6.0 CURB RADII GUIDELINE

Road Engineering Design Guidelines

Version 1.1

June 2017

City of Toronto, Transportation Services

Background

In early 2014, Transportation Services initiated a review of the Division's design guidelines and standards to move our organization in a direction consistent with the transportation departments of many other large North American cities. Roadway design engineers in Canada have historically relied on the Transportation Association of Canada's (TAC) Geometric Design Guide for Canadian Roads (GDGCR) (1999) as the basis for engineering roadway designs. However, most guidelines within this document were developed decades ago, have not been substantially revisited, and have not always fully considered all modes of travel.

While as a part of the TAC GDGCR update attempts are being made to provide separate guidance suitable for urban areas, it has been determined that the City of Toronto would benefit from more context sensitive and in-house engineering design, an approach taken by several other municipalities.

In response, Transportation Services has embarked on updating technical guidance on street design. This guideline is the result of extensive research and consultation with key partners and reviewing relevant policy and design documents such as:

- National Association of City Transportation Officials (2013). Urban Street Design Guide. Island Press, Washington.
- Complete Streets Guidelines of other comparable jurisdictions such as Chicago, Philadelphia, and Boston.
- Ontario Ministry of Transportation. Ontario Traffic Manuals
- Transportation Association of Canada (TAC) (1999). Geometric Design Guidelines for Canadian Roads
- American Association of State Highway and Transportation Officials. (2004). A Policy on Geometric Design of Highways and Streets (5th ed.). Washington, DC: AASHTO.

This guideline is primarily for use by engineering staff to determine the size of **curb radii at intersection corners**. This document will eventually be part of a future document containing City of Toronto specific engineering design guidelines for road works.

6.0 Curb Radii

6.1 Introduction

The size of curb radii at intersection corners have impacts on vehicle types, vehicle speeds, pedestrian crossing distances, visibility, and pedestrian storage. All these factors must be considered and balanced when determining the appropriate size for a curb radius. These guidelines were designed to provide appropriate motor vehicle accommodation at an intersection corner while improving pedestrian comfort, safety, and visibility.

There are many benefits of appropriately sizing curb radii. Appropriately sized curb radii provides sufficient space for vehicles to negotiate turns while minimizing the radius. Designing curb radii using the minimum vehicle turning path often results in smaller curb radii. Smaller curb radii require vehicles to slow down while manoeuvring right turns. This reduces the impact speed in the event of a collision and provides additional time for a driver to react to unexpected events. Approximately one quarter of pedestrian collisions at intersections occur between right turning vehicles and pedestrians. Of these collisions, over 90% occur when the pedestrian has the right-of-way. As a result, there are significant safety benefits to be gained by reducing vehicle turning speed. Smaller curb radii also allows for a smaller crosswalk setback from the parallel through lane. Reducing the crosswalk setback increases visibility for pedestrians and drivers providing additional reaction time. Smaller curb radii also reduces the pedestrian crossing distance which reduces the time a pedestrian is exposed to vehicular traffic while crossing the road.

Curb radii are determined using various design controls such as vehicle types, turning volumes, and road classifications. The guidelines provided should be used with experiential knowledge and good engineering judgement to determine appropriately sized curb radii.

Applying standard curb radii at all intersection corners would be unsound design given varying characteristics of intersection corners across the City.

6.1.1 Definitions

Constrained Corner
Constrained corners are locations with right-of-way limitations, pedestrian clearway limitations or obstructions preventing the implementation of preferred curb radii.

Large Truck
Large trucks are vehicles that are trucks greater than 11.0m in length such as tractor semi-trailers (WB-20) or heavy single unit trucks (HSU).

Truck Turn
Truck turns in the context of the Curb Radii Guidelines are right turns manoeuvred at intersections by large trucks.

Vehicular Travel Lane
Vehicular travel lanes are lanes used by vehicles travelling along a route. Bus bays, bike lanes, and 24 hour parking lanes are not considered vehicular travel lanes.

6.2 Design Controls

6.2.1 Intersection Corner Type

Intersection corners shall be classified into the following types based on the Road Classification System and functional classification. Of the two intersecting roads at an intersection, the road classification of the road with the lower classification should be used as the intersection corner type.

- Major/Minor Arterial
- Collector/Local - Commercial/Industrial
- Collector - Residential
- Local - Residential

6.2.2 Truck Turn Type

Truck turn types for right turning movements at intersection corners are based on the frequency of large trucks manoeuvring right turns at an intersection corner. Truck turn types are typically not applied to residential roads. Residential road intersection corners are typically assumed to be non-truck turns. Truck turn type should be determined using the right turning large truck peak hour and turn type thresholds identified in Table 6.2.2.A. This method provides a good estimate of truck turn types based on historical data. Good engineering judgement and experiential knowledge should be used when determining the presence and frequency of large trucks.

Table 6.2.2.A Truck Turn Types

Truck Turn Type	Right Turning Large Truck Peak Hour Volume
Frequent Truck Turns	5.00+
Occasional Truck Turns	3.00-4.99
Infrequent Truck Turns	0.01-2.99
Non-Truck Turns	0.00

A link to a map classifying truck turn types at every signalized intersection corner can be found in Section 6.5.2 Truck Turn Type Map.

<u>Non-Truck Turns</u>
Intersection corners with no large truck right turns or all day large truck turning restrictions shall be assumed to be non-truck turn types. Many intersection corners in Toronto and East York District are currently designed and built as non-truck turn types. District Traffic Operations shall be consulted to determine if an intersection corner located in Toronto and East York District should be classified as a non-truck turn type. District Traffic Operations shall be consulted anytime a Major or Minor Arterial or a Commercial/Industrial intersection corner is determined to be a non-truck turn type.

Large Truck Percentage

Where data on frequency of large trucks is unavailable, the percentage of trucks that are large trucks should be determined based on the large truck percentage for the area within which an intersection is located. The large truck percentage is the percentage of all trucks that are large trucks. These values are based on Cordon Count Data provided by the University of Toronto's Data Management Group. When an intersection lies on a boundary of two areas, the larger percentage of the two areas should be used.

A link to maps identifying the percentage of trucks that are large trucks for different areas can be found in Section 6.5.3 Large Truck Percentage Map.

6.2.3 Design and Control Vehicles

Different vehicle types manoeuvre intersection corners at varying frequencies and in different ways. Vehicles used to design intersection curb radii have been categorized to reflect varying frequencies and behaviours. Typical design and control vehicles for different intersection corner types can be found in Table 6.2.3.A. Additional consideration should be given to vehicles that are not typical design and control vehicles that may be required to manoeuvre a turn at a particular intersection.

Design Vehicle
Design vehicles are typically the largest frequent vehicle type manoeuvring a right turn at an intersection corner. The turning movement of design vehicles are frequent and the design should allow for turns to be made with relative ease.

Control Vehicle
Control vehicles are typically the largest vehicle type required to manoeuvre a right turn at an intersection corner. Control vehicles make up a small fraction of all vehicles and manoeuvre turns at intersection corners at a relatively low frequency. Control vehicles use more space than design vehicles to manoeuvre right turns.

Vehicles

The following common vehicle types should be used as design and control vehicles for different intersection corner types. Other vehicles not listed may be used as design and control vehicles where necessary. Common vehicle type dimensions should be as per TAC Geometric Design Guide for Canadian Roads, 1999. Typical dimensions for common vehicles can be found in Section 6.5.1.

- WB-20 – Tractor-Semitrailer with standard 53 foot trailer
- HSU – Heavy Single Unit Truck
- MSU – Medium Single Unit Truck
- LSU – Light Single Unit Truck
- P – Passenger Car
- B-12 – Standard Single Unit TTC Bus
- TTC Articulated Nova Bus
- TTC Articulated New Flyer Bus
- Toronto Aerial Fire Truck

Table 6.2.3.A Typical Design and Control Vehicles for Intersection Corner Types

Intersection Corner Type	Truck Turn Type	Design Vehicle	Control Vehicle
Major/Minor Arterial	Frequent Truck Turn	WB-20	N/A
	Occasional Truck Turn	MSU	WB-20
	Infrequent Truck Turn	MSU	WB-20
	Non-Truck Turn	MSU	MSU
Collector/Local – Commercial/Industrial	Frequent Truck Turn	WB-20	N/A
	Occasional Truck Turn	MSU	WB-20
	Infrequent Truck Turn	MSU	WB-20
	Non-Truck Turn	MSU	MSU
Collector – Residential	Non-Truck Turn	LSU	MSU
Local – Residential	Non-Truck Turn	P	MSU

Additional Considerations

Passenger Car
Passenger Cars shall be used as an additional design vehicle at all intersection corners where right turn movements are permitted.

Fire Trucks
Fire trucks shall be used as an additional control vehicle at all intersection corners.

TTC Vehicles
Appropriate TTC vehicles shall be used as an additional design vehicle at all intersection corners where bus turns are a part of a bus service route. Planned bus routes that are confirmed to be operational in the near future should also be considered.

6.2.4 Vehicle Speed

The selection of vehicle design speed should vary based on vehicle type. Vehicle speeds should be used to determine vehicle turning envelopes. Table 6.2.4.A provides guidance on selection of vehicle speeds for various vehicle types. Where ranges of speeds are provided, the higher vehicle speeds should typically be used and the lower vehicle speeds should be used for constrained corners.

Table 6.2.4.A Vehicle Turning Speeds

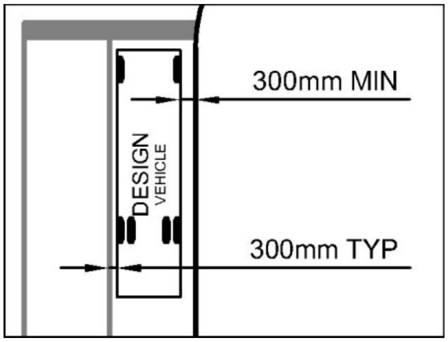
Vehicle Type	Vehicle Speed
Large Truck Control Vehicles	5km/h
Control Vehicles (excluding large trucks)	5-10km/h
Large Truck Design Vehicles	5km/h
Design Vehicles (excluding large trucks)	5-10km/h
TTC Vehicles	10-15km/h
Fire Trucks	10-15km/h
Passenger Vehicles	5-10km/h

6.3 Vehicle Positions and Clearances

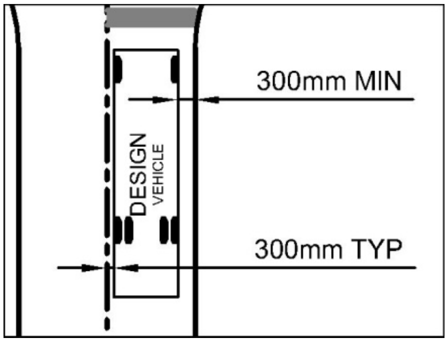
Assumptions about vehicle start and end position and vehicle envelope clearances influence the design of curb radii. These assumptions are described in the subsections below.

6.3.1 Vehicle Starting Position

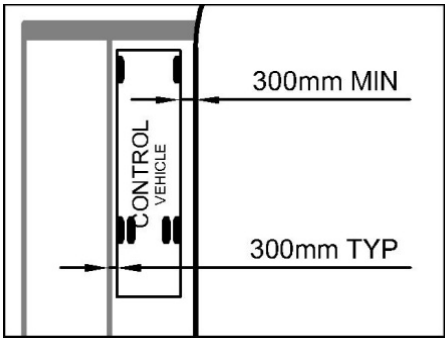
Vehicles should be assumed to initiate a right turn movement from different positions based on vehicle frequency and vehicle type. Design vehicles are always assumed to initiate turns from the designated right turn lane. In some cases, control vehicles are assumed to initiate turns from an offset from the designated right turn lane or from the lane adjacent to the designated right turn lane.



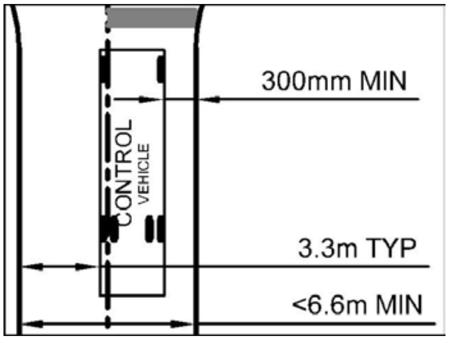
Design Vehicles - on roads with lane markings
Design vehicles shall initiate a right turn from a designated right turn lane or the vehicular travel lane closest to the curb on the right side of the vehicle where there are no designated right turn lanes. Vehicles shall initiate a right turn from a minimum 300mm offset from the face of curb or the center of the lane marking on the right side of the vehicle and a typical 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.



Design Vehicles - on roads without lane markings
Design vehicles shall initiate a right turn from the right half of the roadway. Vehicles shall initiate a right turn from a minimum 300mm offset from the face of curb on the right side of the vehicle and a typical 300mm offset from the center of the roadway on the left side of the vehicle. If offsets on both sides of the vehicle cannot be maintained due to limited road 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.

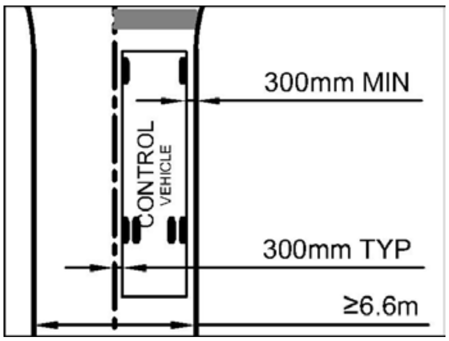


Control Vehicles (excluding large trucks) - on roads with lane markings
Control vehicles shall initiate a right turn from a designated right turn lane or the vehicular travel lane closest to the curb on the right side of the vehicle where there are no designated right turn lanes. Vehicles shall initiate a right turn from a 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 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.



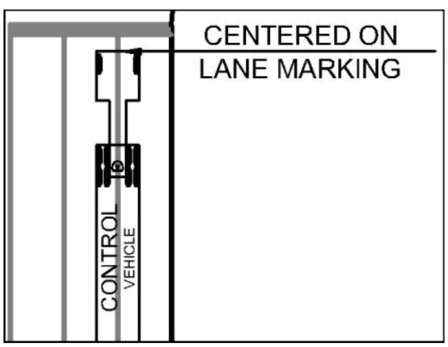
Control Vehicles - on roads without lane markings (less than 6.6m in width)

Control vehicles shall initiate a right turn from the right side of the roadway. Vehicles shall initiate a right turn from a minimum 300mm offset from the face of curb on the right side of the vehicle and a typical 3.3m offset from the face of curb on the left side of the vehicle. If offsets on both sides of the vehicle cannot be maintained due to limited road width, the 300mm offset on the right side of the vehicle shall be maintained and the offset on the left side of the vehicle should be reduced.



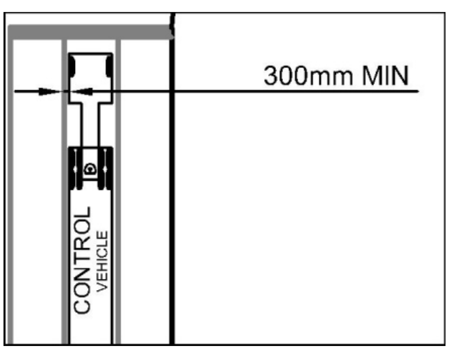
Control Vehicles - on roads without lane markings (equal to or greater than 6.6m in width)

Control vehicles shall initiate a right turn from the right side of the roadway. Vehicles shall initiate a right turn from a minimum 300mm offset from the face of curb on the right side of the vehicle and a typical 300mm offset from the center of the road on the left side of the vehicle. If offsets on both sides of the vehicle cannot be maintained due to limited road width, the 300mm offset on the right side of the vehicle shall be maintained and the offset on the left side of the vehicle should be reduced.



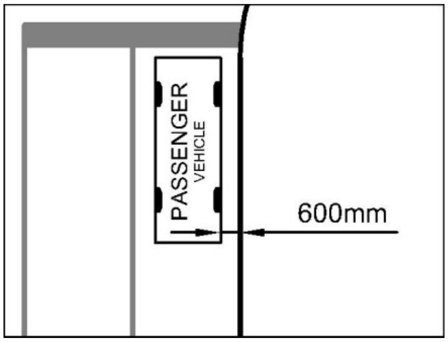
Large Truck Control Vehicles - occasional truck turn - on roads with lane markings

Control vehicles shall be permitted to initiate a right turn with the vehicle centered on the lane marking on the left side of the vehicular travel lane closest to the curb on the right side. Control vehicles should not initiate a right turn while encroaching into the opposing lane.



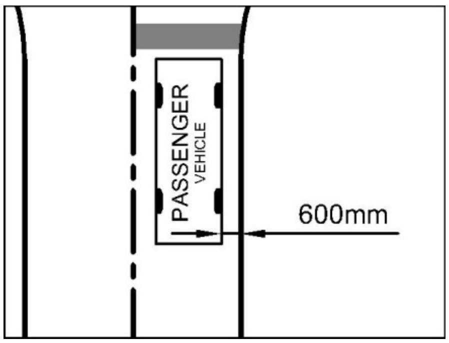
Large Truck Control Vehicles - infrequent truck turn - on roads with lane markings

Control vehicles shall be permitted to initiate a right turn from the second vehicular travel lane closest to the curb on the right side. Vehicles shall initiate a right turn from a minimum 300mm offset from the center of the lane marking or face of median island curb on the left side of the vehicle. Control vehicles should not initiate a right turn while encroaching into the opposing lane.



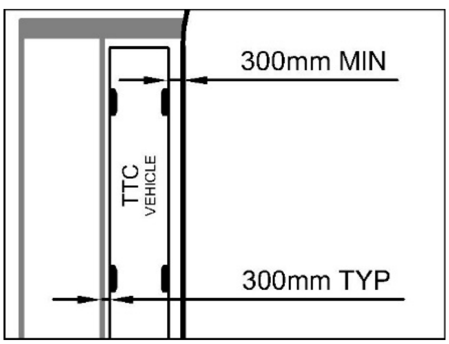
Passenger Vehicles - on roads with lane markings

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.



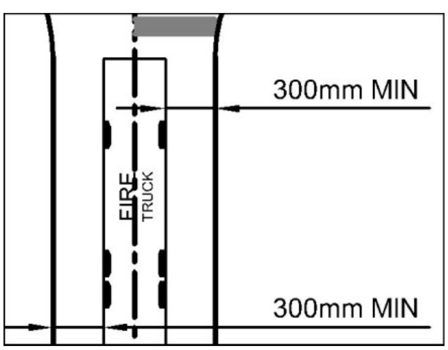
Passenger Vehicles - on roads without lane markings

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.



TTC Vehicles

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.



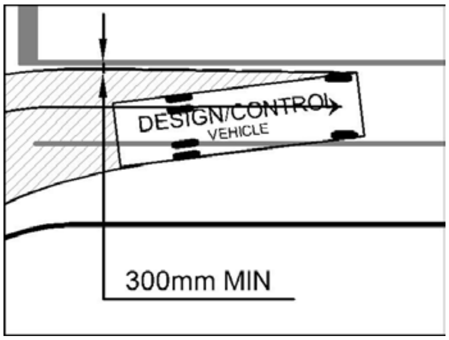
Fire Trucks

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.

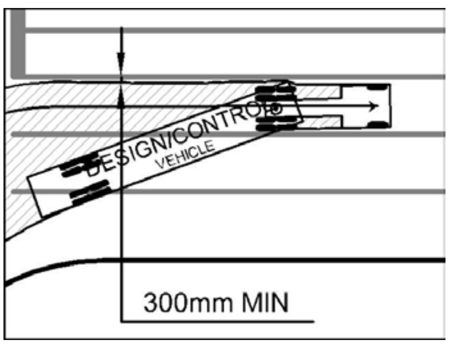
6.3.2 Vehicle Ending Position

Vehicles should be assumed to manoeuvre right turns into different lanes based on the vehicle frequency, vehicle type, and the road classification. Design vehicles are always assumed to turn into the designated receiving lanes. On low volume roads, control vehicles may be assumed to turn into the opposing side of the road.

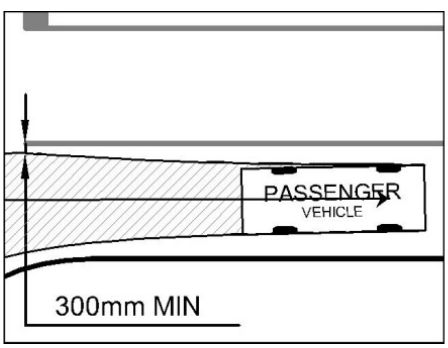
Arterial Roads



Design and Control Vehicles (excluding large trucks)
Design and control vehicles that are not large trucks shall be assumed to manoeuvre right turns using up to 2 receiving vehicular travel lanes where available. Vehicle turning envelopes shall maintain a minimum 300mm offset from the center of the lane marking or face of median island curb on the left side of the vehicle.

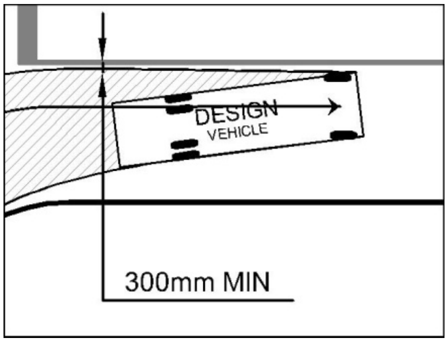


Large Truck Design and Control Vehicles
Design and control vehicles that are large trucks shall be assumed to manoeuvre right turns using up to 3 receiving vehicular travel lanes where available. Vehicle turning envelopes shall maintain a minimum 300mm offset from the center of the lane marking or face of median island curb on the left side of the vehicle.



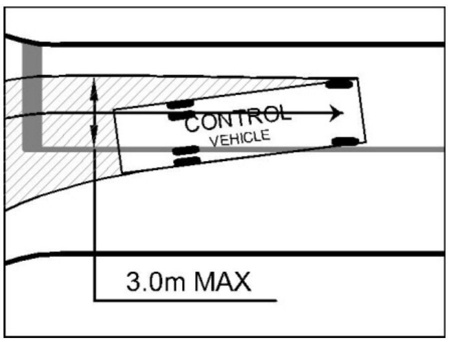
Passenger Vehicles
Passenger vehicles shall be assumed to turn into a designated receiving lane or the vehicular travel lane closest to the curb on the right side. Vehicle turning envelopes shall maintain a minimum 300mm offset from the center of the lane marking or face of median island curb on the left side of the vehicle.

Collector Roads and Local Roads - with lane markings



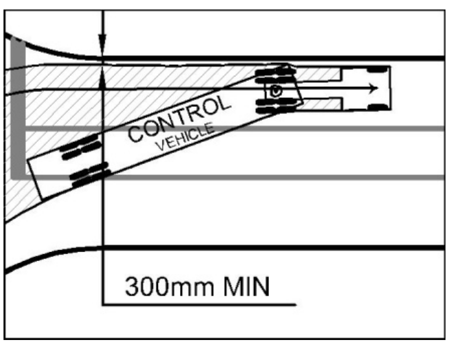
Design Vehicles

Design vehicles shall be assumed to manoeuvre right turns using all available receiving lanes. Vehicle turning envelopes shall maintain a minimum 300mm offset from the center of the lane marking or face of median island curb on the left side of the vehicle.



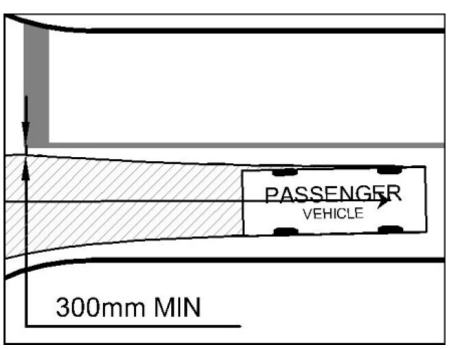
Control Vehicles (excluding large trucks)

Control vehicles that are not large trucks shall be assumed to manoeuvre right turns while encroaching up to 3.0m beyond the centre of the solid yellow line. Vehicle turning envelopes shall maintain a minimum 300mm offset from the face of curb on the left side of the vehicle.



Large Truck Control Vehicles

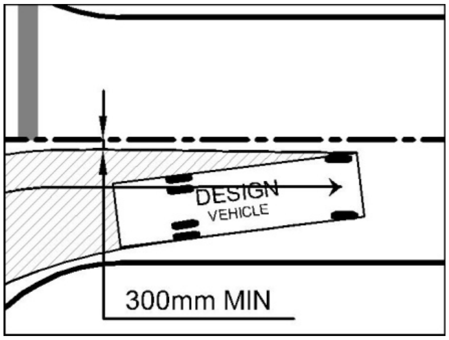
Control vehicles that are large trucks shall be assumed to manoeuvre right turns using the entire width of the roadway. Vehicle turning envelopes shall maintain a minimum 300mm offset from the face of curb on the left side of the vehicle.



Passenger Vehicles

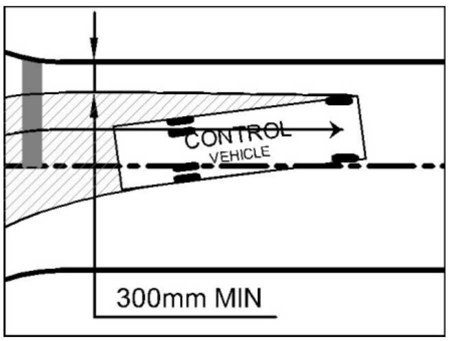
Passenger vehicles shall turn into a designated receiving lane or the vehicular travel lane closest to the curb on the right side of the vehicle where there are no designated receiving lanes. Vehicle turning envelopes shall maintain a minimum 300mm offset from the center of the lane marking or face of median island curb on the left side of the vehicle.

Collector Roads and Local Roads - without lane markings



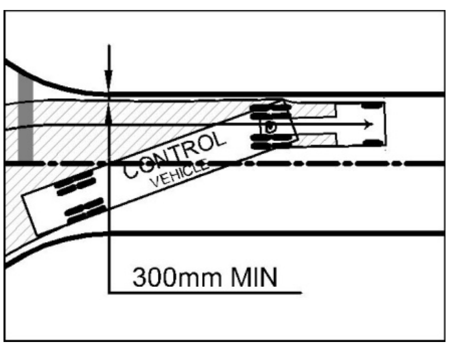
Design Vehicles

Design vehicles shall turn right into the right side of the roadway. Vehicle turning envelopes shall maintain a minimum 300mm offset from the centre of the road on the left side of the vehicle.



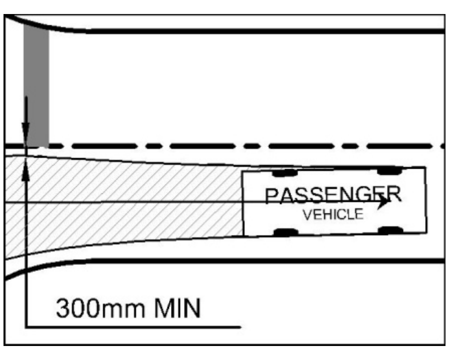
Control Vehicles (excluding large trucks)

Control vehicles that are not large trucks shall be assumed to manoeuvre right turns using the entire width of the roadway. Vehicle turning envelopes shall maintain a minimum 300mm offset from the face of curb on the left side of the vehicle.



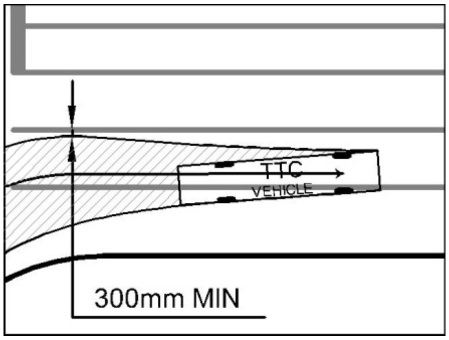
Large Truck Control Vehicles

Large truck control vehicles shall be assumed to manoeuvre right turns using the entire width of the roadway. Vehicle turning envelopes shall maintain a minimum 300mm offset from the face of curb on the left side of the vehicle.



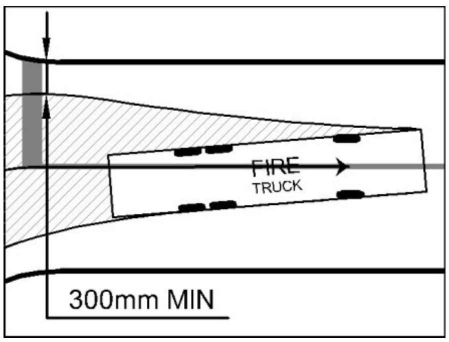
Passenger Vehicles

Passenger vehicles shall turn into the right half of the roadway. Vehicle turning envelopes shall maintain a minimum 300mm offset from the centre of the road on the left side of the vehicle.



TTC Vehicles

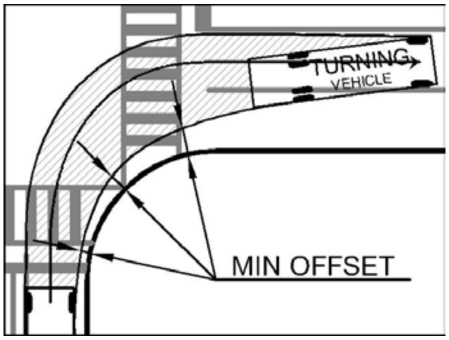
TTC vehicles shall be assumed to manoeuvre right turns using up to 2 receiving vehicular travel lanes where available. Vehicles shall maintain a minimum 300mm offset from the center of the lane marking or face of curb on the left side of the vehicle.



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.

6.3.3 Vehicle Envelope Clearances from Curb Radii



Vehicle turning envelope clearances from curb radii should be based on vehicle type. A minimum 300mm offset from the face of curb around curb radii should be maintained for all turning envelope clearances. TTC vehicles should maintain a minimum offset of 500mm from the face of the curb and a 300mm offset from the face of curb should only be used at constrained corners.

6.4 Curb Radius Design

6.4.1 Design Considerations

Various factors should be considered when determining a curb radius.

Maximum Radius

A typical intersection curb radius should not exceed 15.0m. If following the design methodology outlined in this guide results in a recommended radius exceeding 15.0m, the truck turn type should be downgraded by one level. When a curb radius exceeds 15.0m, an intersection corner identified as a frequent truck turn type should be downgraded to and designed as an occasional truck turn type. An intersection corner identified as an occasional truck turn type should be downgraded to and designed as an infrequent truck turn type. Truck turn types should not be downgraded to a non-truck turn type if there are any right turning large trucks. The final intersection curb radius may exceed 15.0m if there is clear evidence that a larger curb radius is required for the safe operation of the intersection or if there is a clear justification that truck traffic should be prioritized. Improvements to pedestrian crossing distance at locations with large curb radii can typically be made by using two centered compound curves where large single centered curves are required. District Traffic Operations should be consulted prior to implementing curb radii exceeding 15.0m and prior to downgrading the truck turn type.

Minimum Radius

A typical intersection curb radius without right turn restrictions should not be less than 4.0m. Smaller radii may only be used at constrained corners if there are right of way limitations, pedestrian clearway limitations or obstructions preventing the implementation of a 4.0m radius.

Two-way Left Turn Lanes

Two-way left turn lanes may be used as an additional receiving lane for control vehicles manoeuvring right turns at constrained intersection corners if the existing conditions require control vehicles to use the two-way left turn lane to manoeuvre right turns. Two-way left turn lanes may also be considered for use as an additional receiving lane at Intersection corners where implementation of a smaller radius is a priority to address safety issues.

Right Turn Restrictions

Intersection corners with all day no right turn restrictions do not need to accommodate right turning vehicles. Intersections with one way roads also have default right turn restrictions. Curb radii at these locations should be constructed to a 1.0 meter radius. Fire trucks shall be able to manoeuvre right turns at all intersection corners regardless of turning restrictions or one way traffic flow.

<u>Corners with Existing Radii Smaller than Recommended Radii</u>

Existing radii should not be increased to the recommended radii unless there is clear evidence that a larger radius is required for the safe operation of the intersection and there is a history of known issues. District Traffic Operations should be consulted prior to increasing existing curb radii.

<u>Radii Type - Single Centered Circular Curves and Two Centered Compound Curves</u>

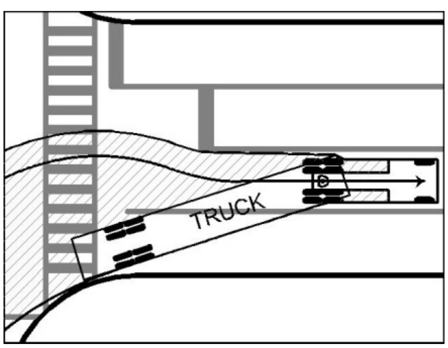
Curb radii are typically single centered circular curves or two centered compound curves. A single centered circular curve should be used in most cases. A two centered compound curve should be used if it is determined that any one direction of a pedestrian crossing at an intersection corner measured from the centre of the crosswalk can be reduced by at least 500mm by using a compound curve. Arterial to Arterial intersection corners and industrial intersection corners should be checked to see if a compound curve can be used.

<u>Effective Turning Radius</u>

The effective turning radius can be greater than the physical turning radius if the right turning and/or receiving lane is not immediately adjacent to the face of curb. This often occurs where there are bike lanes, urban shoulders, or all day on street parking on any of the intersecting roads. Where these elements exist, vehicles will use the effective turning radius to navigate a right turn movement and a smaller physical curb radius should be constructed appropriately.

<u>One Way to One Way Left Turn</u>

Intersection corners with left curb lane to left curb lane left turns shall be designed by applying the methodology used to design curb radii for right turns.

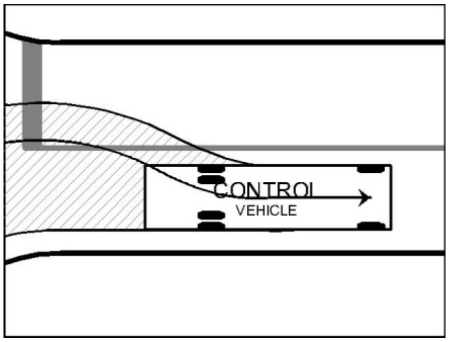


<u>Stop Bar Set Back</u>

The stop bar for the opposing lane of traffic on the receiving leg of an intersection may be offset back from the intersection to provide room for oversteering turning movements of large vehicles at constrained corners. The typical maximum offset is 5.0m. District Traffic Operations shall be consulted prior to moving stop bars to accommodate turning vehicles.

<u>Parked Vehicles</u>

Curb radii shall be designed for all turning vehicles to be able to manoeuvre turns without coming into conflict with legally parked vehicles. Control vehicles should recover from oversteering movements into the opposing side of the road in the shortest distance possible. Vehicles shall not come into conflict with legally parked cars on the opposing side of the road while turning using an oversteering movement. Parking bylaws may need to be amended or curb radii may need to be increased to accommodate control vehicles. District Traffic Operations should be consulted when there is a potential for conflicts with parked vehicles.



Opposing Lanes

All control vehicles shall recover from oversteering movements into opposing lanes or the opposing side of the road in as short of a distance as possible. Note that diagrams in Section 6.3.2 Vehicle Ending Position do not show oversteering movements for ease of illustration and demonstration.

TTC

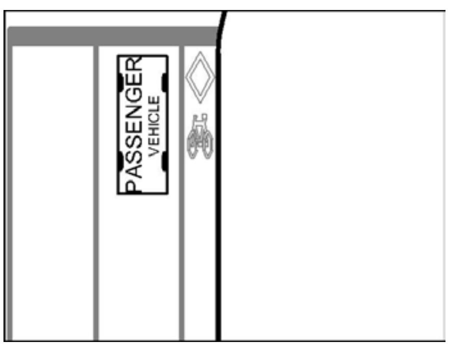
TTC should be consulted when redesigning curb radii where buses are required to turn as part of a TTC bus service route.

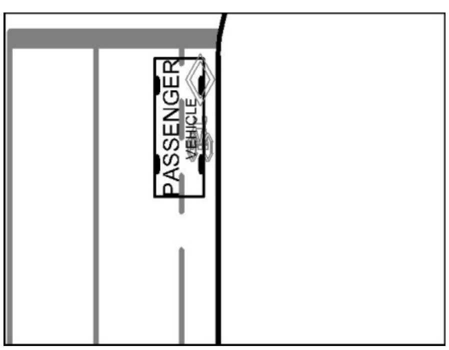
Right Turn Channel Removal

Where intersection corners are being redesigned to remove right turn channels, a vehicle that is able to manoeuvre in the existing right turn channel should be used as the design or control vehicle as required. Vehicles that are unable to manoeuvre through the existing right turn channel should typically not be used as design or control vehicles. Larger vehicles that are unable to manoeuvre through the existing right turn channel should only be used as design or control vehicles if larger vehicles are expected to use the intersection in the future through known land use or truck route changes. District Traffic Operations shall be consulted any time a right turn channel is removed.

Double Right Turns

Double right turns are not common within the City of Toronto and each location is unique. Consultation with District Traffic Operations is required to determine requirements at intersections where double right turns are permitted.





Bike Lanes

Vehicles other than passenger vehicles shall be assumed to initiate a right turn from the vehicular travel lane at the specified offset from the bike lane line marking. Passenger vehicles shall be assumed to initiate a right turn from the vehicular travel lane at the specified offset from the bike lane line marking where bike lanes at the intersection are marked with a solid line. Passenger vehicles shall be assumed to initiate a right turn while encroaching in the bike lane at the specified offset from the face of curb where bike lanes at the intersection are marked with a skip line. Cycling Infrastructure and District Traffic Operations shall be consulted to determine if bike lanes at the intersection should be marked with a solid line or a skip line. All vehicles shall be able to encroach into the bike lane on the receiving leg while manoeuvring a turn unless the bike lane is separated by a physical barrier.

6.4.2 Design Methodology

Curb radii at intersection corners should be designed to be appropriately sized for the turning frequencies of vehicle types at an intersection. Good engineering judgement should be used to ensure that curb radii are not undersized or oversized.

Use of Vehicle Tracking Software

To determine the curb radius at an intersection corner, vehicle turning envelopes shall be determined for all design vehicles, control vehicles and passenger vehicles manoeuvring right turns at an intersection corner. Vehicle turning envelopes should be generated using vehicle starting positions, vehicle starting positions, and vehicle speed. The curb radius should be designed to maintain the specified vehicle envelope clearance from curb radii.

A guide to designing curb radii and using Transoft Solutions AutoTURN to determine a curb radius at an intersection corner can be found at the following link:

http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=f1b900ee600ca410VgnVCM10000071d60f89RCRD

Curb Radii Design Worksheet

The curb radii design worksheet for signalized intersections and non-signalized intersections should be completed and kept on file for reference. The curb radii form summarizes and provides a location to record design vehicles, control vehicles, existing radii, proposed radii, truck turning volumes, etc.

The curb radii design worksheet can be found at the following link:

http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=f1b900ee600ca410VgnVCM10000071d60f89RCRD

Design Tables

Design tables provided in Section 6.5.4 Curb Radii Design Tables and should be used as a reference to check the appropriate physical single circular curve curb radius for an intersection corner. The curb radius selected for implementation at an intersection corner should be the largest of the radii selected for the required design and control vehicles to ensure that all necessary vehicles can be accommodated. The design tables are intended to be used as a rough guide and vehicle tracking software should be used where intersection corners are being redesigned.

6.4.3 Application

The curb radii guidelines should be applied in the following scenarios:

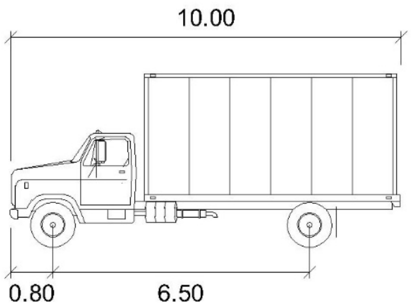
- All intersection corners that are a part of new road construction.
- All intersection corners that are being affected by road reconstruction.
- Intersection corners that are being affected by road resurfacing projects where modification of the curb radius does not have a significant impact on above ground utilities, underground utilities, grading and drainage as determined by the project manager.
- Intersection corners where issues with the existing curb radius are identified by the project manager.
- Intersection corners identified by Transportation Services.

District Traffic Operations may recommend minor deviations from the guideline to address site specific safety or operational issues. Significant deviations from the guideline should be brought to the Safety and Mobility Committee (SMC) Traffic Engineering Subcommittee for consideration.

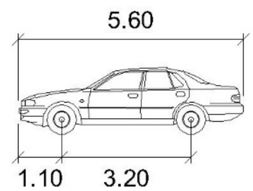
6.5 Supplemental Information

6.5.1 Vehicle Dimensions

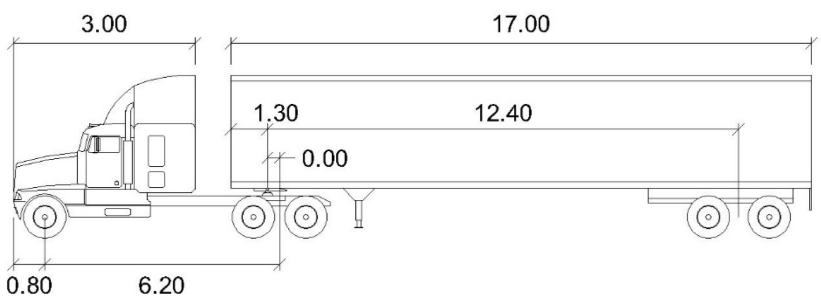
The following vehicle dimensions, as per TAC Geometric Design Guide for Canadian Roads, 1999, should be used for design and control vehicles.



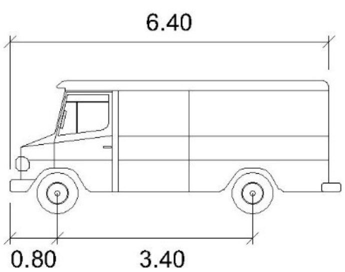
MSU	meters
Width	: 2.60
Track	: 2.60
Lock to Lock Time	: 6.0
Steering Angle	: 40.1



P	meters
Width	: 2.00
Track	: 2.00
Lock to Lock Time	: 6.0
Steering Angle	: 36.2

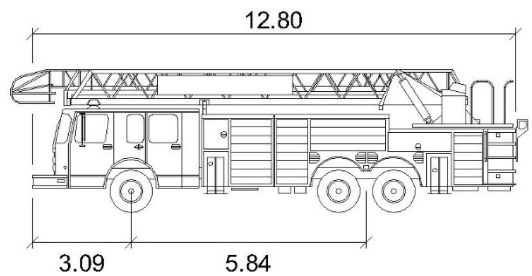


WB-20	meters		
Tractor Width	: 2.60	Lock to Lock Time	: 6.0
Trailer Width	: 2.60	Steering Angle	: 28.3
Tractor Track	: 2.60	Articulating Angle	: 70.0
Trailer Track	: 2.60		



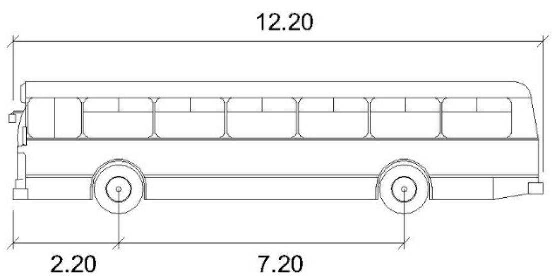
LSU

	meters
Width	: 2.60
Track	: 2.60
Lock to Lock Time	: 6.0
Steering Angle	: 40.8



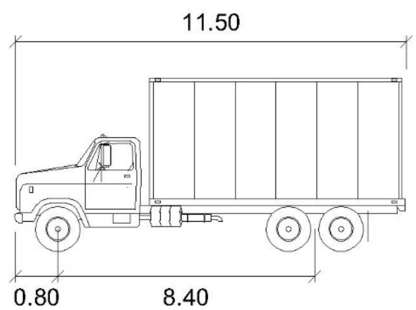
Aerial Fire

	meters
Width	: 2.54
Track	: 2.54
Lock to Lock Time	: 6.0
Steering Angle	: 37.0



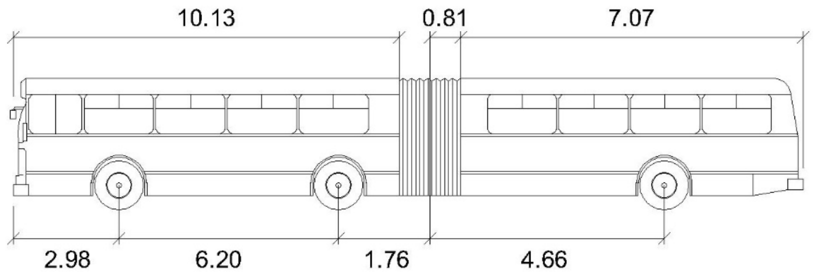
B-12

Width	: 2.40
Track	: 2.40
Lock to Lock Time	: 6.0
Steering Angle	: 37.1



HSU

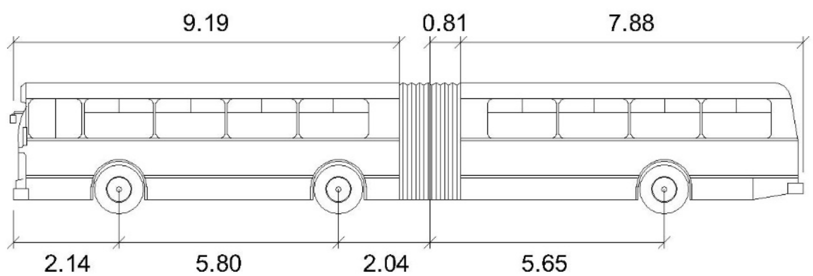
	meters
Width	: 2.60
Track	: 2.60
Lock to Lock Time	: 6.0
Steering Angle	: 39.7



TTC-Articulated Nova Bus

meters

Width	: 2.65	Lock to Lock Time	: 6.0
Track	: 2.59	Steering Angle	: 35.6
		Articulating Angle	: 47.0



TTC-Articulated New Flyer Bus

meters

Width	: 2.58	Lock to Lock Time	: 6.0
Track	: 2.58	Steering Angle	: 40.0
		Articulating Angle	: 70.0

6.5.2 Truck Turn Type Map

Truck turn types at signalized intersection corners are classified using the Right Turning Large Truck Peak Hour Volume and Large Truck Percentage.

Intersection corners with Local - Residential and Collector - Residential roads that are at signalized intersections have been classified by truck turn type in the online map but should be assumed to be non-truck turns. Truck turn types are typically not applied to residential roads.

Maps showing truck turn types at signalized intersections can be found at the following link:

http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=f1b900ee600ca410VgnVCM10000071d60f89RCRD

6.5.3 Large Truck Percentage Map

Large Truck Percentages are the percentage of all trucks that are large trucks. The values in the map are based on Cordon Count Data provided by the University of Toronto's Data Management Group. When an intersection lies on a boundary of two areas, the larger percentage of the two areas should be used.

A Map showing large truck percentages and areas can be found at the following link:

http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=f1b900ee600ca410VgnVCM10000071d60f89RCRD

6.5.4 Curb Radii Design Tables

The curb radii design tables should be used as a reference only and vehicle tracking software should be used where intersection corners are being redesigned. The following design tables were created using the methodology outlined in this document using vehicle tracking software, specified vehicle types, vehicle speeds, vehicle starting positions, vehicle ending positions, and vehicle envelope clearances.

The tables were developed assuming that all lanes that are not adjacent to the curb on right side of the vehicle are 3.0m wide. This conservative assumption is appropriate for design of curb radii in most scenarios.

Design tables are available for the following most common scenarios:

WB-20 design vehicle or control vehicle

- Intersection angle is between 70° and 110°
- Approach curb lane width is 3.3m in width or greater
- Available receiving roadway width is 6.3m in width or greater

MSU design vehicle or control vehicle

- Intersection angle is between 70° and 110°
- Approach lane width is 3.3m in width or greater
- Available receiving roadway width is 6.3m in width or greater

P design vehicle

- Intersection angle is between 70° and 110°
- Approach lane width is 2.9m in width or greater
- Receiving lane width is 3.3m in width or greater

Table 6.5.4.A WB-20 Design Tables

Vehicle: WB-20 Vehicle Speed:5 km/h			Approach Lane Width		
			≥3.3m, <3.6m	≥3.6m, <4.0m	≥4.0m
Receiving Width	Truck Turn Type	Intersection Angle	Radius (m)	Radius (m)	Radius (m)
≥6.3m, <6.8m	Frequent Truck Turn	≥70°, <80°	23*	23*	22*
		≥80°, <90°	22*	21*	21*
		≥90°, <100°	20*	20*	20*
		≥100°, ≤110°	19*	19*	18*
	Occasional Truck Turn	≥70°, <80°	20*	20*	19*
		≥80°, <90°	19*	19*	18*
		≥90°, <100°	19*	18*	18*
		≥100°, ≤110°	17*	17*	17*
	Infrequent Truck Turn	≥70°, <80°	18	17	16
		≥80°, <90°	17	17	16
		≥90°, <100°	17	17	16
		≥100°, ≤110°	16	16	15
≥6.8m, <7.3m	Frequent Truck Turn	≥70°, <80°	21*	21*	20*
		≥80°, <90°	20*	19*	19*
		≥90°, <100°	19*	18*	18*
		≥100°, ≤110°	17*	17*	17*
	Occasional Truck Turn	≥70°, <80°	18*	17*	16*
		≥80°, <90°	17*	17*	16*
		≥90°, <100°	17*	16*	16*
		≥100°, ≤110°	16*	16*	15
	Infrequent Truck Turn	≥70°, <80°	15	15	14
		≥80°, <90°	15	15	14
		≥90°, <100°	15	15	14
		≥100°, ≤110°	14	14	14
≥7.3m, <7.8m	Frequent Truck Turn	≥70°, <80°	20*	19*	18*
		≥80°, <90°	18*	18*	17*
		≥90°, <100°	17*	17*	16*
		≥100°, ≤110°	16*	16*	15
	Occasional Truck Turn	≥70°, <80°	16*	15	15
		≥80°, <90°	16*	15	15
		≥90°, <100°	15	15	14
		≥100°, ≤110°	14	14	14
	Infrequent Truck Turn	≥70°, <80°	13	13	12
		≥80°, <90°	13	13	13
		≥90°, <100°	13	13	13
		≥100°, ≤110°	13	13	12

* Refer to Section 6.4.1 Design Considerations, Maximum Radius if a radius exceeding 15.0m is required.

Table 6.5.4.A WB-20 Design Tables (continued)

Vehicle: WB-20			Approach Lane Width		
Vehicle Speed: 5km/h			≥3.3m, <3.6m	≥3.6m, <4.0m	≥4.0m
Receiving Width	Truck Turn Type	Intersection Angle	Radius (m)	Radius (m)	Radius (m)
≥7.8m, <8.3m	Frequent Truck Turn	≥70°, <80°	19*	17*	16*
		≥80°, <90°	18*	16*	16*
		≥90°, <100°	17*	16*	15
		≥100°, ≤110°	15	15	14
	Occasional Truck Turn	≥70°, <80°	14	14	13
		≥80°, <90°	14	14	13
		≥90°, <100°	14	13	13
		≥100°, ≤110°	13	13	13
	Infrequent Truck Turn	≥70°, <80°	12	11	11
		≥80°, <90°	12	12	11
		≥90°, <100°	12	12	11
		≥100°, ≤110°	12	11	11
≥8.3m, <8.8m	Frequent Truck Turn	≥70°, <80°	18*	16*	15
		≥80°, <90°	17*	15	14
		≥90°, <100°	16*	15	14
		≥100°, ≤110°	15	14	13
	Occasional Truck Turn	≥70°, <80°	13	12	12
		≥80°, <90°	13	12	12
		≥90°, <100°	13	12	12
		≥100°, ≤110°	12	12	11
	Infrequent Truck Turn	≥70°, <80°	10	10	9
		≥80°, <90°	11	10	10
		≥90°, <100°	11	10	10
		≥100°, ≤110°	11	10	10
≥8.8m, <9.3m	Frequent Truck Turn	≥70°, <80°	17*	15	14
		≥80°, <90°	16*	14	13
		≥90°, <100°	16*	14	13
		≥100°, ≤110°	15	13	12
	Occasional Truck Turn	≥70°, <80°	12	11	10
		≥80°, <90°	12	11	11
		≥90°, <100°	12	11	11
		≥100°, ≤110°	11	11	11
	Infrequent Truck Turn	≥70°, <80°	9	8	8
		≥80°, <90°	10	9	9
		≥90°, <100°	10	9	9
		≥100°, ≤110°	10	9	9

* Refer to Section 6.4.1 Design Considerations, Maximum Radius if a radius exceeding 15.0m is required

Table 6.5.4.A WB-20 Design Tables (continued)

Vehicle: WB-20 Vehicle Speed: 5km/h			Approach Lane Width		
			≥3.3m, <3.6m	≥3.6m, <4.0m	≥4.0m
Receiving Width	Truck Turn Type	Intersection Angle	Radius (m)	Radius (m)	Radius (m)
≥9.3m, <9.8m	Frequent Truck Turn	≥70°, <80°	16*	14	12
		≥80°, <90°	16*	13	12
		≥90°, <100°	15	13	12
		≥100°, ≤110°	14	12	12
	Occasional Truck Turn	≥70°, <80°	10	10	9
		≥80°, <90°	11	10	10
		≥90°, <100°	11	10	10
		≥100°, ≤110°	10	10	10
	Infrequent Truck Turn	≥70°, <80°	8	7	6
		≥80°, <90°	9	8	7
		≥90°, <100°	9	8	8
		≥100°, ≤110°	9	9	8
≥9.8m, <10.3m	Frequent Truck Turn	≥70°, <80°	16*	13	11
		≥80°, <90°	15	13	11
		≥90°, <100°	14	12	11
		≥100°, ≤110°	14	12	11
	Occasional Truck Turn	≥70°, <80°	9	9	8
		≥80°, <90°	10	9	9
		≥90°, <100°	10	9	9
		≥100°, ≤110°	10	9	9
	Infrequent Truck Turn	≥70°, <80°	6	6	5
		≥80°, <90°	7	7	6
		≥90°, <100°	8	8	7
		≥100°, ≤110°	8	8	7
≥10.3m, <10.8m	Frequent Truck Turn	≥70°, <80°	15	12	11
		≥80°, <90°	14	12	11
		≥90°, <100°	14	12	11
		≥100°, ≤110°	13	11	10
	Occasional Truck Turn	≥70°, <80°	8	8	7
		≥80°, <90°	9	8	8
		≥90°, <100°	9	9	8
		≥100°, ≤110°	9	9	8
	Infrequent Truck Turn	≥70°, <80°	5	5	4
		≥80°, <90°	7	6	5
		≥90°, <100°	7	7	6
		≥100°, ≤110°	7	7	7

* Refer to Section 6.4.1 Design Considerations, Maximum Radius if a radius exceeding 15.0m is required.

Table 6.5.4.A WB-20 Design Tables (continued)

Vehicle: WB-20 Vehicle Speed: 5km/h			Approach Lane Width		
			≥3.3m, <3.6m	≥3.6m, <4.0m	≥4.0m
Receiving Width	Truck Turn Type	Intersection Angle	Radius (m)	Radius (m)	Radius (m)
≥10.8m	Frequent Truck Turn	≥70°, <80°	14	11	10
		≥80°, <90°	14	11	10
		≥90°, <100°	13	11	10
		≥100°, ≤110°	13	11	10
	Occasional Truck Turn	≥70°, <80°	7	7	6
		≥80°, <90°	8	7	7
		≥90°, <100°	8	8	7
		≥100°, ≤110°	8	8	8
	Infrequent Truck Turn	≥70°, <80°	4	4	3**
		≥80°, <90°	6	5	4
		≥90°, <100°	6	6	5
		≥100°, ≤110°	7	6	6

**4.0m minimum radius should be used

Table 6.5.4.B MSU Design Tables

Vehicle: MSU		Approach Lane Width		
Vehicle Speed: 10km/h		≥3.3m, <3.6m	≥3.6m, <4.0m	≥4.0m
Receiving Width	Intersection Angle	Radius (m)	Radius (m)	Radius (m)
≥6.3m, <6.6m	≥70°, <80°	7	6	5
	≥80°, <90°	7	6	5
	≥90°, <100°	7	6	5
	≥100°, ≤110°	7	6	5
≥6.6m, <7.0m	≥70°, <80°	7	5	4
	≥80°, <90°	7	5	5
	≥90°, <100°	7	6	5
	≥100°, ≤110°	7	6	5
≥7.0m, <7.4m	≥70°, <80°	6	5	3**
	≥80°, <90°	7	5	4
	≥90°, <100°	7	5	4
	≥100°, ≤110°	7	5	5
≥7.4m, <7.8m	≥70°, <80°	6	4	2**
	≥80°, <90°	6	4	3**
	≥90°, <100°	6	5	4
	≥100°, ≤110°	6	5	4
≥7.8m, <8.2m	≥70°, ≤80°	5	3**	2**
	>80°, ≤90°	6	4	3**
	>90°, ≤100°	6	4	3**
	>100°, ≤110°	6	5	4
≥8.2m	≥70°, <80°	5	3**	1**
	≥80°, <90°	5	4	2**
	≥90°, <100°	6	4	3**
	≥100°, ≤110°	6	4	4

**4.0m minimum radius should be used

Table 6.5.4.B MSU Design Tables (continued)

Vehicle: MSU		Approach Lane Width		
Vehicle Speed: 5km/h		≥3.3m, <3.6m	≥3.6m, <4.0m	≥4.0m
Receiving Width	Intersection Angle	Radius (m)	Radius (m)	Radius (m)
≥6.3m, <6.6m	≥70°, <80°	6	5	4
	≥80°, <90°	6	5	5
	≥90°, <100°	6	5	5
	≥100°, ≤110°	6	5	5
≥6.6m, <7.0m	≥70°, <80°	5	4	3**
	≥80°, <90°	6	5	4
	≥90°, <100°	6	5	5
	≥100°, ≤110°	6	5	5
≥7.0m, <7.4m	≥70°, <80°	5	4	3**
	≥80°, <90°	5	4	3**
	≥90°, <100°	5	4	4
	≥100°, ≤110°	6	5	4
≥7.4m, <7.8m	≥70°, <80°	4	3**	2**
	≥80°, <90°	5	4	3**
	≥90°, <100°	5	4	3**
	≥100°, ≤110°	5	4	4
≥7.8m, <8.2m	≥70°, <80°	4	2**	1**
	≥80°, <90°	4	3**	2**
	≥90°, <100°	5	4	3**
	≥100°, ≤110°	5	4	4
≥8.2m	≥70°, <80°	3**	2**	0**
	≥80°, <90°	4	3**	2**
	≥90°, <100°	4	3**	3**
	≥100°, ≤110°	5	4	3**

**4.0m minimum radius should be used

Table 6.5.4.C P Design Tables

Vehicle: P Vehicle Speed: 10km/h and 5km/h		Vehicle Speed 10km/h	 5km/h
Receiving Lane Width	Intersection Angle	Radius (m)	Radius (m)
≥3.3m, <3.5m	≥70°, <80°	9	8
	≥80°, <90°	8	7
	≥90°, <100°	7	7
	≥100°, ≤110°	7	6
≥3.5m, <3.7m	≥70°, <80°	7	6
	≥80°, <90°	6	6
	≥90°, <100°	6	5
	≥100°, ≤110°	6	5
≥3.7m, <3.9m	≥70°, <80°	5	5
	≥80°, <90°	5	5
	≥90°, <100°	5	4
	≥100°, ≤110°	5	4
≥3.9m, <4.1m	≥70°, ≤80°	5	4
	>80°, ≤90°	5	4
	>90°, ≤100°	5	4
	>100°, ≤110°	4	4
≥4.1m	≥70°, <80°	4	3**
	≥80°, <90°	4	3**
	≥90°, <100°	4	3**
	≥100°, ≤110°	4	3**

**4.0m minimum radius should be used