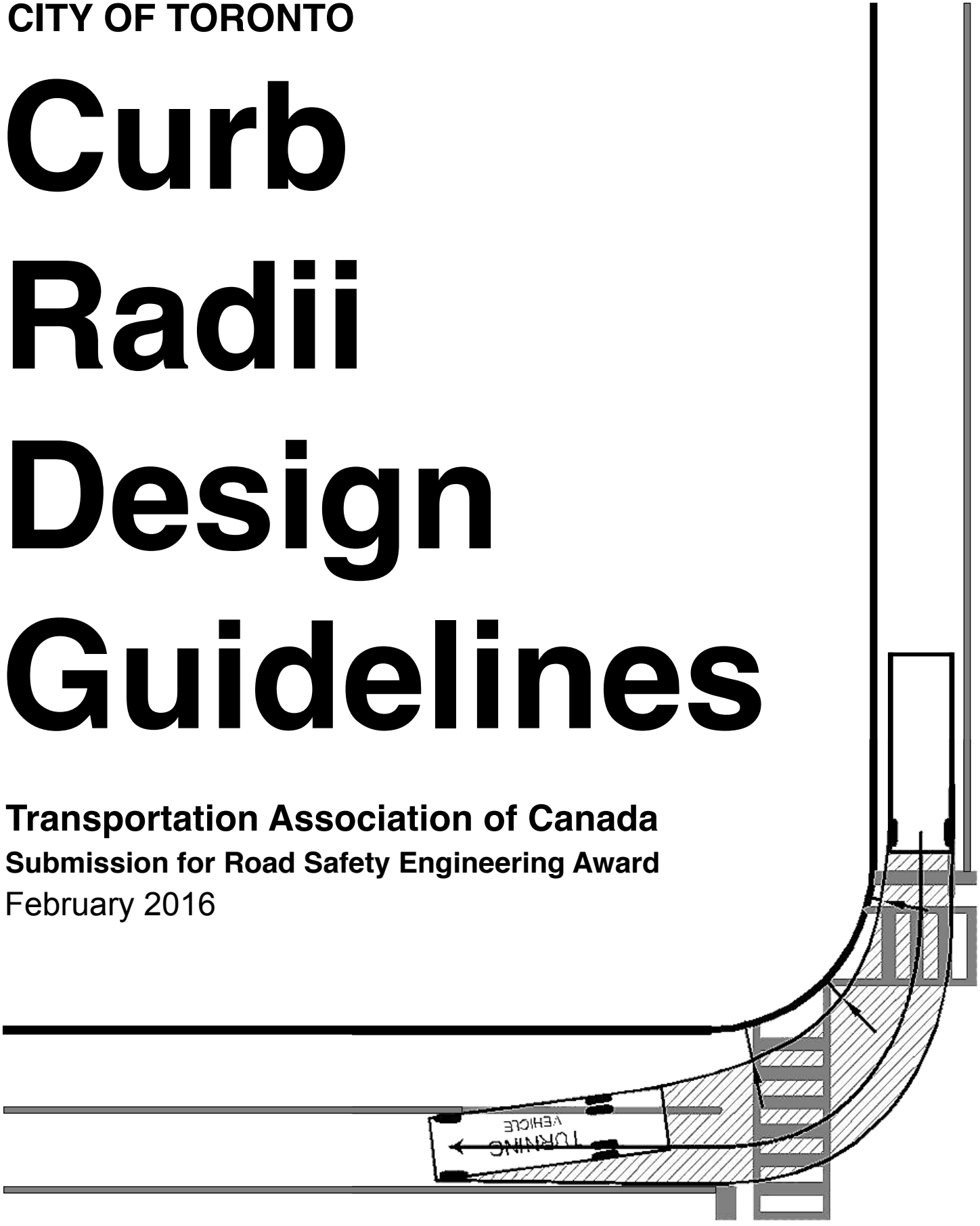
CITY OF TORONTO

Curb Radii Design Guidelines

Transportation Association of Canada

Submission for Road Safety Engineering Award

February 2016



TORONTO

Introduction

Roadway design engineers in Canada have historically relied on design guides as the basis for engineering roadways. However, most traditional guidelines were developed decades ago, have not been substantially revisited, are limited in guidance on urban conditions, and have not always fully considered all modes of transportation.

To respond to the needs of all road users and improve safety of the most vulnerable users (e.g., pedestrians and cyclists), the City of Toronto has developed new and context sensitive Curb Radii Design Guidelines that are used to determine appropriately sized curb radii at intersection corners. The Guidelines consider various factors to determine curb radii at each intersection corner including road classification, truck volumes, expected vehicle types, land use, approach lane widths, departing lane widths, intersection angle, and presence of bus routes and bike lanes.

At the outset of this project, it was determined that the vast majority of intersection corners in the City of Toronto were oversized and could be reduced without any significant impacts to turning vehicles and intersection operations. There are several benefits for vehicles and pedestrians when oversized curb radii are reduced. These include reduced pedestrian crossing distances, reduced vehicle turning speeds, improved driver sight angle and increased pedestrian storage space. . With the drop in manufacturing within the City of Toronto, the conversion of former industrial land uses to residential land uses, in addition to residential densification, there has been a decline in the volume of tractor semitrailers. Since a single standard curb radius was initially constructed at most intersections, many sections of arterial roads with very infrequent large truck volumes have overdesigned curb radii.

Changing long-standing standards and practices in any large organization or industry is not an easy feat. As such, several innovative approaches were used to make these Guidelines context sensitive, practical and easy to apply. Some of these are outlined in this submission.

The City of Toronto Curb Radii Design Guidelines fill a gap in the toolbox of many designers striving to improve road safety for vulnerable road users. As a pioneer in the field, the guidelines are influencing how urban areas across Canada rethink the design of our roads from a multi-modal safety perspective.

Benefits of Developing City of Toronto Specific Guidelines

The current City of Toronto was formed in 1998 through the amalgamation of six former municipalities. Curb radii were constructed to different standards in the former municipalities which resulted in inconsistent practices in constructing curb radii across the City. The former municipalities implemented standard curb radii at all intersection corners based on road classification. The same curb radii were implemented at most arterial road to arterial road intersections and the same curb radii were implemented at most local road intersections without consideration for factors such as truck volumes, available lane widths and road widths. The road network within the City of Toronto is almost completely developed with very few new roads being constructed. As a result, there has not been a harmonized standard or guideline developed

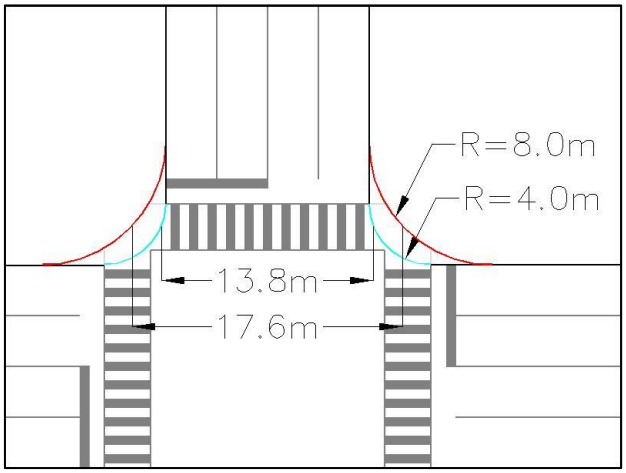
for determining intersection curb radii. Historically, when roads are reconstructed and resurfaced the existing radii has been reinstated. These Guidelines will allow for harmonization and consistency for curb radii across the entire City.

Having City of Toronto specific guidelines also allows for curb radii to be designed for the urban context that exists within the City. The City of Toronto is relatively unique with an almost completely urbanized road network developed to the city limits. Relative to less dense jurisdictions, the City has lower large truck volumes and on average, smaller passenger vehicles. The Guidelines allow for consistent curb radii to be applied to all road works projects that exhibit the net safety benefits of having appropriately sized curb radii.

Benefits of Reducing Oversized Curb Radii

Reducing Pedestrian Crossing Distances

Reductions in curb radii result in reductions in pedestrian crossing distances and pedestrian crossing times. This reduces the time a pedestrian is exposed to vehicular traffic in the intersection reducing the probability of pedestrian-vehicle collisions. Of all pedestrian collisions in the City of Toronto, 54% of the collisions occur at intersections. It can be expected that with shorter crossing distances, pedestrians will be able to clear an intersection quicker, reducing the probability of a pedestrian-vehicle collision. The population of the City of Toronto is also rapidly aging with an increase in the number of senior citizens. Reduced pedestrian crossing distances have a significant impact on senior citizens as they typically walk slower.

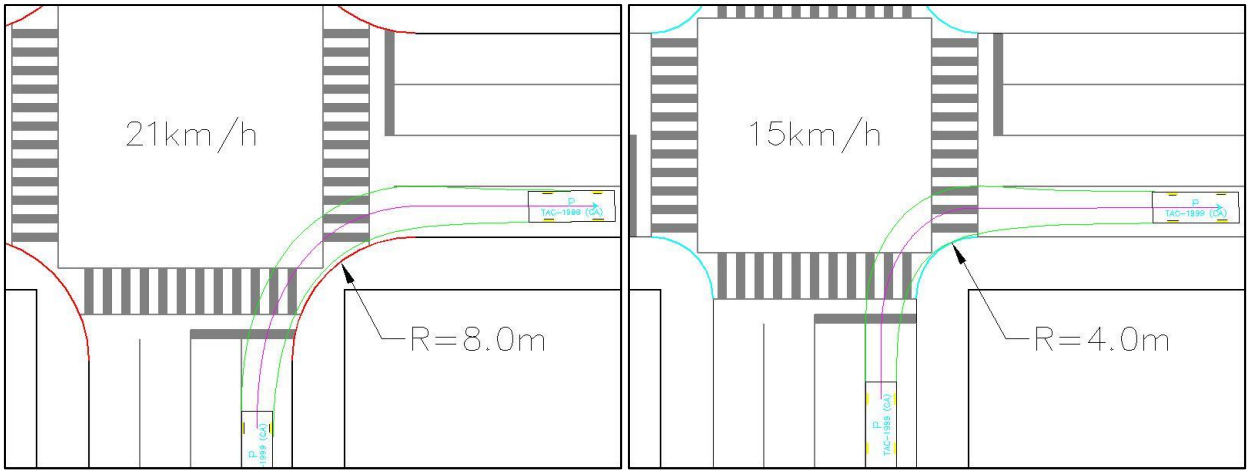


In the scenario depicted above, a reduction in curb radius from 8.0m to 4.0m would improve the crossing distance from 17.6m to 13.8m or by approximately 3.8m (22%).

Reducing Vehicle Turning Speeds

Reductions in curb radii require vehicles to manoeuvre turns at slower speeds. This reduces the impact speed in the event of a collision and increases the available reaction time and stopping sight distance for the driver. Of the pedestrian collisions that occur at signalized intersections in the City of Toronto, 23% occur between right turning vehicles and pedestrians. With reduced

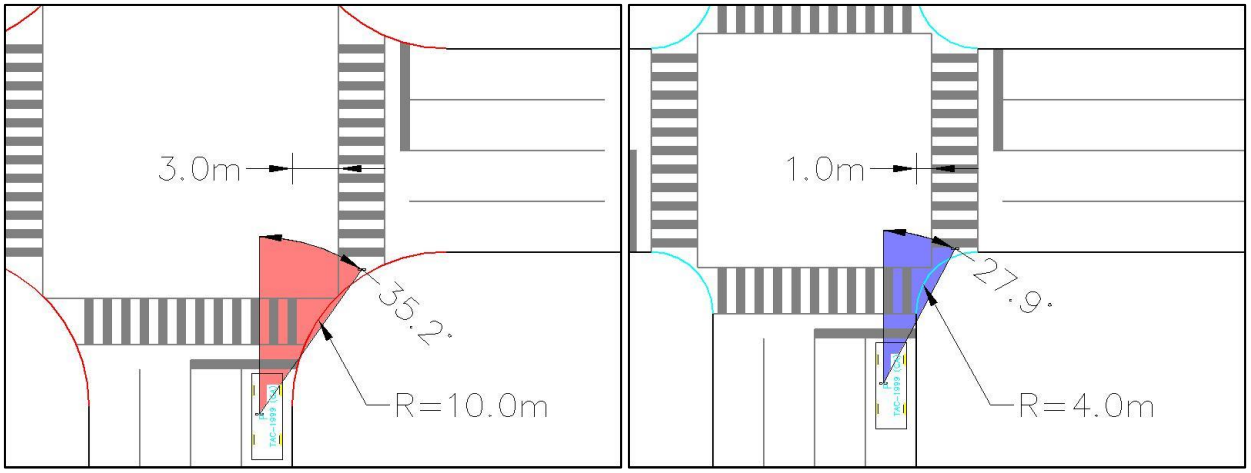
vehicle turning speeds it can be expected that fewer collisions will occur as drivers will have more time to react and avoid a collision. With reduced turning speeds it can also be expected that if a vehicle-pedestrian collision does occur, there will be less severe injuries.



In the scenario depicted above using a TAC passenger vehicle, a reduction in curb radius from 8.0m to 4.0m would reduce the theoretical turning speed from 21km/h to 15km/h or by approximately 6km/h (29%). The TAC passenger vehicle is representative of a full size pick up truck. Though the pick up truck is the best selling vehicle in Canada, sedans, compact SUVs and CUVs are more prevalent within Toronto. The reduction in speed for these other vehicle types would be significantly greater.

Improved Driver Sight Angle of Pedestrian

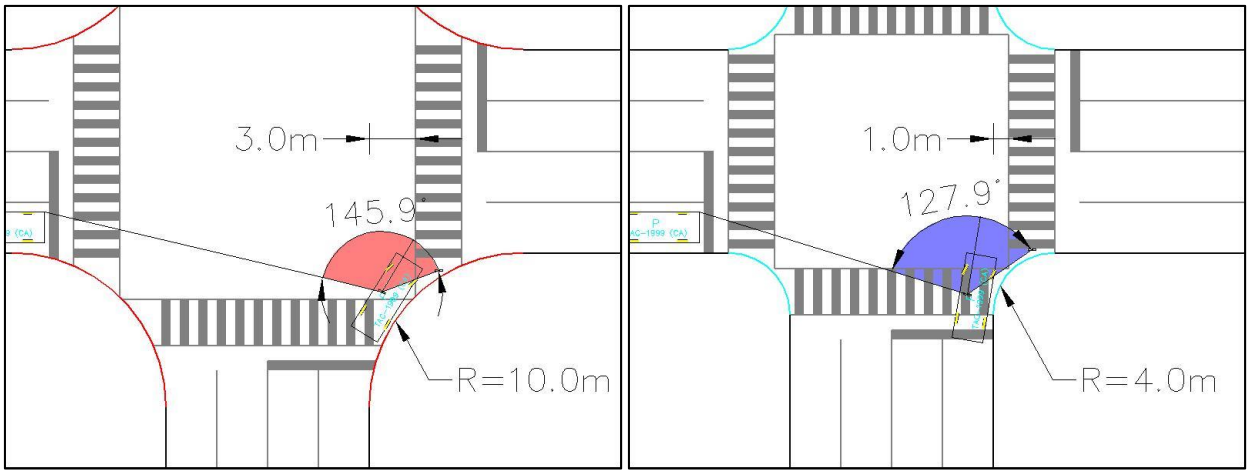
Reductions in curb radii allow the crosswalk to be brought closer to the parallel through lane while minimizing crosswalk overlap at an intersection corner. This improves the visibility of a pedestrian in the crosswalk and allows a driver to view a pedestrian in the crosswalk at a more acute angle and from farther away. With a smaller curb radius, a pedestrian in a parallel crosswalk would appear within a driver's cone of vision earlier, giving a driver additional time to react to the presence of a pedestrian when manoeuvring a right turn.



In the scenario depicted above, a reduction in curb radius from 10.0m to 4.0m would improve the driver's sight angle of the crosswalk from 35.2° to 27.9° or by 7.3°(21%).

Improved Driver Sight Angle of Perpendicular Traffic

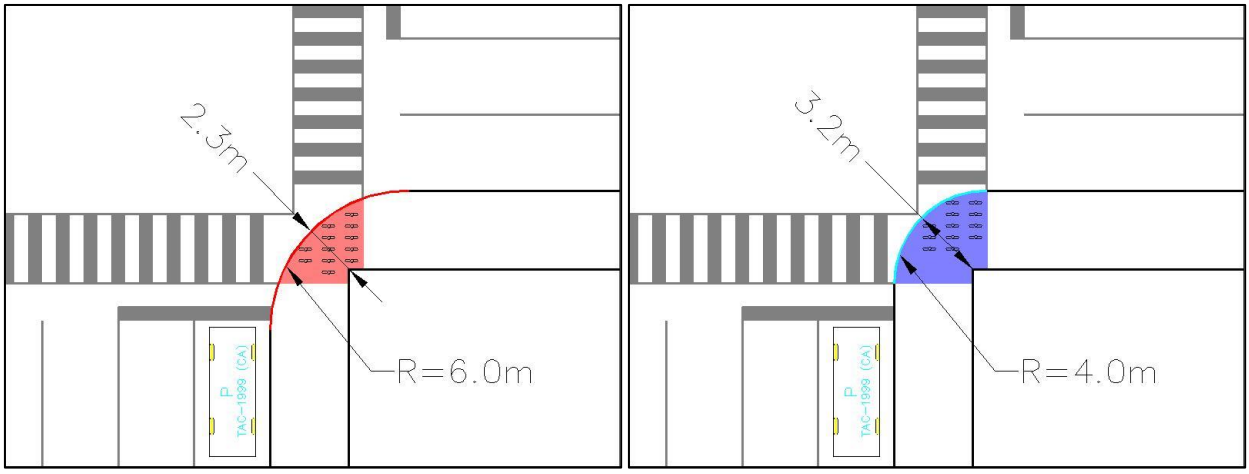
One of the sources of collisions involving right-turning vehicles at stop signs or red lights is the increased driver workload in finding a gap in perpendicular traffic. Collisions may occur when a vehicle proceeds to move forward or turn right while the driver is still looking left for traffic. Reductions in curb radii allow a vehicle turning right to have improved visibility of perpendicular traffic. This reduces the degree to which a driver must turn their head back to look for a gap... This has similar benefits to implementation of a 'smart channel' at channelized right turns.



In the scenario depicted above, a reduction in curb radius from 10.0m to 4.0m improves the angle a driver must look left from 146° to 128° or by 18°(12%)

Increased Pedestrian Storage

Reductions in curb radii provide additional pedestrian storage at intersections with narrow rights-of-way and buildings located at the property line without a setback. Increased curb and sidewalk space allows for more pedestrians to queue at a corner while waiting to cross the road and reduces corner overcrowding. Smaller curb radii also provides wider pedestrian clear space around intersection corners. Where there is insufficient pedestrian storage, pedestrians tend to wait on the road surface to cross and have difficulty stepping off the roadway after finishing their crossing. Providing enough space for pedestrians to gather off the roadway reduces the probability of a pedestrian-vehicle collision.

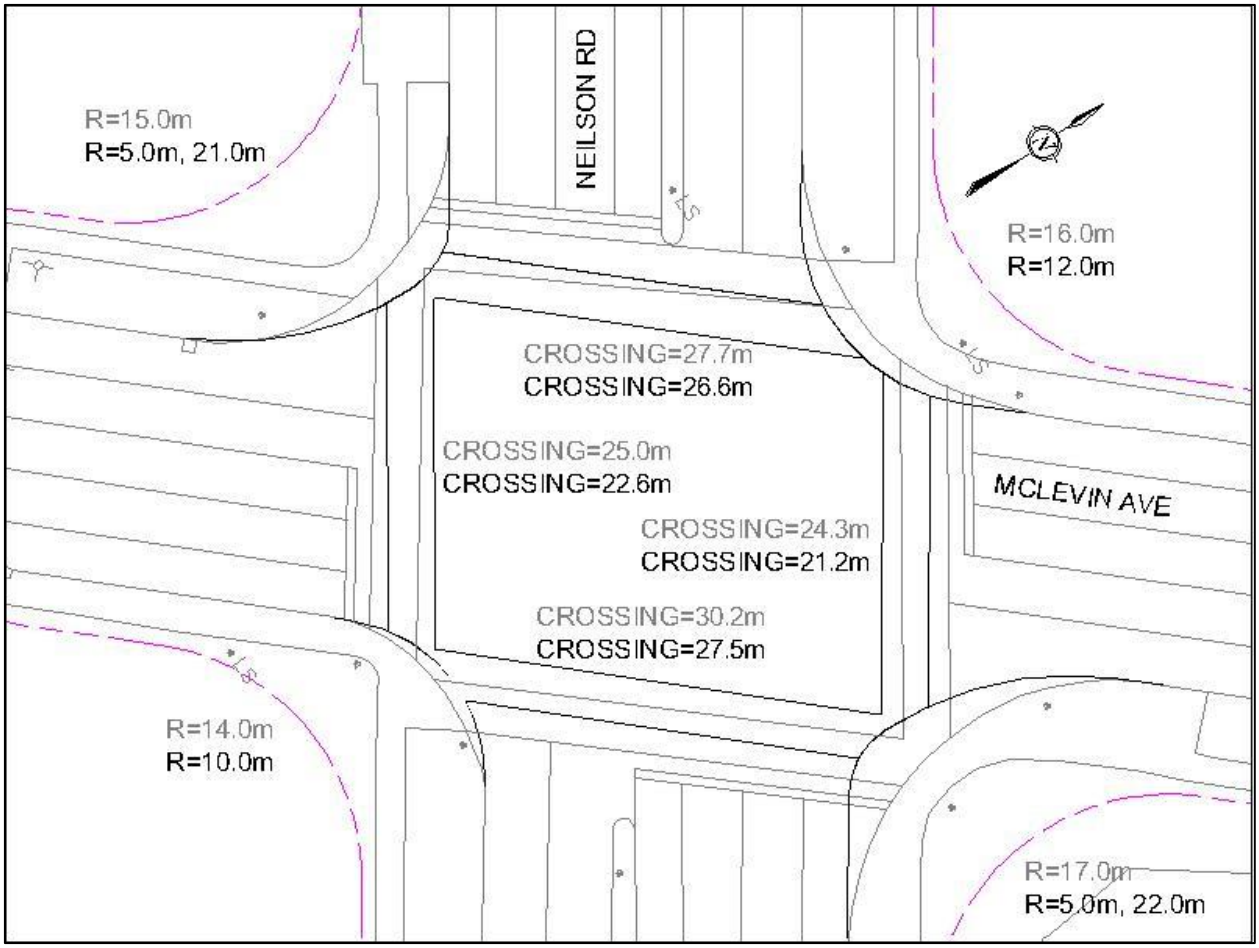


In the scenario depicted above, reducing a curb radius from 6.0m to 4.0m increases the clear space around the intersection corner from 2.3m to 3.2m or by 0.9m (39%). It also increases the available space at the intersection corner from 8.4m² to 12.2m² or by 3.8m² (45%).

Evaluation

The Curb Radii Design Guidelines were completed and released at the beginning of 2015. During the transition phase in 2015, the Guidelines were applied to a limited number of projects. However, the Guidelines were applied to all 2016 projects.

As one of the first applications of the Guidelines the intersection of Neilson Road and McLevin Ave in Scarborough was redesigned. This intersection was identified as one of the top ten most dangerous intersections for pedestrians in a 2013 study based on high pedestrian collision rates. The curb radii at all corners were redesigned and constructed according to the new Curb Radii Design Guidelines.



In the diagram above, the existing dimensions are shown in grey and the proposed and constructed dimensions are shown in black.

Observations were recorded for a 2.5 hour period on similar days and conditions before and after reconstruction of corners. Observations were made of conflicts between pedestrians crossing the northwest leg of Neilson Rd and vehicles manoeuvring right turns at the north intersection corner. Observations showed that prior to construction, 64% of right turning vehicles yielded the right-of-way to pedestrians crossing the road. After construction of the proposed modification, yield behaviour improved to 81%. Preliminary results showed a 17 percentage point improvement in driver yielding behavior after the curb radii was modified according to the Guidelines.

This initial evaluation could be improved by collecting a larger sample of observations, and using a control intersection. The City of Toronto has plans to continue evaluating driver yielding behaviour at various locations across the City that are being reconstructed in 2016.

Innovative Aspects of the Project

The City of Toronto Curb Radii Guidelines are the first of their kind in the country and fill a significant gap in the toolbox of many road designers striving to improve road safety for vulnerable road users. As a pioneer in the field, the Guidelines are influencing how cities across Canada rethink the design of our roads from a multi-modal safety perspective. Innovative approaches were taken in the content and development of the Guidelines.

Context Sensitive Approach

Traditionally, technical engineering guidelines have been relatively absolute, inflexible and insensitive to local context. Avoiding one-size-fits-all guidance and providing relevant context sensitive direction is one of the innovative approaches demonstrated in the development of the City of Toronto Curb Radii Design Guidelines. The City of Toronto has a wide variety of land-uses and road types. These include dense, mixed-use well-developed areas in the downtown with narrower roads, industrial lands with significant heavy truck movement and wider roads, and low-density residential sub-divisions connected by wide arterials roads with high operating speeds. Roadways in each of these scenarios have different characteristics and curb radii at each location should be determined based on those characteristics. The Guidelines seek to replace the traditional guidance that prescribed the same curb radius at all intersection corners across the city with a practical decision making process that takes into account a number of factors such as truck volumes and road classification. This is also what makes the Guidelines easily applicable to other urban communities in Canada, regardless of size and density.

One specific innovation in this area is revisiting the concept of the design vehicle in relation to curb radii design and introducing a new design concept. Traditional guidance requires all curb radii to be designed such that the largest possible vehicle can be easily accommodated when manoeuvring the turn. This guidance is insensitive to the frequency of large vehicles and has resulted in overdesigned curb radii at many intersections. Some designers consider this a 'safer design' because it accommodates very large vehicles, should one happen to turn at a particular intersection. However, in urban conditions with a high level of non-motorized activity and infrequent large truck turns, multi-modal transportation engineering considers this a 'bad design' as opposed to ‘safer design’ as it discourages safe turns and comes at a cost to vulnerable road users. As a part of the new City of Toronto Curb Radii Design Guidelines this design principle was broken down further. The following two categories of vehicles were defined:

- Design vehicle: typically the largest frequent vehicle type manoeuvring a right turn at an intersection corner. The turning movement of design vehicles are frequent and turns should be accommodated with relative ease.
- Control Vehicle: 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. Under the new Guidelines control vehicles will have less available space to manoeuvre a turn than a design vehicle.

This distinction allows for using a smaller more frequent vehicle as the design vehicle and a potentially larger infrequent vehicle as the control vehicle, resulting in smaller, safer curb radii.

Calculated Risk-Taking

Willingness to take calculated risks is another quality of an innovative project that was demonstrated in the new Curb Radii Design Guidelines. In developing a context sensitive Guideline, the City of Toronto took the conscious risk of veering off of old outdated standards, knowing that the overall safety benefits of the new approach is a priority. Potential risks were assessed and mitigated through analysis of several years of collision records and consultations with several experts including City legal staff and the Professional Engineers of Ontario.

Collaborative Process

One of the innovative aspects of the process was the collaborative and inclusive approach taken in developing the Guidelines. The changes being recommended were going to challenge the status quo, change road design practices and impact many different stakeholders. Knowing this, the lead team ensured to identify those stakeholders at the outset and bring them to the table at various points for meaningful contribution. These include Traffic and Road Operations units within the Division, Fire and Emergency Response, City Planning Division, Engineering and Construction Services Division, Toronto Public Health and Toronto Transit Commission.

Application of Technology in Removing Barriers

Another innovative approach in change management was actively identifying and removing barriers to implementation and application of the new Guidelines at every step. In many instances the team took advantage of some of the latest technological tools to achieve this. Some examples include:

- Guidance for application of AutoTURN[1] by practitioners and replacing the traditional approach of using static turn templates on acetate paper.
- Tapping into existing resources such as cordon counts and intersection turning movement counts routinely conducted at all signalized intersections in the City in order to provide guidance on design and control vehicle selection and reduce workload for designers.
- Taking advantage of latest online geospatial platforms such as ArcGIS Online and Oracle databases to offer users of the Guideline with searchable and automatically updated look-up map of intersection truck turning volumes.
- Developing multi-dimensional curb radius look up matrices based on factors such as vehicle speed, approach lane width, receiving lane width(s), truck route type and intersection angle. This minimized the need for using AutoTURN for common scenarios.

[1] AutoTURN is an add-on in AutoCAD and MicroStation which provides customized dynamic templates based on user inputs such as lock to lock steering time and wheel angles, articulating angles and allowable buffers.

Alternative Evaluation Methodology

The conflict analysis approach, an innovative approach in traffic safety analysis, has been utilized for quantifying the safety benefits of recommended changes. Conflict analysis is the concept of observing user (e.g., driver and pedestrian) behaviour for several hours and documenting frequency of observation of non-yields and near-misses. These observations are used as proxies for potential eventual collisions over the long run. Taking this approach allows us to evaluate target corners shortly before and after curb radius modifications. This approach complements the more traditional practice of waiting several years for actual collisions to occur before any conclusions can be made about the safety benefits. In particular, pedestrian and cyclists collisions are random and infrequent events, therefore conflict analysis is a great alternative that offers a much larger sample size and consequently more robust results.

Efficient Financing and Delivery

Every year about 450 kilometres of roadways are reconstructed or resurfaced as a part of the City's state of good repair program. Many of these capital work projects involve reconstruction of the curb and provide the ideal opportunity to maximize safety of all users by updating the radii based on the latest guidelines. While in some cases changing the curb radii involves additional cost such as moving catch basins, in many instance the radius adjustment can be achieved at little additional cost. This approach in financing and delivering future curb radii adjustments is considered innovative as it provides significant benefits at several locations each year for little additional cost.

Transferability to other Canadian Communities and Organizations

With the growth in active transportation and traffic congestion in cities, vulnerable road users (e.g., pedestrians and cyclists) and their safety have become high priority issues for many jurisdictions across Canada and worldwide.

Similar to several other jurisdictions, the City of Toronto is currently working on a Road Safety Strategic Plan with the goal of eliminating fatal and serious injury collisions, in line with other Vision Zero strategies. Application of the Curb Radii Guidelines is one of the tools in the toolbox of countermeasures in achieving this long term goal. Improving the safety of road infrastructure is also one of the key objectives of the National Road Safety Strategy. As one of its guiding principles, the Strategy states that "road traffic systems should take account of human fallibility and minimize both the opportunities for errors and the harm done when they occur". As demonstrated earlier in this document, right-sizing curb radii helps reduce likelihood of driver error by improving vehicle yielding behaviour and reducing driver workload. In addition, tighter curb radii encourage drivers to slow down, resulting in less harm caused by a potential collision.

The Transportation Association of Canada Geometric Design Guidelines are currently in the process of being updated. The City of Toronto Curb Radii Guidelines have had a positive influence on the principles used and approach taken in the draft updates of these guidelines.

There has been a strong national interest in the City of Toronto Curb Radii Guidelines and their application in other cities. There have been several inquiries by Canadian jurisdictions (e.g., Halifax, Hamilton, Ottawa, York) since the public release. As noted earlier, the Guidelines are very context sensitive in nature and take into account several local characteristics. In addition, assumptions made throughout the process have been well documented within the guidelines. This allows other municipalities in the country to easily adapt all or parts of the Guidelines by simply applying their own data to the criteria. Municipalities can also modify the Guidelines relatively easily to suit their needs by choosing to use different assumptions for factors such as minimum traffic volume thresholds and minimum buffer widths.

City of Toronto Curb Radii Design Guidelines can be found at:
https://www1.toronto.ca/City%20Of%20Toronto/Engineering%20and%20Construction%20Services/Standards%20and%20Specifications/Files/pdf/Road%20Design%20Guidelines/Curb_Radii_Guidelines_Jan2015.pdf