mobility, their speed, and their ability to perceive and react to potential conflicts, and recognize and understand traffic control devices. Designs for crossing devices should have regard for the needs of all pedestrians (i.e., the elderly, the young, and persons with a disability). It is also important to note that under the AODA[3] , design elements as part of pedestrian crossings must meet the mandatory accessibility standards (see Section 2.1.4).
Rules of the road	The rules of the road under the HTA[1] provide the basis that governs and manages competing traffic movements; however, inconsistent interpretation, ignorance, or disregard of the law leads to potential for conflicting actions. A balance of continuous education and enforcement contributes to the general population's awareness and understanding, which contributes to the overall safety.

Table 4: Walkability Considerations

Factor	Description
Distance of the trip	Most people are willing to walk 5 to 10 minutes at a comfortable pace to reach a destination, with walking trips averaging a distance of 0.4 km. The threshold for walking trips is approximately 1.6 km in distance. As a result, land-use patterns, community design and population density are great determinants in trip distance and ultimately determine whether a community is walkable.
Perceived safety and security of the route	Walkway design can impact the perceived safety and security by pedestrians. The following are examples of elements that directly impact the perceived and actual safety of pedestrians: • Sidewalks that are too narrow and / or adjacent to vehicular traffic • Pedestrian crossings that have confusing signal indications • Pedestrian crossings that have excessive crossing distances and inadequate crossing times • Pedestrian crossings with fast-turning vehicles • Absence of other pedestrians • Inadequate illumination (poorly lit areas) • Excessive vehicular speeds adjacent to the pedestrian walkway • Passage through secluded areas • Lack of crossing facilities at a convenient location • Poor visibility at pedestrian crossings due to overgrown tree foliage, and improperly placed signage, street furniture and utility fixtures • Insufficient sign distance and corner cutoffs.
Comfort and Convenience	The decision to walk is also influenced by comfort, convenience, visual interest and the existence of potential destinations along the route. Unlike motorists, the slower speed of pedestrians results in a preference for more rather than less environmental stimuli. Some factors that create a visually interesting environment that is conducive to walking include: • A good mix of land use • Continuous and connected pedestrian facilities • Ample separation of pedestrian facilities from high-speed vehicular traffic • Safe, convenient and unambiguous street crossings • Streetscaping and street furniture • Air quality • Shade or sun in appropriate seasons • Proper maintenance of facilities • Access to mass transit

Pedestrian crossings are a critical element among the many factors that influence the overall walkability of an environment. The factors that can affect walkability are shown in Table 4 and include, but are not limited to, distance of the trip, perceived safety and security of the route, and the comfort and convenience of walking versus the alternative modes of transportation.

3.4 Road User Characteristics

Walking has become increasingly important as various jurisdictions strive to make the transportation system more sustainable. In many jurisdictions there is a growing need to provide options for the safe and efficient accommodation of pedestrians and other vulnerable road users. However, in order for people to walk, the system must be able to properly accommodate them.

The proper accommodation of pedestrians is a function of understanding their unique characteristics to provide adequate mobility and accessibility opportunities that will serve them in a safe and equitable manner.

The Institute of Transportation Engineers (ITE) Traffic Engineering Handbook, 2016 (ITE Handbook)[13] explains the necessity of providing accessibility for all pedestrians, including those with disabilities: "Accommodating pedestrians includes considering those with visual, hearing, or cognitive impairments"[13]. Measures for providing pedestrian accessibility to persons with disabilities include: APS, fixed roadway lighting, curbs, curb ramps, islands, audible signals, and other way finding cues. It is important to combine auditory, tactile, and kinaesthetic information to aid in pedestrian movements, particularly at atypical intersections and mid-block crossing locations[13].

TAC's Pedestrian Crossing Control Guide[14] (PCCG) refers to the ITE Handbook[13], which indicates that there are various elements interacting with each other in the street-crossing task. Some of these include road user age, physical ability, and knowledge, and understanding of the way in which traffic moves. The ITE Handbook[13] states that older road users may be affected by failing sensory and information-processing capabilities and slower information processing, while children may have problems with the ability to estimate available and required crossing gaps due to their limited search and attention capacity.

TAC's PCCG[14] indicates that "understanding human factors issues is essential in a holistic approach to planning, designing and operating a road system. Pedestrians, crossing unexpectedly, may make it impossible for a driver to respond in time to avoid them. Research has shown that major human factors issues contributing to pedestrian collisions are[14]:

- Driver response to unanticipated pedestrian movements
- Visual obstacles such as parked vehicles, windshield pillars, newspaper stands, and vegetation
- Limited sight distance due to horizontal and vertical alignments to approaches
- Pedestrian and driver inattentiveness
- Poor visibility due to darkness
- Alcohol use by pedestrians and drivers
- Speeding by drivers
- Children's inexperience in traffic

The following sections discuss some of the unique characteristics associated with aging road users and children as pedestrians relative to younger adults (20-64 years old).

3.4.1 Aging Road Users

It is a known fact that as people age, their visual, mental, and physical capabilities diminish, and the incidence of disability can also increase. People can experience reductions in acuity, contrast sensitivity, and visual field. They can also experience restrictions in the area of visual attention, increased sensitivity to glare, decreased dark adaptation, and decreased motion sensitivity. Furthermore, people can experience a reduction treatment system is justified under the 8-hour criterion. In addition to 8-hour warrants, OTM Book 12-Justification 6 provides 4-hour warrants for installation of pedestrian treatment for smaller communities. Smaller communities are defined as communities with population of less than 10,000.

Figure 5 and Figure 6 show the 4-hour pedestrian volume and pedestrian delay criteria for communities with population less than 10,000.

For further details on Justification 6 – Pedestrian Volume and Delay, refer to OTM Book 12.

5.1.2 Pedestrian Crossover Assessment

If a traffic signal (i.e. IPS, MPS, or full traffic signal) is not warranted at a site, the next step as shown in Figure 2 is to check whether a PXO is warranted. The preliminary assessment for PXOs is based on the following three factors:

Traffic volume: The research conducted by Zegeer et al[18], which analyzed pedestrian collisions at 2000 marked and unmarked crosswalks, found that there is a statistically significant relationship between pedestrian collision rate and traffic volume. Specifically, at locations with marked crosswalks, collision rates increase significantly as a function of traffic volume, for ADTs greater than approximately 9000 vehicles per day. This suggests the need to enhance the marked crosswalks at these locations with additional treatments to improve pedestrian safety. In addition, there is also a relationship between traffic volume and crossing opportunities, which affects pedestrian delay. Therefore, by including traffic volume as a variable within the Pedestrian Crossover System preliminary assessment process, delay considerations are also integrated. This approach is consistent with the TAC's PCCG[14].

Crossing distance: The same research by Zegeer et al. (2005)[18] found that crossing distance has an impact on the likelihood of a pedestrian collision, particularly on roads with higher traffic volumes (i.e., the wider the crossing distance, the more difficult it is for pedestrians to safely cross the street). A particular concern with wider cross-sections is the multi-threat situations that are created by multilane roads. Collisions involving multiple threats typically occur when the driver and pedestrian fail to see each other because of the sight obstruction created by a vehicle that has already stopped for the pedestrian in another lane.

Pedestrian system connectivity: The provision of pedestrian system connectivity is important for proper pedestrian accommodation. As indicated in the guiding principles in Section 4.3, facilitating connectivity between crosswalks and sidewalks, and/or trail networks involves understanding and monitoring pedestrian desire lines, which evolve as a function of land use, the location of pedestrian generators and attractors, and proximity to existing crossing facilities. Providing proper connectivity between origins and destinations allow pedestrians for simple and convenient access to facilities with the shortest possible deviation.

Based on the above factors, the steps to check the requirement of a PXO are as follows:

1. Check minimum pedestrian and vehicular volume as the first step. If the total 8-hour pedestrian volume crossing the main road at an intersection or midblock location during the highest pedestrian traffic hours is greater than 100 "equivalent adult pedestrians" as defined in section 5.1.1 and the 8-hour vehicular volume during the same time period is greater than 750 vehicles, then check whether the distance of the site from the closest traffic control device is more than 200 m. If the distance is more than 200 m then the location is a candidate for a PXO. The 200 m minimum distance required from the site to the nearest traffic control device is consistent with Justification 6 of OTM Book 12 and the TAC's PCCG[14]. Otherwise, check for any justification based on connectivity requirements, such as existing sidewalks or walkways to confirm pedestrian desire lines. If the site cannot be justified for a pedestrian crossing control based on connectivity requirements or pedestrian desire lines, then the site is not a candidate for a pedestrian crossing control.

crosswalk lines should be within the most direct route from sidewalk to sidewalk.

- Crosswalks should be as short as possible without compromising other design factors.
- In case of traffic signal control pedestrian treatments, pedestrian signal heads should be positioned within the extension of the crosswalk if possible.
- Crosswalks should be laid out such that pedestrians (specifically a person with a mobility device) are not forced outside of the lines of the crosswalk due to the angle of the curb ramps.

The details of different types of crosswalk markings are included in Section 6.2.4. Figure 7 demonstrates a typical crosswalk layout with standard crosswalk markings and stop lines for a signalized intersection.

6.2.1.2 Curb Ramps

Curb ramps provide access for people using wheelchairs or scooters at crossings where there is an elevation change between the sidewalk and the street level crossing.

Crosswalks and curb ramps must be laid out in a manner such that the pedestrians (specifically with mobility devices) are not forced outside of the lines of the crosswalk due to the angle between curb ramps and the crosswalk. The location of curb ramps should be coordinated with crosswalks and sidewalks such that they are aligned.

Where traffic islands (refuge islands and medians) are provided within a pedestrian crossing, they must contain a level area for pedestrians to cross and must have curb ramps on both sides.

Specific requirements for curb ramps are provided in Section 2.1.6 – Designing for Accessibility.

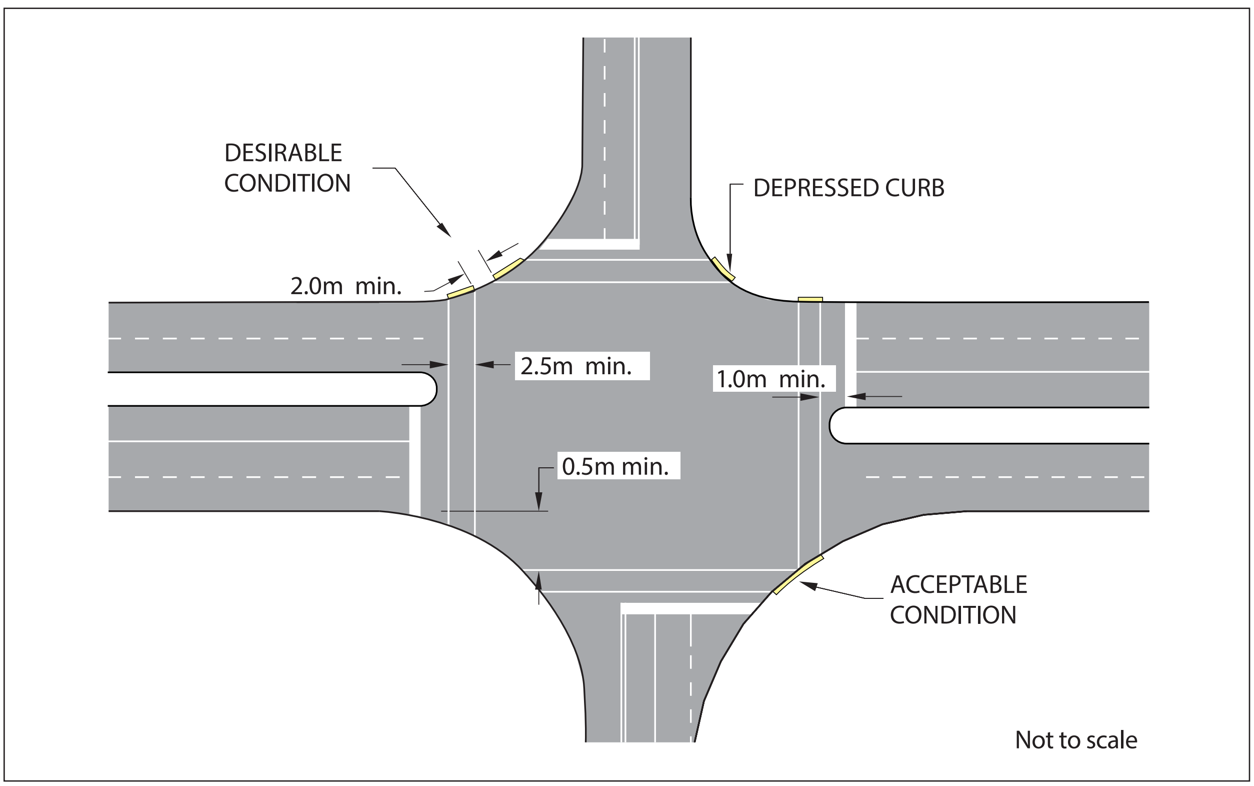


Figure 7: Typical Crosswalk Design with Standard Crosswalk Markings

In some cases, the selection of facilities for construction is based on opportunities that may arise for synergies with other projects, as outlined in **Table 3.11**. Combining works in this way allows bike facilities to be installed while achieving cost efficiencies, however practitioners should consider the completeness of the resulting bikeway network. The implementation of small sections of disconnected bicycle facilities is unlikely to provide meaningful connections for cyclists since those facilities may suffer from low cycling volumes. Practitioners should consider investing some of the resources saved through the aforementioned synergies to provide additional links that properly integrate the new facilities into the network.

2.4.3 Physical Barriers

In some areas, there may be major physical barriers or constraints to bicycle travel caused by topography, rivers, narrow bridges, freeways, railroad tracks or other obstacles. When selecting candidate routes, preference should be given to routes with few or no barriers or constraints that may affect the connectivity and directness of the bike route. If these constraints are unavoidable for a particular candidate route, consideration should be given as to how such barriers will be overcome, and the associated costs, when comparing alternative routes.

2.4.4 Attractiveness

Scenery is an important consideration for any bikeway network, especially for touring and recreational routes. Candidate routes that are attractive and comfortable to use will improve overall user enjoyment and increase the perception of safety. A high quality cycling experience can be provided in a wide range of settings. Bikeways that serve a primarily recreational purpose may be located beside rivers and ravines, or through hydro rights-of-way; existing or former rail corridors may also provide an interesting and attractive route. Recreational cyclists tend to favour routes with adjacent land uses that are attractive; utilitarian cyclists will also prefer these routes, provided they are direct.

2.4.5 Safety and Comfort

The safety and risk exposure of cyclists must be considered when selecting candidate routes. The factors that influence the level of safety and risk exposure for a particular bikeway include: user conflicts, traffic volume and speed, truck and bus volumes, on-street parking, surface quality, sightlines, maintenance considerations and human factors. These variables are discussed in detail within the Bicycle Facility Selection Tool in **Section 3.** The roadway and safety characteristics of the candidate route should also be considered.

Pavement surface quality and traffic volumes are factors that may affect a cyclist's comfort level within the bicycle facility. Candidate routes should have a pavement surface that is free of bumps, potholes and other surface irregularities in order to provide users with a comfortable cycling experience. Candidate routes located on heavily travelled or high-speed roadways may be frequently used by experienced utilitarian cyclists, but recreational cyclists may not be comfortable with this type of facility. A parallel route should be selected where possible in order to accommodate those user groups.

2.4.6 Cost

The evaluation of candidate routes will normally involve a cost comparison. This analysis should identify the capital and maintenance costs for the bicycle facility. Consideration should also be given to the feasibility of constructing and implementing the candidate route.

Funding availability can limit choices; however, a lack of funds can never justify a poorly designed, constructed or maintained facility. It is usually more desirable not to build anything than to construct a poorly planned or designed facility. The decision to implement a bikeway should be made with a conscious, long-term commitment to a proper level of maintenance.

2.4.7 Accommodation of Existing and Future Demand

Routes that are established, successful and popular with cyclists should be selected as candidate routes. Local cyclists and stakeholders may also identify routes as an important future connection, and request that additional facilities be constructed to improve the connection. Routes with scenic corridors along abandoned railroads, and roads where shoulders can be paved have a high potential for cycle tourism, and should be considered as candidate routes.

2.4.8 Consistent with Local Tourism Strategies and Goals

When selecting candidate routes, practitioners should review the strategies and goals identified by Regional Tourism Offices and related organizations to ensure that the route supports, and is consistent with, these strategies and goals. These routes should consider primary regional destinations such as Conservation Areas, and may also include important local destinations such as Community Centres, Universities and Historic Sites.

2.5 Bicycle Design Supporting Complete Streets

Complete Streets are roadways which have been designed to be a safe, attractive, accessible and integrated environment for all road users across all modes. Pedestrians, cyclists, motorists and transit users of all ages and abilities are considered during the design and implementation of Complete Streets.

The benefits include:

- Improved safety for all users;
- More liveable communities;
- Positive impacts on public health; and
- Economic benefits, since people want to be there.

Cycling infrastructure is a key element of the Complete Streets mix. It improves the accessibility of a community and, if effectively planned and designed, allows for seamless transitions between cycling, pedestrian and transit modes.

Corridor projects are a good opportunity for providing continuous bicycle facilities as part of, or in addition to, the planned bikeway network. Combining the provision of bicycle facilities with those for Bus Rapid Transit (BRT) or Light Rail Transit (LRT) planning can lead to implementation synergies and associated cost savings.

2.6 Support Features

There are several key support features which should be considered in the planning and design of bikeway networks. Sometimes these provisions are overlooked, but they often play a key role in providing users a complete bikeway system and encouraging bicycle use.

2.6.1 Bicycle Parking Facilities

Providing bicycle parking facilities is an essential component of a multi-modal transportation system, and is necessary for encouraging more bicycle use. A lack of appropriate bicycle parking supply can deter individuals from considering cycling as their basic mode of transportation.

Table 3.4 – Vehicle Mix

Heavy vehicles, such as transport trucks and buses have a greater influence on cyclists than passenger vehicles. This is partly due to the larger difference in mass between cyclists and heavy commercial vehicles, and the increased severity of any resulting collision. Air turbulence generated by these high-sided vehicles also has a more significant impact on the difficulty of controlling a bicycle, which requires both greater skill and more caution on the part of the cyclist than in the presence of passenger vehicles. As the volume of heavy vehicles increases, so too does the desirability of providing buffers or physical separation of cyclists from motorized traffic. Stationary trucks and buses may also interfere with cyclist movements, creating a need for lane changes on the part of cyclists. This increases the interaction with vehicular traffic, and at times may obstruct other drivers' view of the cyclist on the road at inopportune moments.	
Site Characteristics	**Design Considerations and Application Heuristics**
More than 30 trucks or buses per hour are present in a single curb lane	Separated bicycle facilities may be preferred by many cyclists. If paved shoulders, wide curb lanes or bicycle lanes are considered, additional width should be provided as a buffer.
Bus stops are located along the route	Facilities should be designed to minimize and clearly mark cyclist conflict areas with buses or pedestrians at stop locations. See **Section 5.4.2** for more details.

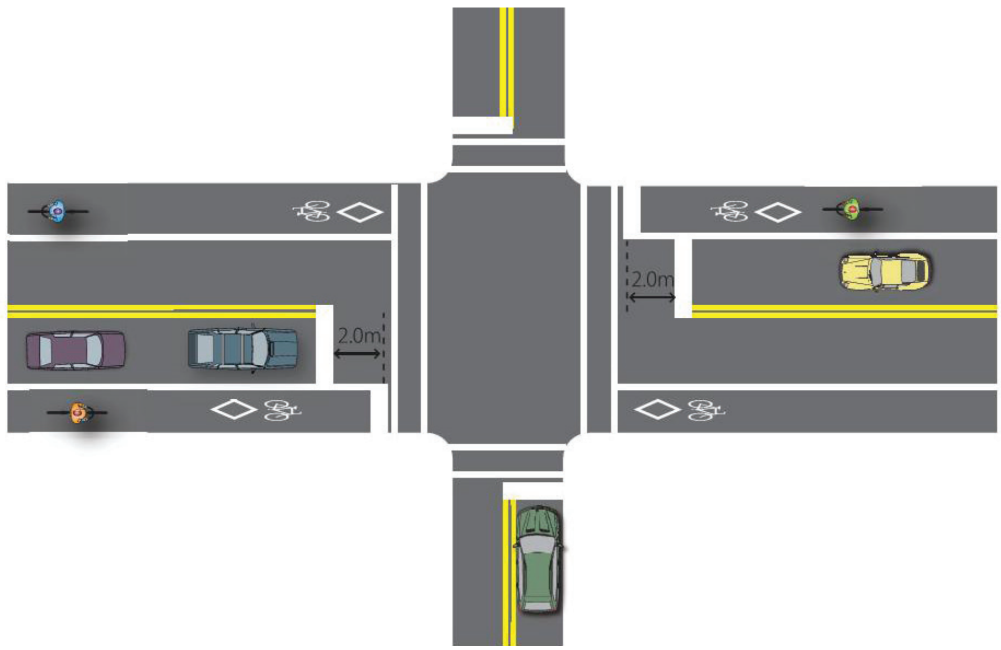
Table 3.5 – Collision History

Where there is evidence of the involvement of cyclists in collisions, historical patterns can sometimes provide valuable indicators of the factors that are present and pose particular challenges for the accommodation of cycling facilities, as well as the mitigating measures that can help resolve them.	
Site Characteristics	**Design Considerations and Application Heuristics**
Bicycle collisions are relatively frequent along the route	A detailed safety study is recommended. Alternate routes should be considered. Separated facilities may be appropriate to address midblock conflicts. If on-road facilities are considered, the operating and buffer space provided to cyclists should be considered.
Bicycle collisions are relatively frequent at specific locations	Localized design improvements should be considered to address contributing factors at high-collision locations, often near intersection and driveway locations.
Noticeable trends emerge from bicycle collisions	The proposed facility and its design should attempt to address noticeable collision trends. For each facility type, safety countermeasures* can be developed. These can be based on road user behaviour and manoeuvres that resulted in the collision, or specific design and policy objectives.
Conflict areas exist between cyclists and motor vehicles or pedestrians	Facilities and crossings should be designed to minimize conflict between different types of users and the conflict area should be clearly marked.

*For detailed scenario-based information, refer to the Bicycle Countermeasure Selection System in the FHWA's BikeSafe guide.

Figure 4.41 – Bicycle Lane Adjacent to Combined Through / Right-Turn Lane (Solid Line with Optional Staggered Stop Bars)

(See Table 4.3 for desired and suggested minimum widths for bicycle lanes. As an option, directional arrows may be applied within the bicycle lane)



Source: MMM/ALTA, 2013

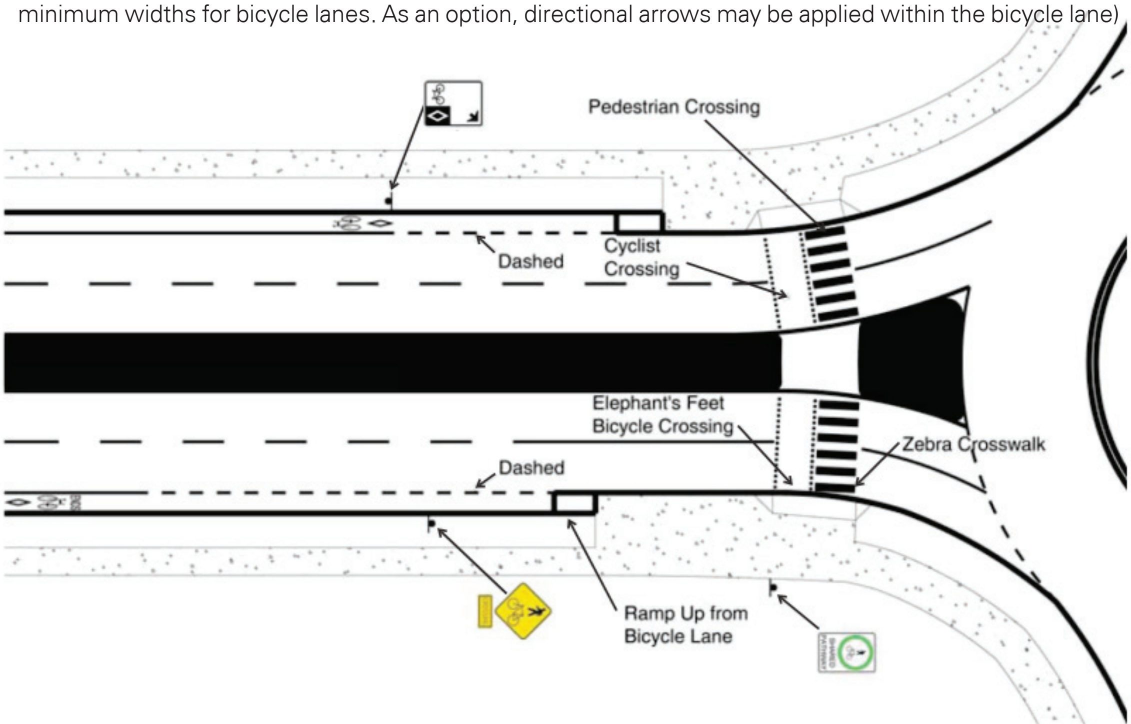
Pavement Markings at Intersections / Conflict Zones for Through Moving Cyclists

Intersections are shared space zones. The entirety of the area where two streets intersect can be used by all vehicles, including cyclists. At certain locations, there may be a benefit to providing pavement markings or treatment through the intersection. Such markings may help to guide cyclists between facilities on either side of the intersection. They also highlight conflict areas where cyclists and motor vehicles will cross paths so that each user group is more aware of the other. The designer should consider whether and how to intersections may be marked. The available treatment options in increasing order of visibility are:

- no treatment;
- bike stencils or chevrons at 1.5 m to 10 m spacing (with optional directional arrows to clarify cyclists' trajectories);
- sharrows at 1.5 m to 15 m spacing;
- dashed guide lines (with optional bike stencils or chevrons but not sharrows);
- green surface treatment; or
- dashed guide lines (with optional bike stencils or chevrons but not sharrows) and green surface treatment.

Figure 5.11 – Bicycle Lane at a Multi-lane Roundabout with Bicycle Bypass

(Signs not directly related to the bicycle facilities have been omitted for clarity. See Table 4.3 for desired and suggested minimum widths for bicycle lanes. As an option, directional arrows may be applied within the bicycle lane)



Source: TAC Bikeway Traffic Control Guidelines for Canada, 2012 (Figure 35, p. 89)

5.4 Conflict Zones

A conflict zone is an area where different types of road user cross travel paths and, therefore, the risk of collisions is higher.

5.4.1 Motorist – Cyclist Conflicts

These conflicts generally occur where a cyclist is making a through movement and a motorist is turning. They can occur within the roadway, particularly through intersections and ramp entry and exit points, as discussed in **Section 5.4.1.1**.

They can also occur when facilities that are outside of the travelled way cross a leg of an intersection where motorists may be turning. Further guidance is given in **Section 5.4.1.2**.

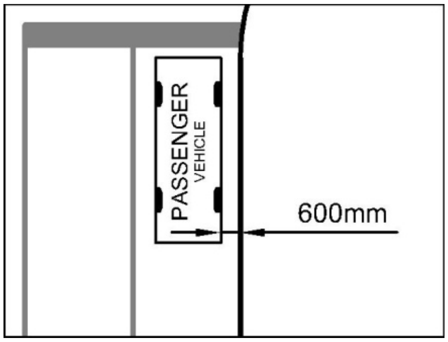
5.4.1.1 On-Road Conflicts

This configuration of conflict zones for motorists and cyclists includes intersections, interchange ramps and private entrances. Pavement markings may be applied to provide guidance to cyclists and motorists in conflict zones.

Several examples of intersection treatments and associated signage are given in **Section 4**. In addition to these, practitioners should give particular

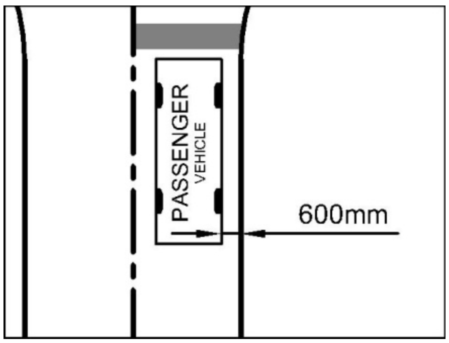
APPENDIX D

City of Toronto Road Engineering Design Guidelines Excerpts



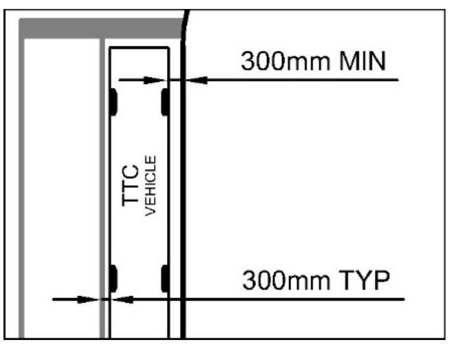
<u>Passenger Vehicles - on roads with lane markings</u>

Passenger vehicles shall initiate a right turn from a designated right turn lane or the vehicular travel lane closest to the curb on the right side of the vehicle where there are no designated right turn lanes. Vehicles shall initiate a right turn from a 600mm offset from the face of curb or the center of the lane marking on the right side of the vehicle.



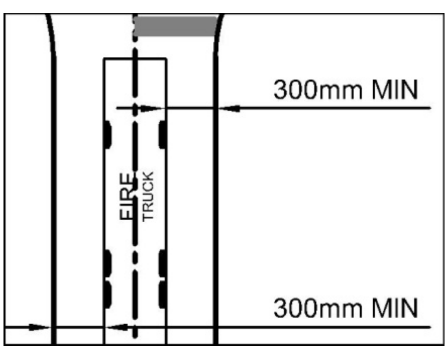
<u>Passenger Vehicles - on roads without lane markings</u>

Passenger vehicles shall initiate a right turn from the right half of the road. Vehicles shall initiate a right turn from a 600mm offset from the face of curb on the right side of the vehicle.



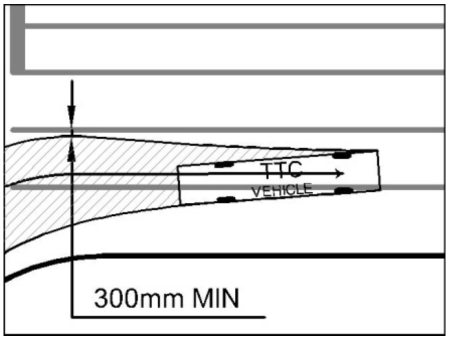
<u>TTC Vehicles</u>

TTC vehicles on service bus routes with a right turn at the design corner shall initiate a right turn from a designated right turn lane or the vehicular travel lane closest to the curb on the right side of the vehicle where there are no designated right turn lanes. Vehicles shall initiate a right turn from a minimum 300mm offset from the face of curb or the center of the lane marking on the right side of the vehicle and a typical minimum 300mm offset from the center of the lane marking on the left side of the vehicle. If offsets on both sides of the vehicle cannot be maintained due to limited lane width, the 300mm offset on the right side of the vehicle shall be maintained and the 300mm offset on the left side of the vehicle should be reduced. At locations with nearside bus stops, a TTC vehicle should be able to negotiate a right turn that is part of a service route starting at the bus stop.



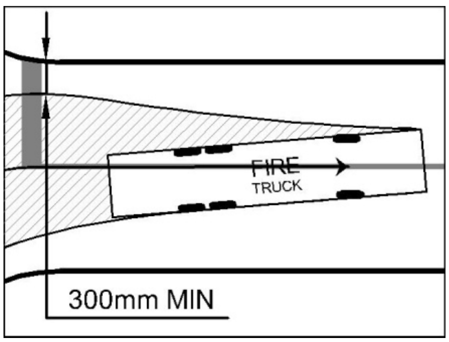
<u>Fire Trucks</u>

Fire trucks shall be assumed to initiate a right turn from anywhere on the roadway in order to be able to manoeuvre a turn. Vehicles shall maintain a minimum 300mm offset from the face of curb.



TTC Vehicles

TTC vehicles shall be assumed to manoeuvre right turns using up to 2 receiving vehicular travel lanes where available. Vehicles shall maintain a minimum 300mm offset from the center of the lane marking or face of curb on the left side of the vehicle.



Fire Trucks

Fire trucks shall be assumed to manoeuvre right turns using the entire roadway. Vehicles shall maintain a minimum 300mm offset from the face of curb.

APPENDIX E

Mississauga Cycling Master Plan Excerpts

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. A reference list of additional research that was reviewed for the Cycling Master Plan update is provided at the end of this Appendix.

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 15km/hr and 30 km/hr and up to 50km/hr 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.

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

In 2010, the Institute of Transportation Engineers released a recommended practice called Designing Walkable Urban Thoroughfares: A Context Sensitive Approach. One of the recommendations of this tool 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 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 minimum turning speed of 10 mph (16 km/hr) 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.

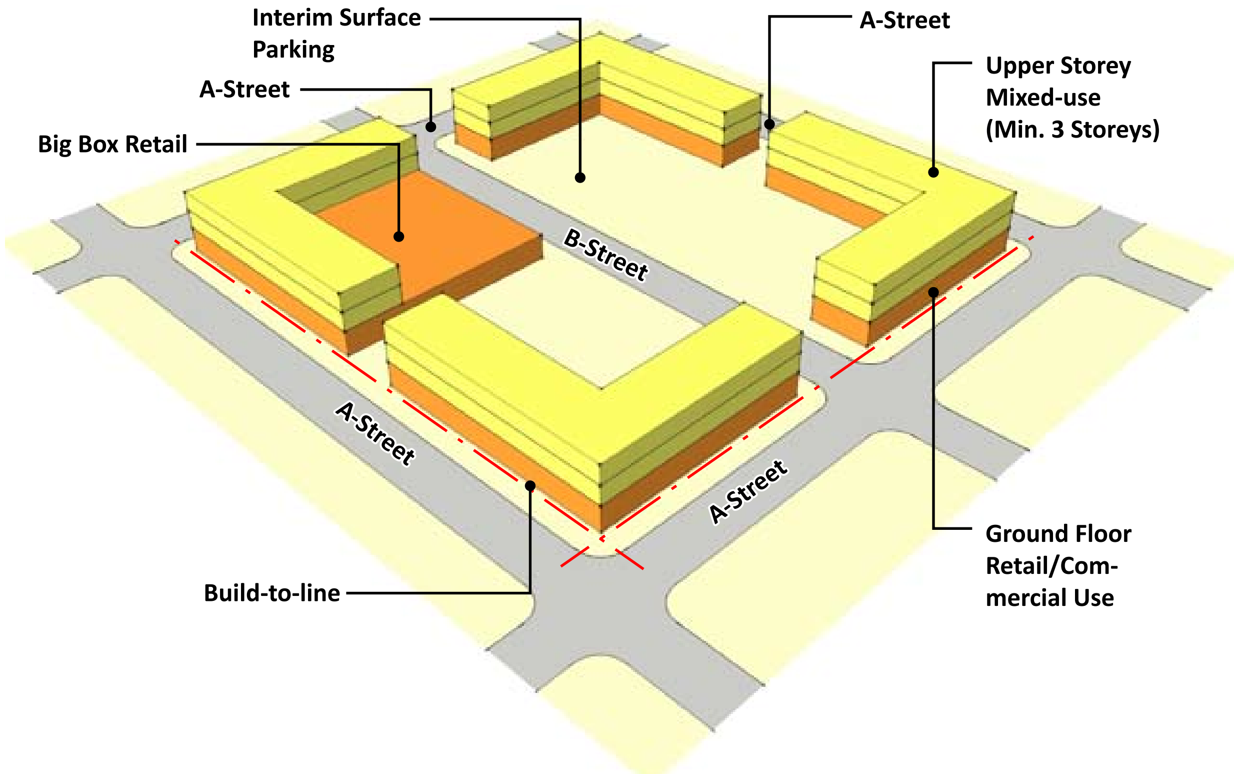
Mid-block multi-use trail crossings

As discussed in Section 3, midblock 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.

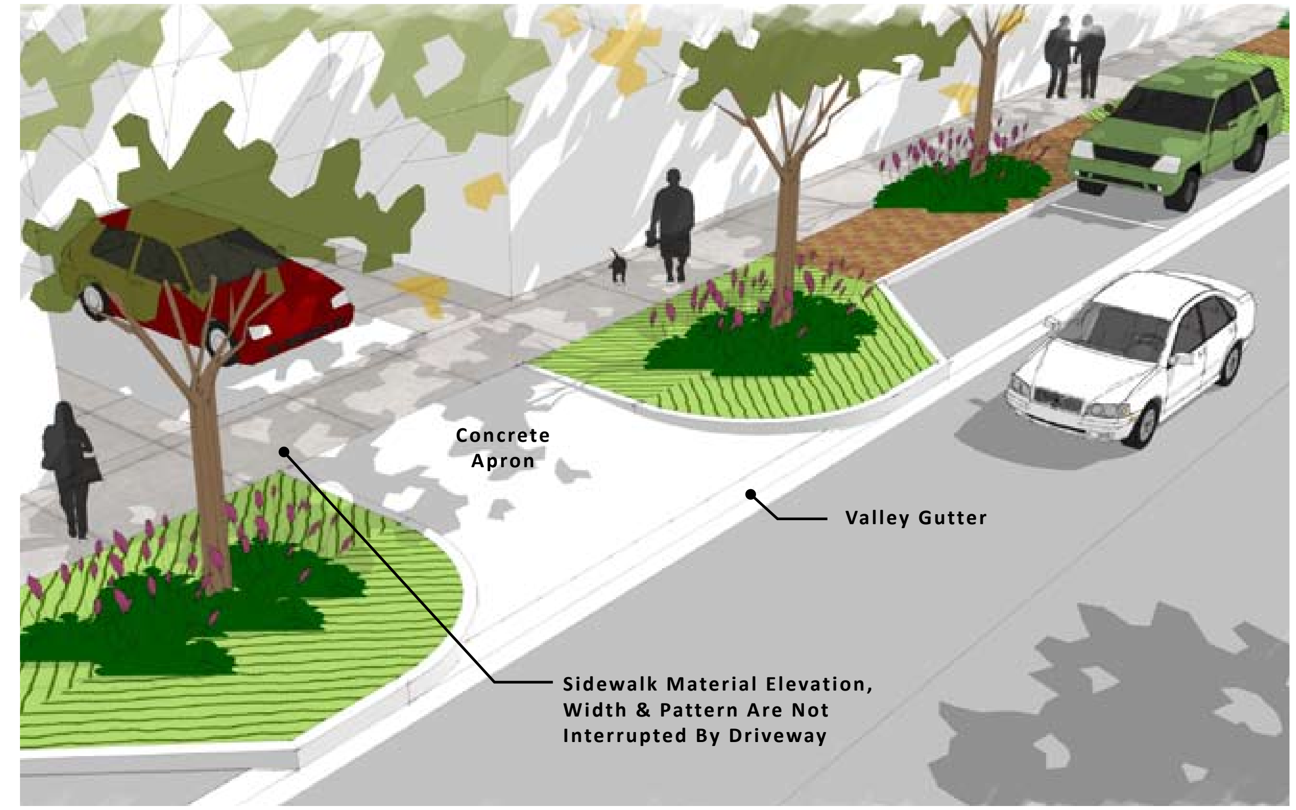
- **Traffic Calming Devices**: Traffic calming can improve cyclist comfort and safety along roadways where cycling

APPENDIX F

City of Mississauga Downtown 21 Master Plan Excerpts



Interim Retail Block Frontage Diagram



Laneway & Driveway Diagram

Interim Retail Block Frontage

Some areas in the Downtown may develop initially as low intensity retail blocks with surface parking and intensify over time as the market changes. To allow for this interim development pattern, A-street frontage requirements apply but, B-street frontage requirements may be relaxed to eliminate the minimum build-to-line frontage requirement. The result of this, with A-street frontage requirements remaining, is an interim built form block pattern that fronts A-streets and leaves the interior of the block for surface parking. The B-street is still required to connect through the block and be designed according to the Street Design Standards, but in the interim is a street that provides access to interior parking lots. Over time this block pattern can be intensified within the established structure of A and B-streets.

Interim Side Property & Party Wall Conditions

As the Downtown incrementally urbanizes with mid-rise and taller buildings, new buildings may be adjacent to smaller existing structures or undeveloped property resulting in blank sidewalls. While exposed blank sidewalls are to be expected during this transition period, design guidelines are required to mitigate the appearance and height of blank walls.

- Blank sidewalls should be designed as an architecturally finished surface and large expanses of blank sidewalls should be avoided.
- To mitigate the impact of blank sidewalls they should be designed with a material finish that complements the architectural character of the main building façade.
- Side stepback walls should be a minimum of 5.5 metres from the property line to allow for sufficient glazing and building separation.

Laneways & Driveways

Laneways provide the secondary service access off of Access Street and B Streets.

- Laneways require a maximum of 6.1m right-of-way with a travel surface that is a minimum of 3.66 m wide, except within 15m of a corner, where the minimum travel surface is 6.1m wide (i.e. the entire width of the laneway).
- If two laneways intersect at 90 degrees, then a 45-degree corner clip is required 3.1 m along each corner.
- The design vehicle for laneways is a SU9m (SU30’) single unit truck; in this way, a garbage truck can access laneways.

Intersection Design

The design and scale of intersections in the Downtown should strive to minimize the width of pedestrian crossings while providing safe, traffic-calmed turning movements.

- The standard corner radius, for all non-roundabout intersections, for all street types, in the downtown, is 7.6m (25’). The design vehicle for downtown is the WB12m (WB40’) tractor trailer. In this way, delivery trucks, busses, and emergency vehicles will be able to reasonably access the downtown; motorists will be encouraged to make turns at reasonably safe speeds, and pedestrians will have reasonably short crossing distances.
- Intersections, involving one or more streets, with more two or more lanes in one direction, may use smaller corner radii than 7.6m (25’).
- Intersections involving streets with medians and one lane on each side of the median, will use the smallest corner radius that permits the WB12m (WB40’) tractor trailer to turn.
- The utilization of adjacent travel lanes to accommodate turning movements is permitted on any street in the downtown, except on corners around which bus routes, LRT routes, and official truck routes turn. However, if the bus, LRT, or official truck route is turning onto, or off of, a street with two or more lanes, going in the same direction as the route, then encroachment is permitted into those lanes.

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