

## **Geometric Design Strategies for Improving Pedestrian Safety and Accessibility at Signalized Intersections**

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## Abstract

The City of Winnipeg has one of the highest modes shares of pedestrians in the prairies (Statistics Canada, 2011 National Household Survey), and continually investigates new methods for improving the safety of pedestrians at signalized intersections through geometric design improvements. Our design approach is typically through the lens of people with a range of disabilities but the end result is increased safety for people of all ages and abilities. This also results in making the pedestrian environment more convenient which encourages people to walk more. The changes in geometric design of the intersection must also be done in unison with the placement and utilization of the evolving traffic control devices.

Over the last five years, the City has researched, implemented and monitored various innovations in geometric design treatments at signalized intersections along with traffic control devices for the purposes of increase the safety and convenience of pedestrians. This process has included review and continuous dialogue with various stakeholders including the Mayor's Access Advisory Committee, Canadian National Institute for the Blind (CNIB) and the Vision Impaired Resource Network.

Through this paper, the City of Winnipeg presents the various geometric design strategies to share the success of our experience. The paper will include the following highlights including appended dimensioned geometric figures:

- How pedestrians with varying levels of vision loss and mobility constraints prefer to navigate signalized intersections which influence geometric design decisions
- How APS installation practices affects the layout and design of sidewalk and curb ramps
- Commentary on how median widths and bullnose design can improve pedestrian navigation and safety
- Commentary on the success of Audible Pedestrians Signals (APS) and Pedestrian Countdown Signals (PCS) implementation
- Commentary on the success of utilizing smart channel designs for right turn channelization in lieu of tradition compound curves
- Commentary on the effect of placing curb ramps at various locations at channelized and non-channelized intersections
- Commentary on the importance of separating pedestrians and cyclists leading up to and at intersection crossings
- Commentary on the success of curb extensions to reduce pedestrian crossing distances.

## **Understanding Visual and Mobility Impaired Pedestrians**

Universal Design is something we strive towards and seek to continue to improve. Achieving universal design means to incorporate the needs of all users in an equitable manner. A facility that is designed to be universally accessible not only accommodates visual and mobility impaired users but will provide increase safety and access for young children, slower moving seniors and parents with strollers.

Just as geometric designers need to understand the operational movements and behavior of cars, trucks and bicycles to design streets, an understanding of the behavior and needs of visual and mobility impaired pedestrians is required to design our streets to be accessible and equitable. Understanding the mobility issues for the visual and mobility impaired also aids designers in understanding the importance of not only designing safe facilities but convenient facilities. The information provided within the document is a cultivation of years of stakeholder engagement.

### *Visually Impaired Pedestrians Operations and Behavior*

Visually impaired pedestrians vary by a variety of means that need to be understood when designing to seek a balanced solution. Visually impaired pedestrians vary in:

#### *Degree of impairment*

The majority of visually impaired pedestrians that are legally blind can still see colours and shapes. The minority, which is 20% of legally blind pedestrians are fully blind. When evaluating and developing geometric options or solutions it is important to consider the value in accommodating the majority of visual impaired. A fully blind person may also have increase skill level in terms of using the touch and hearing senses to facilitate their movement as they are more dependent on them.

#### *Level of way-finding skill*

With our aging population and various sensory degrading onset illnesses such as diabetes, pedestrians are obtaining visual impairment not only from birth or childhood, but also later in life. The implications of onset visual impairment include increase stressed and psychological impact which affect the ability to educate new users on navigating the rights-of-way. This is good reasoning for designing our rights-of-way to be simple and consistent.

#### *Navigating Behavior*

Visually impaired pedestrians 'shoreline' when using exiting public transit or when they cross the street until they reach their 'edge'. The edge is typically whatever material is present at the property line. That provides them with known landmark to continue their journey.

The journey is continued along the clear path of travel. The direction of travel is guided by an 'edge'. Given the higher volume of pedestrians in urban downtown environment it is important to have a sufficient clear path of travel wider than 1.5m such that there is room for abled

pedestrians to shift out of the way of an oncoming visually impaired pedestrian. The importance of the clear path of travel is evident as obstacles such as fire hydrants and street lights can provide additional way-finding workload for the navigating pedestrian. In Winnipeg's downtown streetlights are being relocated to the amenity zone closer to the curb, where feasible.

Grass offers the most universally understood edge for way-finding as it's easily detectable, seasonally colour contrasting and can be felt under foot. Offering breaks in full width sidewalk paving can aid in helping to identify transit stops. In downtown urban environments where full boulevard paving is typical, Winnipeg utilizing paving stone edge banding to delineate the path of travel. Although the pavers used do not meet the full ADA colour contrast ratio<sup>2</sup>, they do offer sufficient contrast for many visually impaired users that are completely blind.

Due to the additional workload and stress of navigating the rights-of-way as a visually impaired pedestrian, consistency is critical especially in terms of where the sidewalk is located with respect to the adjacent traffic lane and cycling facilities. Winnipeg strives to have the pedestrian facilities close to the property line and if cycling facilities are present they shall be placed between the pedestrian facility and the road. This can create a conflict area when pedestrians have to cross the cycling facility to reach a bus stop, but provides more comfort to the pedestrian along the route.

When crossing a typical suburban street, or narrow roads such as legs to single lanes roundabouts that offer wider boulevard and sidewalks leading up to the curb ramp, visually impaired pedestrians establish their crossing trajectory leading up the curb ramp and continue their path in a straight line. In a denser environment like downtown, establishing their line ahead of the crossing is not possible, therefore having properly orientated detectable warning surfaces offer much benefit for identifying the crossing alignment.

When crossing wide roads, visually impaired users seek a mid-point reference such as a median with an area for a pedestrian on the median. Having a median area for refuge is not always feasible due to accommodating truck turning movements, but it's critical to strive to have the bullnose placed as close to the clear crossing as possible to provide a reference point to provide reassurance the pedestrian is still on the right trajectory. Further commentary on design consideration to achieve this is described later in the paper.

When evaluating options in pedestrian crossing locations, routing and alignments it is important to understand as safety must also be complemented with convenience. Visually impaired pedestrians will go from their origin to their destination using a route they feel comfortable and safe navigating, even if it is more circuitous and a longer trip. This is contrary to an able pedestrian whereas the shortest route is the route most taken.

### *Sensory Cues*

Visually impaired pedestrians use various sensory cues for navigating pedestrian facilities and the level and type of sensory varies dependent on the users degree of impairment, their length of impairment and level of education.

When designing detectable surfaces or considering material types it is important to understand that many pedestrians that have their impairment derived from illnesses such as diabetes also have reduced feeling in their feet and therefore utilizing the underfoot sensory approach is not effective. This is to not assume a user with a dog can also utilize senses under their feet.

When designing wayfinding edging, one type of material designed to function for one user may not function as well for another user. It is important to understand this as to not be discouraged or try satisfy all users, but seek the optimal and balanced solution. The reason for the variance not only relates to experience and education of the user but also the type of cane they are using.

The slope of the sidewalk leading up to the ramp is a commonly accepted cue due to the change in elevation. It is recommended to be at least 3% so it can be felt by a visually impaired user but not more than 5% so it can be used easily by the mobility impaired users.

Generally at the corner of an intersection there are two curb ramps to cross either intersecting street. The space between those curb ramps should be a raised curb if space permits as this will aid in differentiating the two directions. If the separation of the edge of curb ramp to edge of curb ramp is less than 2.3m then the curb ramp should be continuous. This approach is taken to prevent the installation of small humps that lead to a tripping hazard, which is especially the case during snow fall events when the small hump is easily hidden under fresh snow.

Hearing is another prevalent sense that must be taken into consideration for planning and designing pedestrian areas. Large objects such as bus shelters alter the movement of surrounding air and reflects ambient traffic noise. This can be detected usually by completely blind pedestrians and aids in land marking and locating bus stops. Visually impaired users that utilize their hearing senses also utilize traffic noise to determine their straight path of travel for crossing skewed intersections. This is important to understand because perpendicular crossings of skewed road may offer as shorter crossings, but add to a visually impaired pedestrian's workload. Additional commentary is provided on this subject later in the paper.

### *Accessible Pedestrian Signals (APS)*

The City of Winnipeg utilized APS at signalized intersections and the design affects signal poles locations as the APS speakers need to be mounted on a pole, close to the curb ramp in order for the APS messages to be heard clearly using acceptable volume levels. The signals pole, intended to have a speaker, is placed in accordance with the Winnipeg Accessibility Design Standard (Section 2.1.4) which determines acceptable distances between the pole to curb ramps and back of curb. The audible signal includes a projected signal from the pedestrians'

destination which should correspond with the alignment of the crossing. Given the abundance of underground utilities present, locating the poles and associated curb ramps is often an iterative process to place the crossing at the optimal location.

The APS speakers are aimed towards the ramps as the user should be waiting there for the signal. This allows us to use volumes that are very well heard by the user, from a minimum distance of 3.7m while still minimizing the potential noise pollution. To date this has worked fine and has not received any negative feedback either from users or others. Yellow speakers are also used as they are more visible by the users.

APS installation is mandatory for each signalized intersection in Winnipeg and is being implemented at new intersections. Retrofitting of existing intersections is done as part of a multi-year capital program. Current implementation rate is at 66%. All signalized intersections are planned to be equipped with APS by 2023. The retrofit of APS is being implemented according to a priority list developed by the department which is based on the pedestrian crossing environment and demand criteria.

### *Sharing Spaces such as Multi-use Pathways*

The City of Winnipeg strives to separate cyclist and pedestrians where feasible. Just as the differential speed of a car and a cyclist on a shared road is high, similarly so is the differential speed between a cyclist and a pedestrian on a shared facility. Another issue is the unpredictability of a pedestrian whether they are impaired or not for an oncoming cyclist. Pedestrian and cycling collisions are an issue but are difficult to statitize due to non-reporting. Separating the pedestrian and cycling at an intersection is highly desirable but is not always obtained due to compliance with the current Manitoba Highway Traffic Act.



Figure 1 – Separate pedestrian and cycling signalized crossing in Winnipeg

### ***Mobility Impaired Pedestrian Operations and Behavior***

When designing alignments, grading plans and choosing material types it's important to understand the variety of mobility impaired users. These are various types include size of wheels, size of chair, manual or automatic controlled chairs. Mobility impaired pedestrians not only include those in wheelchairs, but those who have issues with balance due to loss of limbs or issues with their ears, seniors, or those with issues with their knees or hips. Understanding the high level of workload, effort and risk for a pedestrian with these disabilities takes by utilizing a public right-of-way to walk is critical for designers to ensure grading of streets, sidewalks and boulevards are done within acceptable standards. For these reasons the City of Winnipeg strictly utilizes a 2% cross fall on all sidewalk and up to a maximum of 4% at approaches or at constrained locations like in the downtown. Long stretches of recreational pathways systems also include frequent rest areas to accommodate pedestrians with varying levels of fitness. Minimizing longitudinal grading is also another important factor to accommodate users of varying level of fitness, whereas the levelness of a facility it important, but this needs to be balanced with providing gradual elevation changes to provide the visually impaired with their respected cues. Another consideration is to protect drop-offs near pedestrian facilities utilize an appropriate pedestrian clear space or railing.

Providing accessible grading is not the only consideration but accommodating snow clearing operations and snow storage is critical to provide a clear path of travel during winter months. This is attained by providing appropriate boulevard or amenity zones for snow storage and provided a clear and predictable path for sidewalk plows. Not considering sidewalk plow operations can lead to reduced snow clearing level of service, which can impact users ability to use the facilities in the winter months which has psychological implications

### **Geometric Design Strategies for Improving Pedestrian Safety at Signalized Intersection**

The following are some examples of design strategies that can provide additional predictability and convenience for both a motorist and a pedestrian to improve safety at signalized intersections.

### ***Commentary on how median widths and bullnose design can improve pedestrian navigation and safety***

The City of Winnipeg designs crossing times for signalized intersections in accordance with the TAC Pedestrian Crossing Control Guideline. However there are instances where a pedestrian cannot complete the crossing during the given phase. To provide a form of predictability for pedestrians the City of Winnipeg is utilizing Pedestrian Countdown Signals (PCS). The PCS was first tested in Winnipeg during 2013. Following a successful trial and a user satisfaction survey that showed above 95% satisfaction, a multiyear capital program was established for the implementation of PCS at 40 signalized intersections each year. The PCS are being

implemented according to a priority list developed by the department which is based on the pedestrian crossing environment and demand criteria.

A major benefit of PCS is that many users do not understand the meaning of the flashing red hand and do not have enough information to decide if they have time to cross because of the wide range of walking speeds.

The design of the location and size of a median at a signalized intersection must balance the ability for turning vehicles, the level of compliance with adhering to the painted stop line, provision of a mid crossing trajectory cue for visually impaired, and possibly provide a point of refuge. The City of Winnipeg amended its design standard for median widths in 2011 from 5.0m for a major collector or minor arterial to 5.5m. This provides additional flexibility in design to have the bullnose placed at an optimal location when left turn lanes are present.

For most intersections where the pedestrian crossing distance is not excessive the bullnose should not intercept the path of pedestrian travel. This provides convenience for mobility impaired users and reduces pedestrian congestion in downtown or constrained environments during the crossing.

For large intersections, it is common to have a wider median. Having a median refuge for larger intersections is important to provide additional guidance and safety. Wider medians also enable proper accessible grading. For cycling facilities crossing major roads, the median width should be sufficient room, typically 3.0m, to store a bicycle that includes a pull-behind trailer with a shy distance to the auxiliary or travelling lanes.

### *Commentary on the success of utilizing smart channel designs for right turn channelization in lieu of tradition compound curves*

The City of Winnipeg utilizes the Smart Channel design for most intersections with great success. It has proven to slow vehicles and increase yielding to pedestrians when compared to a traditional compound curve. Its applied typically for channelization between two lower speed roadway or for vehicles departing a higher speed road, including those with deceleration lanes, to a lower class road. When compared to traditional compound curvature (i.e. 50m-25m-50m) advantages include:

- Reduced driver workload, whereas they perceive and focus on the pedestrian crossing directly in front of them, downstream, prior to deciding whether it's safe to enter the intersecting street
- Motorists are forced to slow down due to the discontinuous geometry
- Enables reduced stopping distances
- Accommodates extended islands where required for transit stops



- Beneficial to reduce the amount drivers are required to turn their heads to see oncoming traffic for them to yield to, especially at skewed intersections. This not only accommodates drivers with physiological constraints but makes it easier to perceive through moving cyclists on the intersecting street
- Reduced property requirements



Figure 2 – Example of a smart channel in Winnipeg from an expressway to an arterial

The key geometric principle is to achieve the 70 degree skew however on some skewed intersection this is not always feasible. Winnipeg has developed design guidance and a design domain for the Smart Channel as it usually requires tailored to the site specific context. Aprons have yet to be required to accommodate WB-20 movements or buses. The smart channel should be designed for a WB-20 to utilize all of the receiving road space, and for a transit bus to utilize only the receiving roads curb lane. The design guidance is shown in Figure x.x.

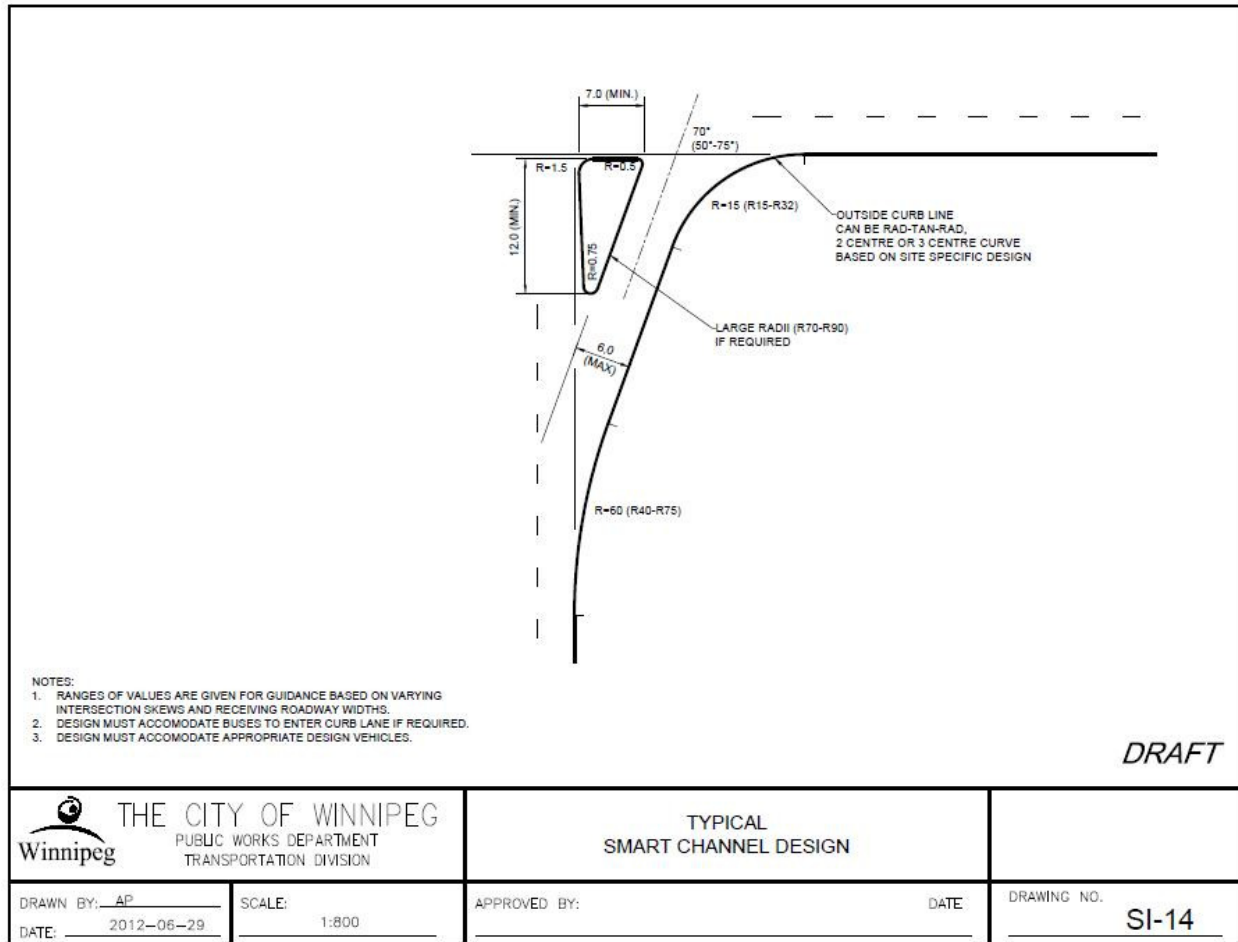


Figure 3 – City Standard Geometry for a Smart Channel

*Commentary on the effect of placing curb ramps at various locations at channelized intersections*

The City of Winnipeg does not strictly standardize the location of a curb ramp crossing with the exception of smart channel designs, which typically require that the pedestrian crossings be downstream of the traffic, the pedestrian crossings are preferred to be in the pedestrians’ line of travel, or established perpendicular to the midpoint of an island. Locating the pedestrian crossing should also consider the closest path and the route the pedestrian will travel once out of the intersection as well as whether a dedicated right turn lane prior to the island is present.

*Downstream End*

Placing the pedestrian crossing at the downstream end allows additional time for the driver to perceive the pedestrian and would allow additional available stopping distance. This location also places the sighting of the pedestrian by the driver at the end of the driver workload which has a negative impact on the driver’s ability to yield if they have determined there is no conflicting traffic. Placement at this location is the usually the most accommodating to align the crossing in the pedestrians’ line of travel.



Figure 4 – Provencher Boulevard right turn onto Tache Avenue demonstrates how the downstream crossing allows for good sight lines for the driver.

#### *At the Midpoint*

Placing the pedestrian crossing at the midpoint is the most common location for within Winnipeg and therefore it is widely understood and expected by both drivers and pedestrians. This location may allow for the shortest crossing distance and is simplest to accommodate accessible sidewalk grades. This locations also can allow space for a vehicle to store between the pedestrian crossing and the cross street.

#### *Upstream End*

Placing the pedestrian crossing at the upstream end allows for the driver's sighting of the pedestrian to be at the top of the driver workload. If there is a lot of street furniture and objects on the island in some cases the pedestrian may be made more visible by situating the pedestrian in front and ahead of the other objects. Where there is no dedicated right turn lane in advance of this crossing, the driver would have to stop in the through lane which may result in a rear end collision.



Figure 5 – McPhillips Street right turn onto Logan Avenue demonstrates the benefits of placing the pedestrian crossing upstream for visibility

***Commentary on the effect of placing curb ramps at various locations at non-channelized intersections***

It is optimal to align the pedestrian crossing and associated curb ramps across intersections to facilitate the natural walking path which is typically the shortest or straightest route. This is not always feasible in downtown environments or at skewed intersections.

For skewed intersections consider if the pedestrian crossing should be perpendicular to the intersecting road, which will offer the shortest distance or alternatively should the street crossing be parallel to the road running along the path of vehicular travel. Running parallel may result in a longer crossing but can be advantageous as the pedestrian will cross the road in the same alignment at the thru traffic and visually impaired users can utilize the traffic noise as guidance. This is further described in Figure x.x

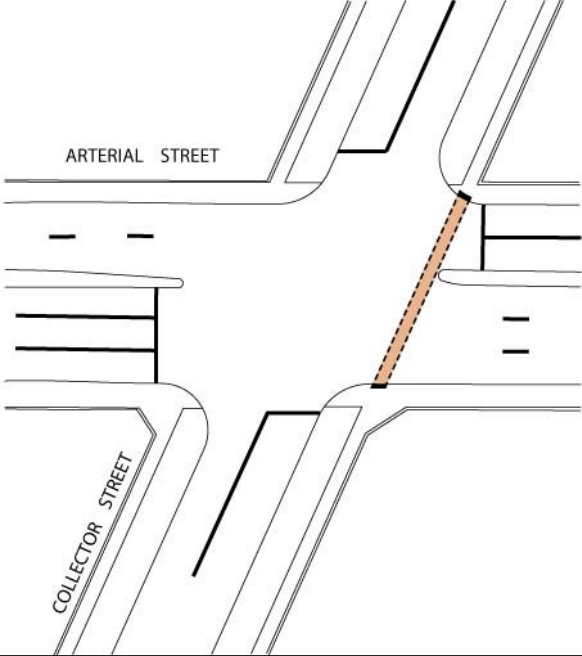
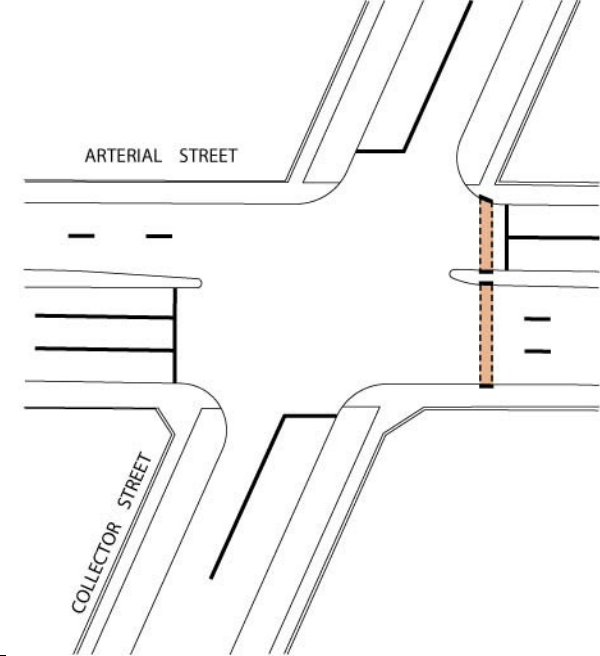
Skewed Crossing Alternative	Perpendicular Crossing Alternative
	
<ul style="list-style-type: none"> <li>• Offers a similar alignment to the adjacent street.</li> <li>• Offers a more direct path</li> <li>• Longer crossing</li> <li>• May have less grade conflicts with existing buildings with no set-back</li> </ul>	<ul style="list-style-type: none"> <li>• Reduces the pedestrian crossing</li> <li>• Pulls one curb ramp further from the intersection</li> <li>• Likely requires additional pole for push button</li> <li>• Driver non-compliance with stop line would result in blocking the pedestrian path</li> </ul>

Figure 6– Pros and cons of two acceptable solutions

### *Commentary on the success of curb extensions (bump-outs) to reduce pedestrian crossing distances*

A common and successful geometric treatment to improve pedestrian safety is the use of curb extensions, or also commonly described as bump-outs. They have many advantages such as defining parking lanes, calming traffic, adding landscaping, facilitating road diets, reducing the pedestrian crossing distance, providing enhanced pedestrian visibility and provide pedestrian queue storage. Winnipeg's design guidance for curb extension is as follows:

- Bump-outs shall have at least a 7.0m tangent section parallel to the through lane to provide sight guidance for motorists.
- The minimum radius is 6.0m to facilitate street cleaning.
- Bump outs should have the appropriate shy distance from the through vehicular lane.