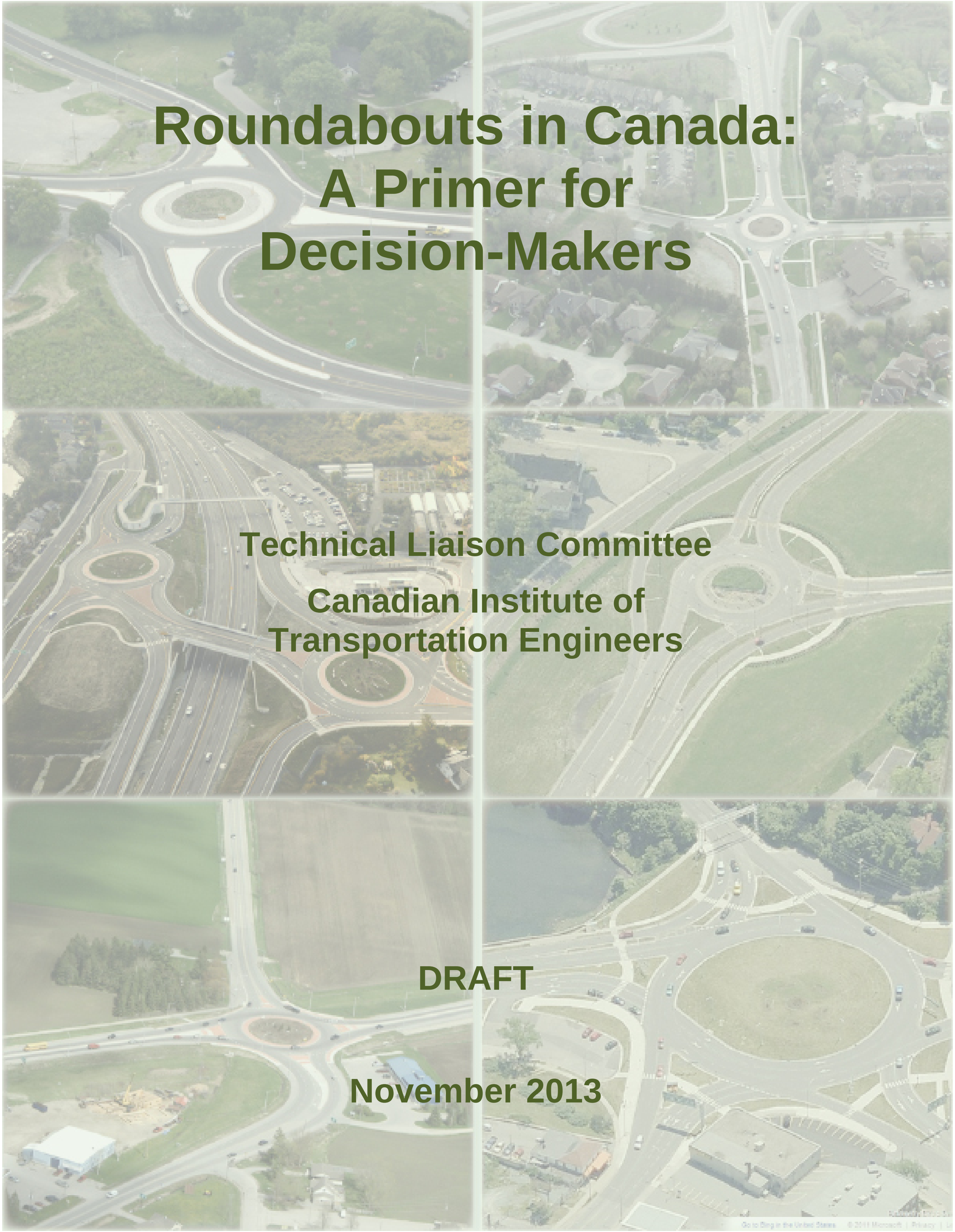

Roundabouts in Canada: A Primer for Decision-Makers

Technical Liaison Committee

Canadian Institute of Transportation Engineers

DRAFT

November 2013

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Foreword / Preface

The Canadian Institute of Transportation Engineers (CITE) Technical Liaison Committee (TLC) is comprised of CITE members, and was originally formed in early 2006 to address technical communications and projects, and to support CITE initiatives. Their project topics to date have included road user safety, roundabouts, transportation planning, bicycle and pedestrian facilities, transit utilization and priority and sustainable transportation.

Roundabouts have been successfully used throughout the world, especially Europe; however, although they are becoming more popular in North America, they could be considered a relatively new type of intersection. Consequently, it was considered that there may not be adequate understanding of roundabouts as a viable form of intersection control by decision-makers, engineers and the public at large.

In 2009, the TLC identified a need to conduct a survey of Canadian roundabout experience to improve the understanding of roundabout status in Canada. It was believed that the existing studies and surveys completed in North America had more of a United States focus and did not adequately represent Canadian roundabout applications and experience. A Roundabout Committee ('the Committee') was subsequently formed under the aegis of the TLC.

The Committee was comprised of volunteer professionals from both private and public sectors and from across Canada, New Zealand and one originally from Britain. The committee members were:

- Sajjad Rasheed (Chair), M.S.C.E., P.E., PTOE, P.Eng.
- Bruce Beames, B.Eng. (Hons), P.Eng., CCA, Stantec Consulting Ltd., Victoria, BC, Canada
- Leanna Belluz, M.A.Sc. & Mustapha Zayoun, B.A.Sc., Transport Canada, Ottawa, ON, Canada
- José Pinto, B.A.Sc., P.Eng., PTOE, McElhanney Consulting Services Ltd., Vancouver, BC, Canada
- Amanda Watson, B.Ed., Dip Highway & Traffic Engineering, City of Vernon, BC, Canada
- Philip Weber, M.Eng., P.Eng., GHD / Ourston Roundabout Engineering, Markham, ON, Canada
- Don McKenzie, BE (Hons), CPEng., IntPE., Traffic Design Group, Auckland, New Zealand

The editorial contributions of Victoria Nowell, McElhanney Consulting Services Ltd., are also gratefully acknowledged.

This document includes an introduction to roundabouts, another section on potential issues with roundabouts and finally roundabout experiences in Canada which includes survey results of Canadian roundabout practice in terms of policy, implementation, operations, safety and maintenance. Selected Canadian roundabouts from across the country are represented in 22 case studies that include roundabout images and provide salient design and performance information. Also included is a brief summary of the status of research in Canada, along with resources and contact persons.

It is anticipated that this report will become a primer for decision-makers in Canada to help them effectively make informed decisions about the suitability of a roundabout for a specific location.

1.0 INTRODUCTION TO ROUNDABOUTS

1.1 ROUNDABOUT TERMINOLOGY

The various features of a roundabout with two-lane entries and exits are illustrated in **Figure 1-1**.

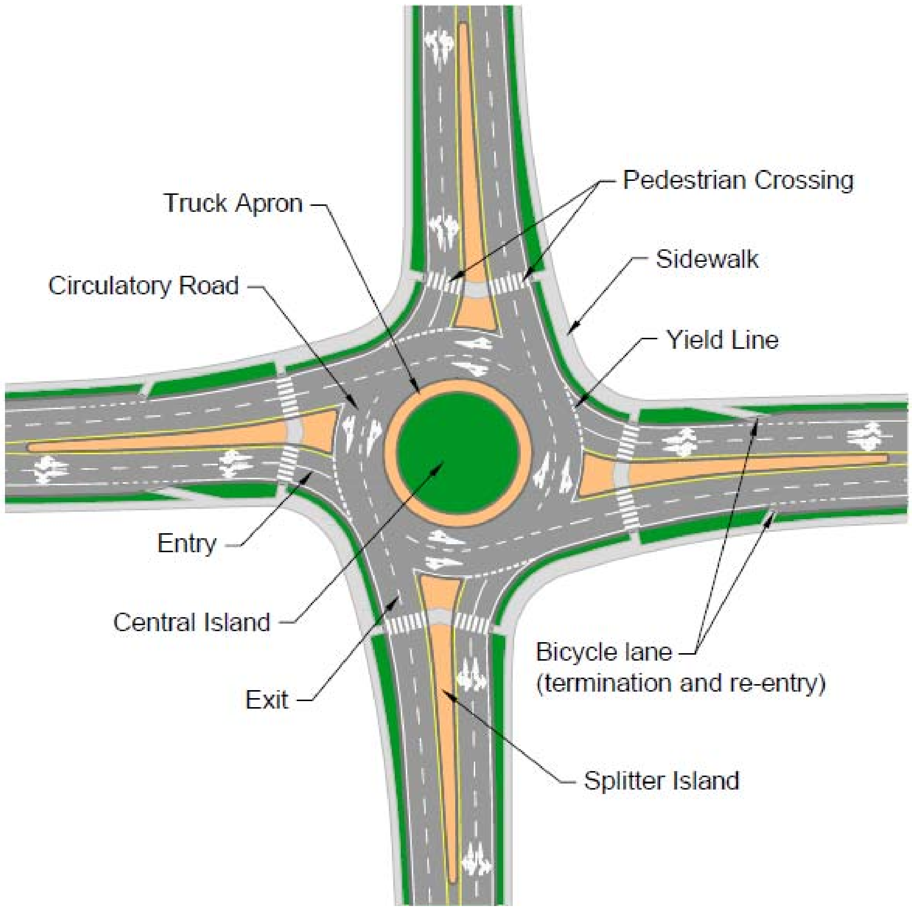


Image: GHD/Ourston Roundabout Engineering

Figure 1-1 Key Features of a Roundabout

1.2 TRAFFIC CIRCLES, ROTARIES AND ROUNDABOUTS

Traffic circles, rotaries and roundabouts are all types of circular intersections or junctions where entering vehicles must travel in one direction around a central island. The terms are often mistakenly used interchangeably. Each type of circular intersection has its own distinguishing features and characteristics.

Traffic Circles

"Traffic circle" is a generic term often used to describe both small-diameter circles (see **Figure 1-2**) and large-diameter circular intersections such as Columbus Circle in New York City (see **Figure 1-3**).

Image: Google Maps

Figure 1-2 Small-Diameter Traffic Circle (Vancouver, British Columbia)

Image: Bing Maps

Figure 1-3 Large-Diameter Traffic Circle (Columbus Circle, New York City)

Small-diameter traffic circles, also called traffic calming circles or neighbourhood traffic circles, are usually installed at local street intersections as a traffic calming measure or aesthetic enhancement. They can be retrofitted within an existing intersection without impacting the outer curbs. They are meant to increase intersection safety and pedestrian mobility by slowing down approaching traffic, but they do not specifically enhance intersection control or capacity. In fact, many neighbourhood traffic circles have no specific control posted.

Large-diameter traffic circles are more likely to be found in urban areas with high pedestrian volumes. They tend to have been constructed originally as civic features and may have statues or monuments in the central island. These types of traffic circles have certain attributes that are similar to rotaries (refer to **Figure 1-4**), and the terms are sometimes used interchangeably.

Rotaries

Rotaries are large-diameter circular intersections, sometimes greater than 100 metres, which were generally installed in eastern Canada and the United States prior to the 1960s. An example is shown in **Figure 1-5**. Rotaries in western Canada (i.e. Edmonton) tend to be known as traffic circles, although they are otherwise similar in operating characteristics.

Image: Google Maps

Figure 1-4 Rotary Adjacent to Shopping Centre (Moncton, New Brunswick)

Due to their size and the distance between intersecting legs, traffic operations at many rotaries have become problematic as a result of high circulating speeds and weaving between entries and exits. At some rotaries priority is given to entering traffic, which can result in queuing and congestion of the circulating road as more vehicles are able to enter than can exit. Due to congestion and high collision rates, rotaries fell out of favour as an effective traffic control device.

Weaving occurs when drivers are allowed to enter beside circulating traffic. A typical case is when someone in the right lane enters beside someone circulating in the inside or left lane. If the driver in the right lane wants to continue around the rotary and the driver in the left circulating lane wants to exit just past where the other driver is entering, a conflict or crash can result (see **Figure 1-5**, left image).

Comparatively, roundabout operations are straightforward as all entering drivers must yield to all circulating traffic (see **Figure 1-5**, right image). The smaller size of the roundabout makes this seem intuitive and, overall, they exhibit less collision risk and are more comfortable to drive than traffic circles.

Photo: GHD / Ourston Roundabout Engineering

Figure 1-5 Comparison of Weaving Potential at a Rotary (left) and a Roundabout (right) in Edmonton, Alberta

Roundabouts

The British are credited with re-engineering early forms of circular intersections in the 1960s to develop the first modern roundabouts. Although they are much smaller than rotaries, roundabouts have higher capacities for the same number of lanes and improved safety performance. The difference in size between a rotary and a roundabout can be seen in **Figure 1-6**. The use of roundabouts has been popular throughout Europe, Australia and other parts of the world since the 1970s. Their use in Canada and the United States has increased over the past 15 years.

Photo: New York State Department of Transportation

Figure 1-6 Rotary Being Replaced by Roundabout (Kingston, New York)

Drivers entering a roundabout must yield to all circulating traffic. A dashed yield line marks the outside edge of the circulating road at each entering street. Roundabouts have raised splitter islands on each leg that separate the entry and exit lanes of a street and assist in deflecting vehicles around the central island. This can be seen in the two-lane roundabout shown in **Figure 1-7**.

Photo: GHD / Ourston Roundabout Engineering

Figure 1-7 Two-Lane Roundabout (Waterloo Region, Ontario)

Pedestrians cross a roundabout at marked crosswalks located one passenger car length (or multiple car lengths) behind the yield line of each entry. This separates the driver tasks of looking for pedestrians at the crosswalk and for circulating traffic at the roundabout entry.

The size of a roundabout is selected so that it is large enough to adequately accommodate the design vehicle, but not so large that other vehicles can attain high speeds. Different forms of roundabouts have also proven to be successful, such as mini-roundabouts and odd shapes and configurations to fit awkward approach geometries and other constraints. The capacity of a roundabout is primarily influenced by the number of entering and circulating lanes, as opposed to its size. More information on the traffic capacity characteristics of roundabouts can be found in Chapter 2.

Mini-roundabouts have a fully-mountable central island and, occasionally, fully-mountable splitter islands as well. They can be installed where property or other constraints preclude use of a normal roundabout, yet still allow trucks to travel through the intersection by off-tracking the central island (see **Figure 1-8**).

Photo: Michigan Department of Transportation

Figure 1-8 Mini-Roundabout (Dimondale, Michigan)

Although the terms are often used interchangeably, a mini-roundabout is a specific type of roundabout and not just a “small” roundabout. Mini-roundabouts can be useful as a form of control at small or constrained intersections. However, they are not necessarily as useful at controlling speeds. Therefore, they differ in function and purpose from neighbourhood traffic circles.

1.3 ADVANTAGES AND DISADVANTAGES OF ROUNDABOUTS

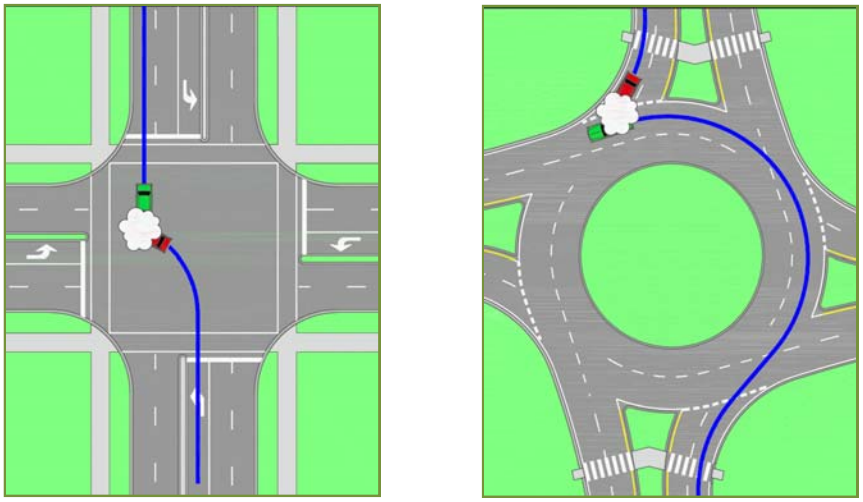
Roundabouts have a number of advantages and disadvantages compared to stop or traffic signal control. Several of them are described below.

Advantages

Safety for All Users

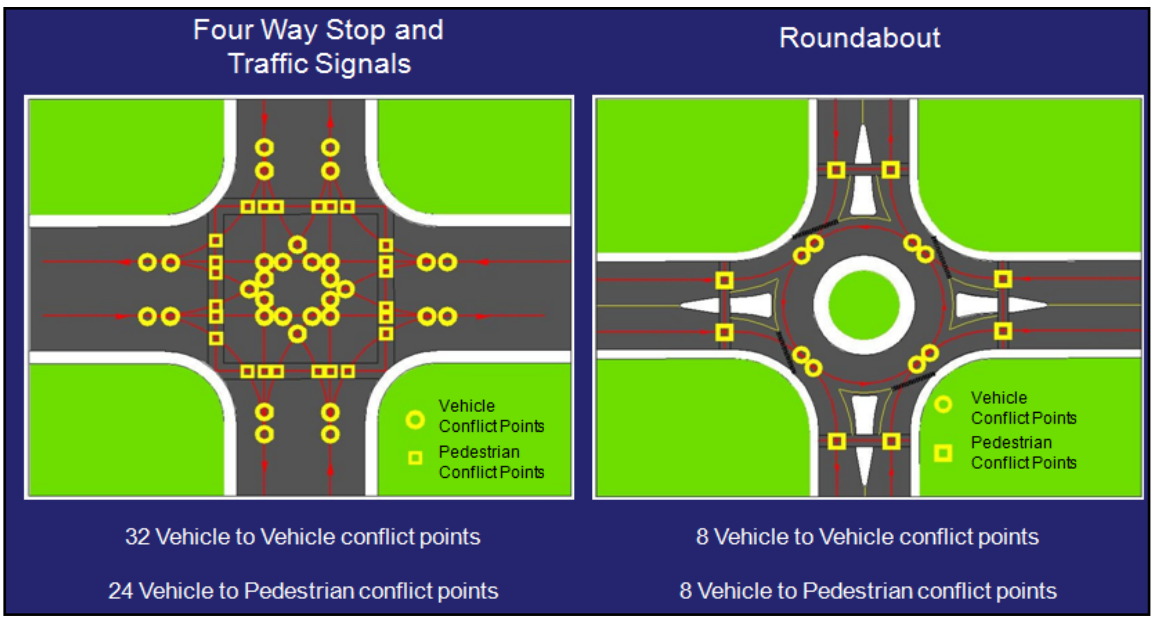
The main reason provincial and municipal agencies are building roundabouts is safety. Roundabouts are statistically safer for motorists than other types of at-grade intersections for three main reasons:

- Lower vehicle speeds.
- Reduced crash angles, where right-angle and head-on crashes are eliminated or replaced by less-injurious side-swipe and rear-end crashes (see **Figure 1-9**).
- Fewer conflict points (see **Figure 1-10**).



Graphic: GHD / Ourston Roundabout Engineering

Figure 1-9 Crash Angles at a Signalized Intersection and a Roundabout



Graphic: City of Vernon Engineering Department

Figure 1-10 Conflict Points at an Intersection and a Roundabout

A landmark study in 2000 by the Insurance Institute of Highway Safety reviewed 24 intersections in the United States that had been converted from stop control or traffic signal control to roundabouts. It concluded that, on average, roundabouts reduced all crashes by 39%, injury crashes by 76%, and fatal and incapacitating crashes by over 90%.[1] These roundabouts were single-lane or multi-lane and in a mix of urban and rural areas. Further research in the United States at 55 intersections converted to roundabouts has confirmed these crash

1 Persaud, Bhagwant, Richard Retting, Per Garder and Dominique Lord, Crash Reductions Following Installation of Roundabouts in the United States, Insurance Institute for Highway Safety (IIHS), March 2000.

reductions and even disaggregated some of them by prior traffic control (stop or traffic signal), setting (rural, suburban or urban) and number of lanes in roundabout.[2]

Studies in several countries have shown that roundabouts tend to be statistically safer for pedestrians as well.[3,4,5] Some reasons for this are:

- Vehicle speeds are lower resulting in lower severity collisions.
- There is more time for drivers and pedestrians to react to each other because vehicle speeds are lower.
- The crossing distance is usually less.
- Pedestrians only have to watch for traffic in one direction at a time.
- A driver is more likely to be looking in the direction of a pedestrian. When turning at a traffic signal, the driver is often watching for conflicting traffic and the signal and not where they are going.

Even though pedestrian safety at roundabouts is statistically high, many do not perceive roundabouts to be as safe for pedestrians due to the absence of a positive exchange of right-of-way priority by a traffic signal. More information on pedestrians at roundabouts can be found in Chapter 2.

Studies internationally are less conclusive about cyclist safety at roundabouts. Most show that cyclists are safer at single-lane roundabouts than at other intersections, but not always safer at multi-lane roundabouts.[6,7] Care should be taken in interpreting cyclist safety data because the roundabouts may have been older designs with higher motor vehicle speeds, or different cyclist facilities than what is typically implemented with modern designs.

In the absence of off-road bike paths, the preferred practice is for cyclists to travel through a roundabout either as a vehicle (by riding in the traffic lane) or as a pedestrian (by using the sidewalks and crosswalks). More information on cyclists at roundabouts can be found in Chapter 2.

Traffic Delays and Queues

For the same number of lanes, roundabouts almost always result in lower vehicle delays and shorter queues than signalized intersections.[8] These improved operations are primarily due to the lack of an all-red interval and drivers at roundabouts are free to proceed when there is no opposing traffic. At signalized intersections, drivers are regularly stopped at red lights even

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2 National Cooperative Highway Research Program (NCHRP) Report 572, Roundabouts in the United States, Transportation Research Board, 2007, Table 28.

3 Maycock, G. and R. Hall, Accidents at 4-arm Roundabouts, TRL Laboratory Report LR1120, 1980.

4 Schoon, C. and J. van Minnen, Accidents on Roundabouts: II. Second Study into the Road Hazard Presented by Roundabouts, Particularly with Regard to Cyclist and Moped Riders, SWOV, Netherlands, 1993.

5 Swedish National Road and Transport Research Institute (VTI), What Roundabout Design Provides the Highest Possible Safety, Nordic Road and Transport Research, 2000.

6 Alphand, F, U. Noelle and B. Guichet, Roundabouts and Road Safety: State of the Art in France, 1991.

7 VTI, ibid.

8 This can be verified through capacity analysis comparisons, which individually can be correlated with actual delay and queue observations.

when there is no traffic on the cross street. Roundabouts are thus very responsive to minor changes in traffic demand throughout the day.

Approach Lanes

Roundabouts usually require more space than stop or traffic signal control at the intersection itself. However, they may not require as much space upstream or downstream because fewer lanes are needed to achieve the equivalent traffic capacity. The difference is usually less need for left-turn storage. An example is shown in **Figure 1-11**. At this location, roundabouts were selected for control at the interchange ramp terminals because they did not require widening the road underneath the highway overpass structure to accommodate the back-to-back left-turn lanes that would have been needed with a signalized intersection. The result at this location was a significant cost savings.

GHD / Ourston Roundabout Engineering

Figure 1-11 Roundabouts at Interchange Ramp Terminals (Vail, Colorado)

Access Management

Roundabouts can potentially manage intersections or access driveways along a corridor in two ways:

- They result in lower speeds and usually result in shorter queues; therefore, access driveways can be located closer to the intersection.
- They provide opportunities for U-turns. If a roundabout is installed on either end of a corridor and access between them is restricted to right turns only, then drivers have the opportunity to make a left turn by turning right at a driveway and making a U-turn at the nearest roundabout. An example of this can be seen in **Figure 1-12**.

Image: Google Maps

Figure 1-12 Left Turn from Right-Turns-Only Driveway using Roundabout (Golden, Colorado)

Environmental and Social Considerations

It seems intuitive that roundabouts should result in lower fuel consumption and emissions than other types of at-grade intersections because of lower vehicle delays. Also, speeds are slower and more uniform at roundabouts, with less starting and stopping and less idling. This is especially the case during off-peak periods, when there is a lower potential of being stopped. Unfortunately, at this time there are few studies that have quantified these environmental benefits.[9]

An environmental benefit of roundabouts that is quantifiable is that total pavement area is usually reduced, again because there is usually less need for left-turn storage. Less total pavement area means less untreated groundwater runoff. Still another benefit of roundabouts is that they do not require power to function, and can continue to provide traffic control during power outages.

Roundabouts can have social benefits as well, such as increased opportunities for gateway treatments and landscaping. Examples are shown in **Figures 1-13** and **1-14**.

9 The SIDRA software package has an algorithm for calculating emissions and fuel consumption for different forms of intersection control based on vehicle drive cycles. The results have not been verified in the field, but are probably sufficient for certain types of relative comparisons. The results show that reductions in fuel consumption and emissions are generally commensurate with reductions in vehicle delay, and are in the order of 30% during peak periods.

Photo: GHD / Ourston Roundabout Engineering

Figure 1-13 Central Island Feature at a Roundabout (Sylvan Lake, Alberta)

Photo: City of Vernon

Figure 1-14 Historic Location Marker in Roundabout (Vernon, British Columbia)

Life Cycle Costs

Life cycle costs of an intersection can be lower with roundabouts compared to signalized intersections because they do not require periodic signal timing changes, bulb replacement or eventual signal plant replacement. This is reflected in the example shown in **Table 1-1**.

Table 1-1 City of Vernon Roundabout Cost Assessment in 2009

Method of Control	Annual Maintenance Costs	10 Year Replacement Costs	25 Year Replacement Costs
Roundabout	$3,785 [1]	$12,000 [3]	$27,000 [5]
Traffic Signals	$4,816 [2]	$51,000 [4]	$44,000 [6]

Notes:

1. The cost of removal of previous year's and installation of new annuals and bulbs $2485, weeding and irrigation $1300. Street lamp replacement (8) $16 each.
2. The average cost in Vernon per intersection per year (including LED replacement) $4800 + street lamp replacement (4) at $16 each.
3. $1500 ballast replacement in street lamps (8).
4. The life expectancy of the controller is 7 – 10 years at a cost of $30,000; traffic detection system is ten years ($15,000) on four approaches and $1500 ballast replacement in street lamps (4).
5. The life expectancy of a road signs is 20 years $150 (20) and 25 years for street lights on individual posts $3000 (8).
6. The life expectancy of the steel signal poles is 25 years at a current value of $40,000 including removal of the old poles (4) and the installation of the new poles. The life expectancy of the street lights is 25 years (attached to signal poles); current value $1000 (4).

Roundabouts can be significantly less costly if the societal costs of collisions are taken into account. For example, for engineering analyses the Ministry of Transportation Ontario (MTO) uses human capital costs of $1,582,000 per fatal crash and $59,000 per injury crash. If a roundabout has the potential to eliminate one fatal crash every 20 years and one injury crash every 2 years, then over a 20 year life cycle that can amount to a present cost saving of about $1.5 million. However, this would be a societal saving, as not all of it could be directly recovered by the road agency.

Human capital or societal costs differ depending on the jurisdiction. By way of example, for engineering analyses the provinces of Alberta and British Columbia use a cost of $100,000 per injury crash.

Disadvantages

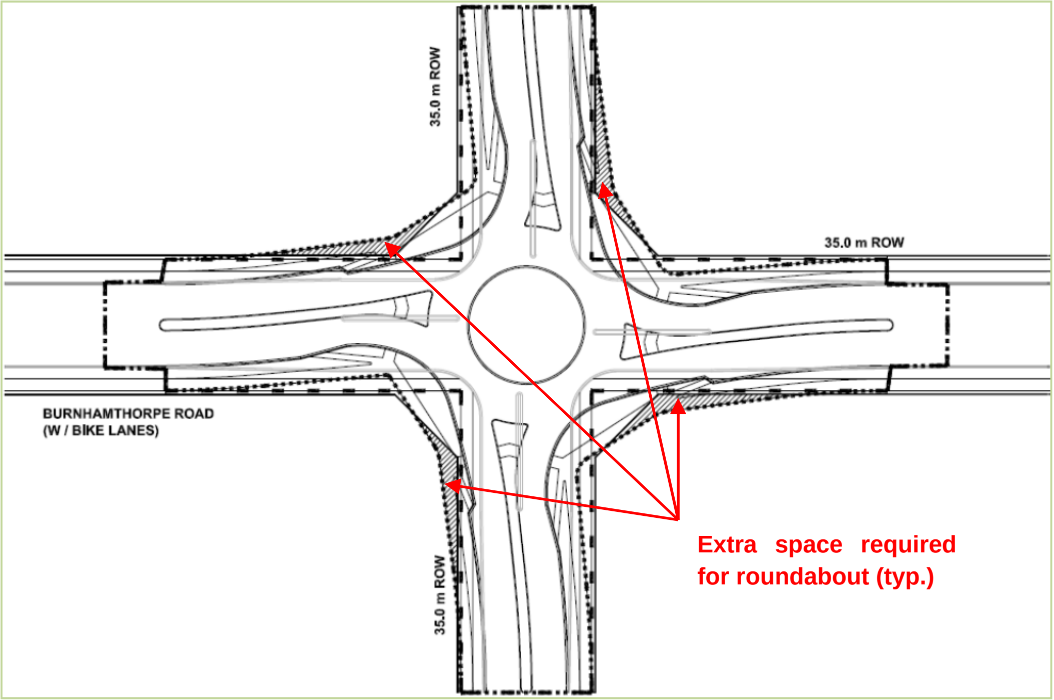
Construction Costs

Although life cycle costs can be lower for roundabouts, roadway construction costs are usually higher, particularly in retrofit situations. This additional cost is mainly due to the extra road structure needed outside the footprint of a typical intersection, more road structure in total, and additional concrete for curbs, stormwater systems, splitter islands and the central island. However, the additional roadway costs for roundabouts are often offset by the cost of not having to install signals and auxiliary lanes.

Because enhanced landscaping opportunities are one of the benefits of roundabouts, there is a tendency to install higher cost landscaping applications and features, which are seen as community enhancements but can drive up the cost of a roundabout.

Space at an Intersection

Roundabouts usually require more space than stop or traffic signal control at the intersection itself, and will often encroach outside a typical right-of-way due to its size and the alignment of the exits. A typical example is shown in **Figure 1-15**.



Graphic: GHD / Ourston Roundabout Engineering

Figure 1-15 Typical Footprint Comparison Between 4-Leg Intersection and Roundabout

Constructability

In retrofit situations, the construction process for a roundabout tends to be longer, more complex, and is more likely to require temporary lane closures and detouring of traffic.

When a stop-controlled intersection meets warrants for traffic signals, it can be a relatively straightforward process to convert it to a signalized intersection. In some cases, left-turn lanes need to be added, but often all that is required is that traffic signal plant be installed. The underground work for the traffic signals may already be in place in anticipation of a future warrant for signalization.

Converting an existing stop-controlled or signalized intersection to a roundabout is a complex and often expensive task. Full road reconstruction will be necessary for any areas needed for a roundabout that are not already in place for the existing intersection. Additional property outside the right-of-way often has to be acquired. Because utilities are usually installed in straight line segments along a corridor, consideration must be given to where access for these utilities will be with roundabouts in place.

Operational Considerations

Capacity at a signalized intersection is defined in terms of average control delay. Delay could fluctuate between zero and several minutes depending on level of congestion, the point in the cycle at which a driver arrives, and whether a through or turning movement is to be made.

At a roundabout, delay should be defined in terms of average approach delay and geometric delay. Geometric delay will dominate during off-peak periods, when approach delay is negligible but everyone must slow to navigate the intersection. It is a very small component of the total delay when a roundabout is busy. Average delay on a roundabout approach will depend mainly on the entering flow and the circulating flow past that entry. When one approach has a high entering flow and a low opposing circulating flow, it will tend to dominate the roundabout and cause delays to traffic on the other entries. Conversely, when one approach has both a high entering flow and a high opposing flow there may be long delays and queues at that entry, even when the other entries are operating with low delays.

Unlike signalized intersections, where signal timings can be altered to account for changes in traffic demand, a roundabout must be designed in anticipation of varying demands throughout the day and over time. This makes them difficult to modify in response to major or unanticipated changes in long term traffic patterns.

Further information on roundabout capacity can be found in Appendix D.

Accommodating Pedestrians and Cyclists

Where regulatory pedestrian crosswalk signs are in place, pedestrians have the legal right-of-way at a roundabout crossing in Canada except Ontario. However, pedestrians must ensure that traffic has stopped before they proceed, just as they should at other types of intersections. It is acknowledged that some user groups, such as young children and seniors, will find that task more difficult than others. And people with vision loss will find it even more difficult. The likelihood of these groups using the intersection should be considered and balanced against the other benefits a roundabout will provide.

Note that although traffic signals control right-of-way priority at signalized intersections, some of the worst crashes can occur when that priority is violated (i.e. red light running) or when drivers are not looking in the direction of a pedestrian (i.e. looking left while turning right or looking for oncoming traffic while turning left).

Maintenance

As previously mentioned, compared to signalized intersections, roundabouts do not require periodic signal timing changes, bulb replacement or eventual signal plant replacement. However, they may require additional maintenance because of landscaping in the central island, and may be more difficult to plough in the winter, especially small roundabouts in residential areas. Depending on the design snow removal equipment can damage curbs at the central island and splitter islands.

Public Outreach

The introduction of roundabouts in any area where they are a new form of traffic control requires extensive public outreach. The main component of the outreach is educating users on how to drive, walk or cycle through a roundabout. At multi-lane roundabouts this must include proper lane use, as incorrect lane changes within circulatory lanes can lead to conflicts or crashes. Another component of the outreach may involve informing the public about what a roundabout is, what benefits roundabouts can provide, and why they are different from older traffic circles or rotaries they may have experienced. More information on public outreach for roundabouts can be found in Chapter 2.

Summary

The decision whether to implement a roundabout should be made based on its advantages and disadvantages relative to the alternatives. The alternative could be stop or traffic signal control, either existing or some future version.

The main advantages and disadvantages of roundabouts compared to stop or traffic signal control are summarized in **Table 1-2**.

Table 1-2 Summary of Roundabout Advantages and Disadvantages

Advantages of Roundabouts	Disadvantages of Roundabouts
• Improve safety: o 75% reduction in injury crashes for motorists. o Better safety for pedestrians. o Usually better safety for cyclists. • Lower overall delays and queues for motorists, and more responsive to minor changes in traffic demand. • Fewer lanes on an approach, which can lessen need to widen upstream structures. • Access management benefits: o Closer intersection spacing. o Opportunities for U-turns from right-turn-only driveways. • Environmental benefits: o Lower fuel consumption and emissions. o Reduced pavement area. o Opportunities for gateway features and landscaping. • Lower life cycle costs.	• Higher construction costs. • More space (and often property) required at an intersection. • More difficult to construct in live traffic. • More difficult to upgrade from stop control, or change in response to major changes in traffic demand. • Perception that they are not as safe for pedestrians and cyclists. With large roundabouts it may be difficult to provide good access for young children, seniors, and visually-impaired pedestrians. • Requires public education and outreach. • Difficulty in accommodating long load vehicle turning movements.

1.4 SITE SELECTION

Several jurisdictions in Canada and the United States have instituted policies whereby roundabouts are considered under certain circumstances. Some of these policies even state that roundabouts shall be considered as the first alternative when an intersection is to be modified or reconstructed, or a new intersection built. The provinces of British Columbia and Alberta have adopted such "roundabouts first" policies. Other jurisdictions such as the Region of Waterloo, Ontario, add that roundabouts must also be considered where capacity or safety problems have been identified at an existing intersection.

The interpretation of the word "considered" can vary. Ideally, it would involve some type of technical comparison of alternatives, perhaps preceded by a screening process. For example, at a possible candidate intersection the Region of Waterloo would undertake an initial screening to determine if a roundabout is feasible based on preliminary costs and right-of-way requirements. In some cases a roundabout is not feasible because of building proximity, excessive property requirements, etc. However if it is feasible, then the roundabout alternative is compared to other alternatives (usually the signalization of an intersection or modifications to an existing intersection) based on traffic operations, safety performance, construction costs, and life cycle costs including the societal costs of injury crashes. In addition to an economic comparison, other less-quantifiable criteria may be looked at, such as speed control, conditions for pedestrians and cyclists, accommodation of emergency services and transit vehicles, and access management.

In general, roundabouts are relatively expensive for low volume locations, but they provide safety and capacity benefits at high volume locations. Since most intersections have low flows, most intersections should be under minor-street stop control.

In addition to their benefits at high volume locations, roundabouts also provide improved safety benefits at high-speed sites, especially where a signalized cross intersection would be the alternative. In general, signalized cross intersections are more dangerous than roundabouts everywhere, but the safety advantage of roundabouts over signalized intersections is greatest at high-speed crossings.

Roundabouts can be highly suitable at closely-spaced intersections, or locations having up to five legs or unusual geometry. Accommodating greater than five legs is also possible, but it becomes difficult to achieve ideal geometry. They can also enhance an area through attractive landscaping or act as a gateway treatment between a high-speed rural approach and a low-speed urban area.

Roundabouts are challenging to implement where sufficient intersection space is not available or in retrofit situations because construction staging can be costly and complicated. Other difficult site conditions can include crest vertical curves where stopping sight distance of the roundabout is not available, where approach grades are excessive (although other intersection types may be problematic as well), and traffic signal coordinated networks where a roundabout would disrupt signal progression along the major street.

2.0 POTENTIAL ISSUES WITH ROUNDABOUTS

2.1 PEDESTRIANS

Crosswalks are typically installed at roundabouts where there is a reasonable chance of pedestrian activity. They are typically located one or more passenger car lengths behind the yield line of each entry to separate the driving tasks of looking for pedestrians and looking for oncoming traffic in the circulatory road. Pedestrians can cross in between vehicles if the vehicles are queued at the yield line.

A crosswalk can be straight across the entry and exit, or angled through the splitter island. A straight crosswalk results in a shorter walking distance for pedestrians following the road through the intersection, and generally maintains a one-vehicle-length separation from the yield line across multiple lanes. An angled crosswalk results in a shorter crossing distance, especially across multiple lanes, and creates a more definitive two-stage crossing. Regulatory pedestrian crosswalk signs and either parallel, zebra or ladder crosswalk markings are commonly installed to indicate that pedestrians have the right-of-way. Examples of unmarked and marked crosswalks are shown in **Figure 2-1**. Caution should be taken in applying signs and markings, which can make pedestrians feel overconfident (and less vigilant) at roundabouts where pedestrian activity may be unexpected by drivers.

Photo: GHD / Ourston Roundabout Engineering

Photo: GHD / Ourston Roundabout Engineering

Figure 2-1 Unmarked (left) and Marked (right) Pedestrian Crosswalks at a Roundabout

Studies in several countries have shown that roundabouts tend to be statistically safer for pedestrians. However, many do not perceive roundabouts to be as safe as signalized intersections due to the absence of a positive exchange of right-of-way priority. One reason for this is that pedestrians experience an exaggerated level of security at signalized intersections because the signals indicate it is their turn to cross. The pedestrian assumes it is safe to cross and often proceeds without being vigilant. Drivers are not always vigilant either, and most crashes occur when they turn left or right across the crosswalk while the pedestrian has a walk indication.

Another reason that roundabouts are not perceived to be as safe is that pedestrians must actively seek or create gaps in traffic in order to cross. Not everyone is comfortable finding or creating such a gap. Seniors can find this task difficult, and children may not have experience or confidence at busy roundabouts. This can be especially pronounced at multi-lane roundabouts, where traffic is moving faster and where a driver in the near lane may yield to a pedestrian, but drivers in the adjacent lane may not.

Roundabouts can be made safer for pedestrians by controlling motor vehicle speeds. Treatments may include tighter entry and exit curvature, narrower entry and circulatory road widths, entries that are more perpendicular (as opposed to tangential) to the roundabout, and refuge areas on the splitter islands that are at least 2.0 metres wide to accommodate a pedestrian pushing a stroller or walking a bicycle. Since single-lane roundabouts are safer for pedestrians than multi-lane roundabouts, efforts should be made to implement single-lane designs were possible, and only expand them to multi-lane operation when warranted by traffic demand.

2.2 ACCESSIBILITY FOR PEOPLE WITH VISION IMPAIRMENT

People with vision impairment can find roundabouts even more difficult to navigate than seniors or children because of unfamiliarity with the layout, the continuous movement of motor vehicles, and difficulty in finding or creating a gap in traffic. Extra treatments can be used to help them locate the crosswalk, establish alignment, and decide when it is safe to cross.

Treatments that can help people with vision loss locate a crosswalk at a roundabout and establish alignment include:

- Railings or low-height landscaping to direct pedestrians to the crossing location.
- Score lines or guide strips in the sidewalks and crosswalk ramps that can be picked up by a cane.
- Tactile walking surface indicators, typically raised truncated domes made in a colour that contrasts with the sidewalk that can be detected underfoot.

Treatments that can help people with vision impairment decide when it is safe to cross at a roundabout include:

- Rumble strips in the roadway that allow them to hear when a vehicle is nearby.
- Raised pedestrian crossings that can further slow traffic and increase yield rates for pedestrians.
- Crosswalks further from the roundabout, to more clearly separate the sound of traffic entering or exiting the roundabout from the continuous movement of traffic in the circulatory road.
- Audible pedestrian signals.

According to a recent U.S. study the treatments that seemed to increase the willingness of drivers to yield to pedestrians were raised crosswalks, pedestrian beacons or signals with audible tones.[10]

An example of pedestrian signals at a roundabout can be seen in **Figure 2-2**. There is one set of signals with audible tones per entry and exit. The crosswalk is staggered through the splitter

10 National Cooperative Highway Research Program (NCHRP) Report 674, Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities, Transportation Research Board, 2011.

island to separate the audible tones so that people with vision loss can determine to which part of the crossing the tone applies. The cycle lengths are short because pedestrian crossing distances are short and each stage is accommodated separately. The signals rest on green for drivers and change to red upon actuation by a pedestrian.

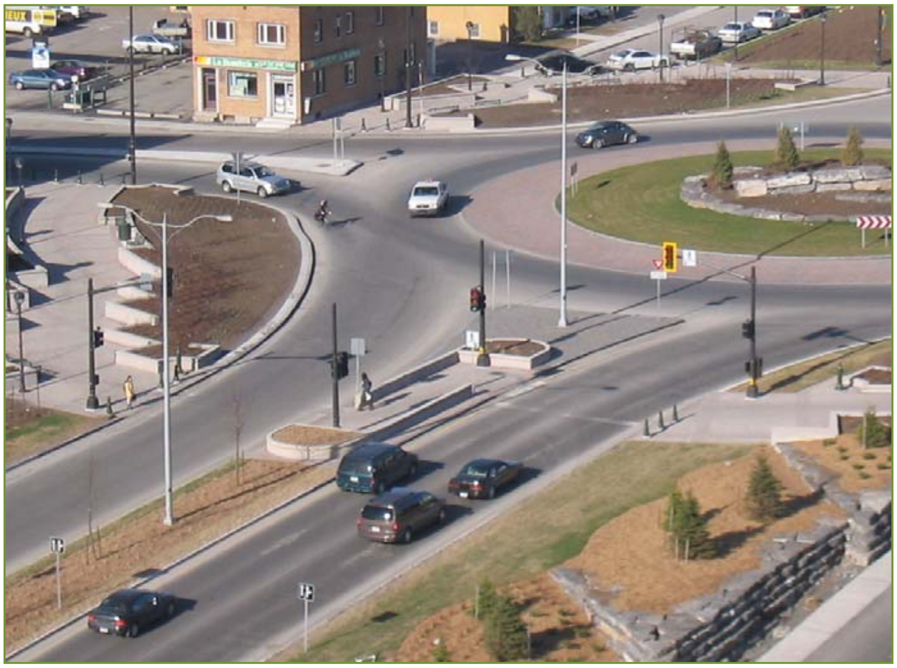


Photo: GHD / Ourston Roundabout Engineering

Figure 2-2 Pedestrian Signals at a Roundabout (Gatineau, Quebec)

Pedestrian beacons or signals are not commonly installed at roundabouts in Canada and the United States. One reason is that they negate some of the operational advantages of roundabouts in terms of low vehicle delay and responsiveness to changing traffic demand. Another reason is that pedestrian beacons or signals will add considerably to the overall construction cost of a roundabout, especially if they are installed across all legs, and may therefore result in a roundabout not being constructed when it would be advantageous to do so otherwise.

The use of pedestrian signals at roundabouts is generally being advocated by vision loss groups such as the Canadian National Institute for the Blind (CNIB). However decision-makers should be aware of their operational impacts and costs. Although they can aid in making a roundabout more accessible for people with vision loss, there are a number of additional considerations that are not yet fully understood:

- Pedestrians have the right-of-way at roundabout crosswalks where regulatory pedestrian crosswalk signs are in place. However if some locations have pedestrian signals and others do not, there may be confusion among drivers as to who actually has the right-of-way when a roundabout does not have pedestrian signals. There may also be confusion among drivers when some pedestrians actuate the signals and others do not.
- Whether the presence of a green signal indication for drivers conflicts with the downstream Yield sign at the roundabout entry and decreases the overall safety of the roundabout.
- Whether pedestrian signals actually increase pedestrian safety.

The likelihood of seniors, children and people with vision loss using an intersection should be considered and balanced against the other benefits a roundabout will provide. It should be recognized that people with vision loss also have challenges at other intersections. Physical treatments such as pedestrian signals may increase accessibility but are not always safer, and education and enforcement are also vital components of intersection safety. Pedestrian crosswalk design involves trade-offs. In particular, the decision whether to implement pedestrian signals at a roundabout should be made on a case-by-case basis.

Further information on how to mitigate difficulties for people with vision loss at roundabouts are contained in Appendix A.

2.3 CYCLISTS

In the absence of off-road bike paths, the preferred practice at roundabouts is for cyclists to travel through them either as a vehicle or as a pedestrian. Travelling through as a vehicle means merging with motor vehicle traffic and riding through in the centre of the appropriate traffic lane. Most cyclists on the roadway will be comfortable merging with traffic because speeds for motor vehicles in roundabouts are not much higher than typical cyclist speeds. If cyclists are not comfortable with this, then they can travel through the roundabout as a pedestrian. This usually means dismounting their bike and taking a ramp connection to the sidewalk. A typical bike lane termination and connection to the sidewalk for a roundabout under construction is shown in **Figure 2-3**.

Photo: GHD / Ourston Roundabout Engineering

Figure 2-3 Typical Bike Lane Termination at a Roundabout

Cyclists are encouraged to ride in the traffic lane through a roundabout is so they are more visible. Experience in other countries has demonstrated that, when bike lanes are carried through a roundabout, cyclists remain at the outer edge of the circulatory road where they are less visible to entering or exiting drivers.[11] Therefore bike lanes are not carried through roundabouts in most countries. Exceptions to this can be found in the United Kingdom and Australia.

11 Fortuijn, L.G.H, Pedestrian and Bicycle-Friendly Roundabouts; Dilemma of Comfort and Safety, Delft University of Technology, The Netherlands, 2003.

It is generally agreed that off-road bike paths are preferred by cyclists over on-road facilities, and are considered safer as long as adequate provisions are made at locations where they cross at intersections. In the case of roundabouts, this requires dedicated crossings for cyclists that are visible and obvious to drivers. Dedicated cyclist crossings at roundabouts can be found in some European counties such as The Netherlands, but are rare in Canada.

As mentioned in Chapter 1, international studies are not conclusive about cyclist safety at roundabouts. Most show that cyclists are safer at single-lane roundabouts than at other intersection types, but not always lower risk at multi-lane roundabouts. As for pedestrians, roundabouts can be made safer for cyclists by controlling motor vehicle speeds as much as possible, and by implementing single-lane designs where practical.

More discussion of the various treatments that can be used to accommodate cyclists at roundabouts can be found in Appendix B.

2.4 TRUCKS

It is important that the design vehicle be considered early in the roundabout design process. The overall diameter and many geometric design details are a direct function of the design vehicle, or largest type of vehicle expected to use the intersection on a regular basis. In some cases, accommodation of larger oversize vehicles (even larger than the design vehicle) must also be considered, even though the occurrence of such vehicles may be rare. The functional classification of the intersecting roadways may dictate the need to account for occasional oversize vehicles.

At single-lane roundabouts, trucks may be accommodated without encroachment outside the curbs by making the entries and exits wide enough for their swept paths and using pavement markings to visually narrow the roadway. Another option is to use partially-traversable truck aprons. These are a design compromise to accommodate trucks at small roundabouts while still providing speed control for passenger vehicles. Truck aprons are usually installed around the central island, although outer truck aprons are sometimes employed. **Figure 2-4** is an example location that has both treatments. Truck aprons should be capable of being mounted by large vehicles, but should be unattractive to passenger vehicles because they are raised and have a slope and/or textured surface. They are usually constructed using a semi-mountable curb and a surface that looks different from the asphalt or concrete in the roadway.

New York State Department of Transportation

Figure 2-4 Central Island and Outer Truck Aprons

In some cases where insufficient inscribed diameter is available, typically at mini-roundabouts, full-mountable central islands are implemented to allow larger trucks to fully traverse the central island. Splitter islands may also be fully traversable in these cases.

Unlike single-lane roundabouts, no special geometric treatments are necessarily needed to physically accommodate large commercial vehicles at multi-lane roundabouts. However, there are still a number of considerations in terms of lane use. They include whether to allow for trucks to over-track adjacent lanes, and whether to install lane lines in the circulatory road.

Accommodating Trucks at Multi-Lane Roundabouts

Case 1 Designs

With what may be referred to as Case 1 truck accommodation, large commercial vehicles track across adjacent lanes as they enter, circulate and exit the roundabout (see **Figure 2-5**). This is the most common means of designing a multi-lane roundabout and is analogous to other types of intersections where trucks will track across adjacent lanes as they make left or right turns. The difference with these roundabouts is that large trucks will need to do this for through movements as well.

Photo: GHD / Ourston Roundabout Engineering

Figure 2-5 Example of Case 1 Truck Accommodation

There is an obvious disadvantage with a Case 1 designs in that they may lead to side-swipe collisions between light vehicles and trucks through the roundabout entry. This can be mitigated by training truck drivers to straddle the entry lanes so that other vehicles cannot drive beside them. These operations are easier to accomplish when a roundabout entry adds lanes through a flare (i.e., one lane flares to two, for example).

There are several advantages to these designs. Case 1 roundabouts will likely be smaller than roundabouts where trucks can maintain their lane, with narrower entries and exits and higher entry angles. These features will act to increase the overall safety performance of the roundabout through more speed control and better sightlines for entering drivers. Also, since this design is smaller, it will occupy less land area and be less expensive to construct.

Case 2 Designs

With Case 2 truck accommodation, large commercial vehicles can maintain their own lane through the entry, but not as they circulate and exit the roundabout (see **Figure 2-6**). The entry will be wider than that of a Case 1 design so that a passenger vehicle and a large truck can line up side-by-side, after which one vehicle will have to give way to the other upon proceeding into the roundabout.

A disadvantage with this design is that it may relocate side-swipe collisions from the entry to within the circulatory road. The probability should not be as high as with Case 1 designs because even when two vehicles line up side-by-side, one will naturally pull ahead. In addition, the wider entry will make it more difficult to achieve sufficient speed control on the approach.

The advantage of this design is the ability to handle higher truck percentages. Case 2 designs can therefore be considered more appropriate on roads with a high percentage of trucks and where the design compromises associated with accommodating them are reasonable.

Photo: GHD / Ourston Roundabout Engineering

Figure 2-6 Example of Case 2 Truck Accommodation

Case 3 Designs

With Case 3 truck accommodation, large commercial vehicles can maintain their own lane as they enter, circulate and exit a multi-lane roundabout (see **Figure 2-7**). This design allows for a passenger car and a large truck to travel side-by-side through the roundabout, although in extreme cases two large trucks can be accommodated side-by-side.

Case 3 designs will be larger and faster than Case 1 and 2 designs and will require a central island truck apron to keep trucks in the inner lane as they circulate, unless the roundabout is made very large. Truck aprons are common at single-lane roundabouts, but are not necessarily needed at multi-lane roundabouts if trucks do not have to be accommodated in their own lane.

Generally, Case 3 designs should only be considered when truck percentages are very high and the design compromises associated with accommodating them completely within their lanes are acceptable.

Photo: MTJ Engineering

Figure 2-7 Example of Case 3 Truck Accommodation

2.5 ROUNDABOUT LANE LINES IN THE CIRCULATORY ROAD

In most countries, multi-lane roundabouts have lane lines on the entries and exits, but not in the circulatory road unless special conditions make them necessary. This is analogous to signalized intersections not having lane lines continue through the intersection except to aid certain movements.

Circulatory road lane lines at roundabouts tend to be the rule rather than the exception in the United States. Circulatory road lane lines are usually installed in Canada but, on provincial roads in Nova Scotia, they are not except under special conditions. Interestingly, early roundabout designs in the United States (prior to 2001) did not have circulatory road lane lines at all.

A roundabout with lane lines around part of the circulatory road, in this case for southbound movements from a three-lane entry, can be seen in **Figure 2-8**. Note that this roundabout has since been modified to include lane lines around the entire circulatory road.

Photo: GHD / Ourston Roundabout Engineering

Figure 2-8 Example of Partial Circulatory Road Lane Lines (Waterloo Region, Ontario)

Advantages of circulatory road lane lines are that they:

- Provide a reminder to drivers to maintain their lane position while circulating.
- May improve lane utilization and therefore increase capacity.
- Educate drivers on how to correctly turn left in conjunction with approach signs and markings that indicate lane choice.
- Are necessary for complex configurations with exclusive left turns to guide drivers through the roundabout. This is analogous to signalized intersections having guiding lines for left-turns.

Disadvantages of circulatory road lane lines are that they:

- Can lessen the potential for drivers to yield at entry because the lane lines make it look like the lane continues through the roundabout entry.
- Can be a challenge to design, and difficult to implement accurately in the field. If lane lines are not implemented accurately then they can create path overlap. This is an undesirable situation where drivers are naturally led from the outside lane to the inside lane when entering the roundabout, or from the inside lane to the outside when exiting.
- May necessitate truck aprons where not normally required.
- Can encourage passenger car drivers to circulate next to trucks, where the design does not allow for trucks to maintain their own lane in the circulatory road (Case 1 and 2 designs).

The decision to implement circulatory road striping at a multi-lane roundabout should therefore be made on a site specific basis.

The British Columbia Ministry of Transportation & Infrastructure installed warning signs in an effort to counter the tendency for drivers of light vehicles to circulate next to trucks at roundabouts with circulatory road lane lines (Refer to **Figure 2-9)**.

Photo: GHD / Ourston Roundabout Engineering

Figure 2-9 "Truck Encroachment" Warning Sign

2.6 ROUNDABOUT CAPACITY PREDICTION

Traffic capacity at roundabouts is determined by estimating the capacity of each roundabout entry, and then averaging the results to calculate an overall intersection capacity. Most roundabout capacity analysis software accomplishes this using deterministic programs based on either a gap-acceptance model or an empirical model. Lately, micro-simulation models are also becoming popular as a means of predicting roundabout capacity. At present, there are no Canadian-based roundabout capacity models.

Gap-Acceptance and Empirical Models

Australian and U.K. Capacity Models

Gap-acceptance models are models developed from the use of gap-acceptance theory. This is a concept familiar to transportation practitioners, as it is consistent with models used to estimate delays at stop-controlled intersections. Inputs to the model include the volume of traffic at each entry, the circulating flow past that entry, the number of entering lanes, and appropriate gap-acceptance and follow-up times. The most-commonly used gap-acceptance model was developed in Australia and is employed in the computer program SIDRA™.

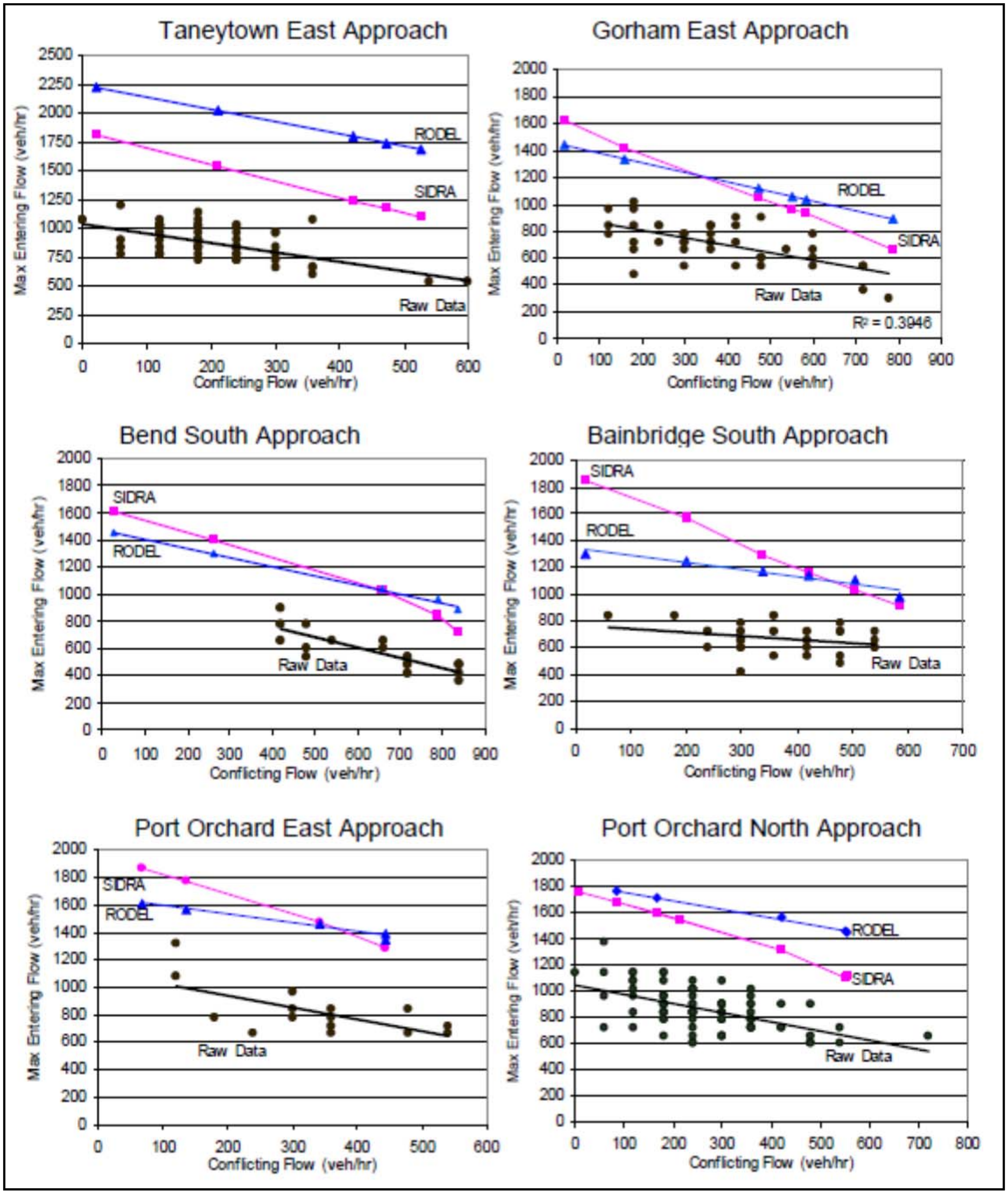
Empirical models are models developed using actual observed data. The most commonly-used empirical roundabout model was developed in the United Kingdom in the late 1970s. It consists of over 11,000 minutes of at-capacity observations at a significant number of roundabouts in the U.K. Inputs to the model include the volume of traffic at each entry, the circulating flow past that entry, and the geometry of the entry. The U.K. empirical model is employed in the computer programs RODEL™ and ARCADY™.

The foundation of gap-acceptance models is the selection of appropriate gap-acceptance and follow-up times at a location. However, these times can vary based on the amount of traffic congestion being experienced at that location at a given time. Empirical models have an advantage in that they are based on actual observed capacities, and thus are not dependent upon such a foundation. However, the disadvantage of empirical models is that they require a large amount of at-capacity data to develop.

Development of a U.S. Capacity Model

An effort has been made in the U.S. to develop a roundabout capacity model based on U.S. conditions and roundabouts. In 2007 a study was completed based on approximately 300 minutes of at-capacity observations collected at 14 roundabouts in 2003.[12] Some of the results are shown in **Figure 2-10**.

12 National Cooperative Highway Research Program (NCHRP) Report 572, Roundabouts in the United States, Transportation Research Board, 2007, Chapter 4.



Source: *"Information for the Highway Capacity and Quality of Service Committee", NCHRP 3-65, July 2004*

Figure 2-10 Results of the 2007 US Roundabout Capacity Study

The actual at-capacity observations are shown as the raw data points in the graphs. To these, best-fit linear regression lines are depicted as the heavy black lines. It can be seen that the capacity predictions of SIDRA and RODEL are higher than the actual observed capacities. In other words, these programs over-estimated the capacities of the roundabouts used in the study. The finding is not surprising, given that roundabouts are familiar to drivers in Australia and the U.K. but relatively new to drivers in the U.S. Also, the sample size of the study was small, and there was little sustained at-capacity operation at the 14 roundabouts observed.

However, it can be seen in the graphs in **Figure 2-10** that the slopes of the RODEL (empirical) capacity estimates more closely reflect the actual observations. This indicates that the U.K empirical model may be easily calibrated for U.S. conditions by adjusting the y-intercept of the capacity prediction. The SIDRA (gap-acceptance) model can also be calibrated, but it would involve adjusting both the y-intercept and the slope of the capacity prediction.

While it may be straightforward to estimate the degree to which a model can be calibrated to reflect conditions at U.S. roundabouts at present, an unknown is what degree of calibration may be appropriate in the future (i.e. 20 years). It is likely that U.S. (and, presumably, Canadian) drivers will be more familiar with roundabouts by then, and thus capacities will be higher than what is currently the case.

The U.S. roundabout capacity model is currently a gap-acceptance model developed from the 2007 study and included in the 2010 Highway Capacity Manual (HCM). The computer program SYNCHRO incorporates the model, but the HCM advises that other programs may be more appropriate in certain cases.

Micro-Simulation Models

Micro-simulation programs such as VISSIM, AIMSUN and PARAMICS can be used to model roundabouts. However, caution is advised as these programs currently have only limited theoretical basis, which is largely based on gap acceptance theory with which to determine roundabout capacity.

Micro-simulation models can be useful in building upon the results of a deterministic model to perform system-wide analyses. The animation features of these programs are also useful to visually demonstrate future intersection operations.

2.7 PUBLIC OUTREACH

Since roundabouts are still relatively new in Canada, public outreach should be an important part of any project that introduces a new or more complex roundabout to an area. The outreach should include the reasons why a roundabout is being considered or constructed, and instructions on how each road user should navigate it.

A number of road agencies in Canada have developed public education material on roundabouts. This includes Transport Canada, most provincial governments, and a large number of regional, county and local governments. **Table 2-1** provides a summary of websites in Canada having roundabout-related material.

Table 2-1 Provincial and Municipal Websites Offering Roundabout Education

Juris-diction	Website	Back-ground	Edu-cation	Manoeuvre-ability	Other Features
Alberta	http://www.transportation.alberta.ca/3644.htm	NO	YES	YES	• List of Provincial Roundabouts • Educational video on roundabout manoeuvring (animation and real life video)
British Columbia	http://www.th.gov.bc.ca/roundabouts/index.html	YES	YES	YES	• Animation on how to manoeuvre a roundabout. • Videos that explain roundabouts and how emergency vehicles navigate a roundabout. • Roundabout signs • Reader-friendly
Calgary	http://www.calgary.ca/Transportation/TP/Pages/Safety/Roundabout-Safety/Traffic-roundabouts.aspx	NO	YES	YES	• Several videos that each explain a different manoeuvring procedure on a roundabout
Fredericton	http://www.fredericton.ca/en/transportation/roundabouts.asp	NO	YES	YES	• Animation on manoeuvring a roundabout • Video on how cyclists use a roundabout • Roundabout locations in Fredericton • Frequently asked questions
Halifax	http://www.halifax.ca/traffic/roundaboutsFAQ.html	YES	YES	YES	• Explanation of conflict points in roundabout. • Roundabout signs • Link to Transport Canada roundabout brochure and other helpful links
Hamilton	http://www.hamilton.ca/CityDepartments/PublicWorks/TrafficEngineeringAndOperations/RoadsTrafficModernRoundabout.htm	YES	YES	YES	• Figures that demonstrate conflict points and roundabout safety benefits • Locations of roundabouts in the City of Hamilton • Provides several helpful links to other useful roundabout education websites
MTO	http://www.mto.gov.on.ca/english/dandv/driver/handbook/section2.6.7.shtml	NO	YES	YES	• Picture that explains travel direction in roundabout.
Ottawa	http://www.ottawa.ca/residents/onthemove/driving/traffic/roundabout/index_en.html	NO	YES	YES	• An animation has been developed that demonstrates how pedestrians, cyclists, and motorists should travel through the intersection • Navigating roundabouts pamphlet available

Juris-diction	Website	Back-ground	Edu-cation	Manoeuvre-ability	Other Features
Prince Edward Island	http://www.gov.pe.ca/tir/roundabouts	YES	YES	YES	• Animation that describes roundabout manoeuvring • Links available to download single and multi-lane roundabout brochures
Quebec	http://www.mtq.gouv.qc.ca/portal/page/portal/grand_public_en/vehicules_promenade/reseau_routier/carrefours_giratoires	YES	NO	YES	• Link provided to Quebec Roundabout Brochure • Explanation of conflict points in a roundabout vs. an intersection • Explanation of road signs in roundabouts
Saskatoon	http://www.saskatoon.ca/DEPARTMENTS/Infrastructure%20Services/Transportation/neighbourhood/Pages/Roundabouts.aspx	NO	YES	YES	• A 30-second video on how to drive a roundabout
Transport Canada	http://www.tc.gc.ca/eng/roadsafety/tp-tp14787-menu-179.htm	NO	YES	YES	• Brochure that describes roundabout manoeuvring for cyclists, pedestrians and drivers. • Ability to order copies of brochure • Brochure available for downloading in PDF.
Waterloo	http://www.regionofwaterloo.ca/en/gettingaround/roundabouts.asp	YES	YES	YES	• Understanding roundabout signs • Several videos that explain certain situations that could arise in a roundabout • Locations of roundabouts in the Region of Waterloo • Several links to brochures

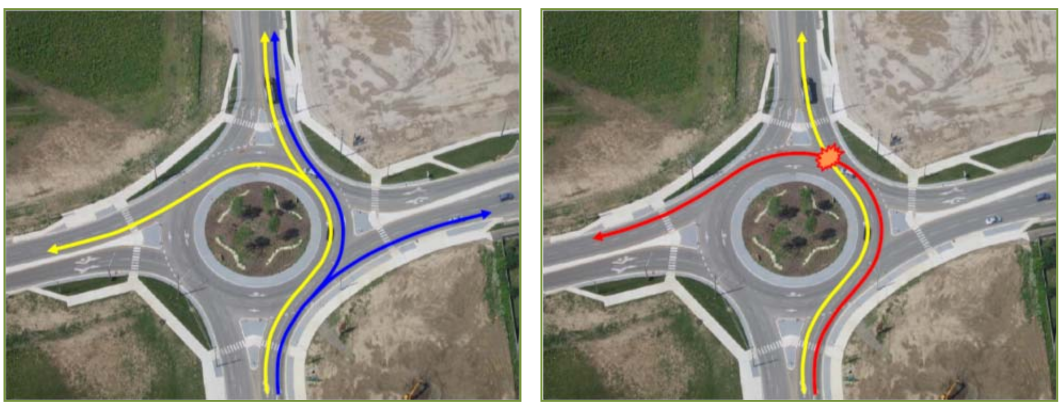
Additional public outreach material may include the following:

- Brochures or flyers;
- Posters;
- Lists of frequently asked questions for posting on websites and distribution to decision-makers, agency staff, police and emergency response personnel, local media, etc.;
- Scale models of a roundabout for use at public meetings; and,
- Visualizations and animations.
- The inclusion of roundabouts in provincial drivers' handbooks, driver education courses and children's safety villages.

It is important to remind the public that a roundabout is simply an intersection with an island in the middle. This explanation is preferred to describing a roundabout as a series of T-intersections.

There are a number of other messages that driver education efforts should focus on. They consist of the following:

- Entering drivers yield to circulating traffic at all roundabouts;
- Drivers should select the appropriate destination or exit leg before entering the roundabout.
- At multi-lane roundabouts, drivers should select the appropriate entry lane before entering the roundabout;
- At multi-lane roundabouts, left turns are made from the left entry lane. If drivers make a left turn from the right entry lane then they can collide with drivers making a through movement from the left entry lane, which is usually a permitted movement (Refer to **Figure 2-11**);
- Be prepared to yield to pedestrians in the crosswalk or about to cross;
- Give space to cyclists and large trucks;
- Drivers should signal their intentions;, and,
- If an emergency vehicle approaches, drivers should pull over to the side of the roadway to let it through. If already in the roundabout then drivers should exit before pulling over so they do not block the emergency vehicle in the roundabout.



Graphic: GHD / Ourston Roundabout Engineering

Figure 2-11 Comparison of Correct (left) and Incorrect (right) Left Turns at a Multi-Lane Roundabout

Driver education efforts should be periodically updated, both as a means of keeping messages fresh and interesting to the public, and in response to the planning and construction of new or more complex roundabouts.

3.0 ROUNDABOUT EXPERIENCE IN CANADA

3.1 THE SURVEY

The main objectives of the survey was to assess and document the current state of practice of roundabouts in Canada and to obtain a snapshot of their status and practice in terms of policy, implementation, operations, safety and maintenance.

In 2010 all jurisdictions that were known to have existing or planned roundabouts were sent a bilingual survey (see Appendix C). To prevent the inclusion of traffic calming measures roundabouts on residential streets were not included in the study. Kittelson & Associates, Inc. (KAI) created and maintains a comprehensive database of roundabouts in North America which was developed as part of a website created for the Federal Highway Administration's (FHWA) Roundabouts: An Informational Guide, 1st Edition. As of November 2012 it included roundabouts in British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Quebec, Saskatchewan and the Yukon Territory. To ensure all authorities known at the time to have roundabouts had been sent the survey the KAI database was cross referenced. The results of this comparison are shown in **Table 3-1** and the jurisdictions responsible for these roundabouts are listed in **Table 3-2**.

The number of roundabouts in Canada, based on committee member knowledge and survey responses, ranged from 117 to 237. The majority are in urbanized areas of the most populous provinces. The Northwest Territories and Nunavut did not report any roundabouts.

The survey was designed to be completed for each roundabout in a jurisdiction. The survey questions were grouped under nine major headings as follows:

- General including location and reasons for installation;
- Design inputs;
- Traffic operational characteristics;
- Pedestrians / cyclists;
- Safety;
- Maintenance;
- Policy;
- Public acceptance; and,
- Other

Table 3-1 Roundabouts in Canada

Province	Kittelson Database[1]	Responses Received	Not Currently in Database	Roundabouts		
				Total Confirmed	Other Possible	Total Possible
AB	19	19		19	3	22
BC	30	51	21	51	1	52
MB	8	3	2	10		10
NB	3	0		3		3
NL					1	1
NS	3	1		3		3
NT						0
NU						0
ON	29	19	10	39	5	44
PE		1	1	1		1
QC	21	5	75	96		96
SK	2	1		2		2
YK	2	3	1	3		3
Total	**117**	**103**	**110**	**227**	**10**	**237**

[1] http://roundabouts.kittelson.com/Roundabouts

Sample Size

As shown in **Table 3-2**, the responses from various agencies helped to establish a statistically significant sample size for the provinces and also for Canada as a whole.

There were a significant proportion of "No Response" to a number of questions in the original survey, and for that reason they are not listed in the summary. These included questions regarding volume levels and Level of Service (LOS). In addition, some other questions were also omitted as there was some misinterpretation by various jurisdictions.

Table 3-2 Jurisdictions with Roundabouts and Sample Size

Province / Territory	Jurisdiction	Number of Responses Received	Total by Province / Territory Responses Received	Total Possible	Sample Size
AB	Alberta Transportation	-	19	22	86%
	City of Calgary	-			
	City of Edmonton	6			
	City of Lethbridge	12			
	Town of Sylvan Lake	1			
BC	City of Abbotsford	5	51	52	98%
	City of Burnaby	-			
	City of Chilliwack	1			
	City of Coquitlam	1			
	City of Dawson Creek	1			
	City of Fort St. John	1			
	City of Kamloops	4			
	City of New Westminster	1			
	City of North Vancouver	-			
	City of Port Moody	1			
	City of Prince George	1			
	City of Surrey	8			
	City of Vernon	2			
	District of Central Saanich	1			
	District of North Saanich	5			
	District of Saanich	-			
	District of Summerland	2			
	District of Vancouver	7			
	District of West Kelowna	4			
	District of West Vancouver	-			
	Fraser Valley Regional District	1			
	Metro Vancouver (UBC Campus)	1			
	Municipality of North Cowichan	1			
	Town of Sidney	1			
	Township of Langley	2			

Province / Territory	Jurisdiction	Number of Responses Received	Total by Province / Territory Responses Received	Total Possible	Sample Size
MB	City of Brandon	3	3	10	30%
	City of Winnipeg	-			
	Manitoba Transportation & Government Services	-			
NB	City of Miramichi	-	0	3	0%
	Sunbury County	-			
NL	City of St. John's	-	0	1	0%
NS	Halifax Regional Municipality	1	1	3	33%
	Nova Scotia Department of Transportation & Infrastructure Renewal	-			
ON	City of Guelph	-	19	44	43%
	City of Hamilton	1			
	City of North Bay	-			
	City of Oshawa	5			
	City of Ottawa	-			
	City of Waterloo	-			
	County of Essex	4			
	County of Grey	1			
	County of Oxford	1			
	County of Lambton	-			
	County of Prince Edward	1			
	Town of Ajax	-			
	Town of Aurora	-			
	Town of Collingwood	2			
	Town of Markham	-			
	Town of Mattawa	1			
	Town of Plymton-Wyoming	1			
	Town of Wasaga	2			
	Ministry of Transportation Ontario	-			
	Regional Municipality of Waterloo	-			
PE	City of Summerside	1	1	1	100%

Province / Territory	Jurisdiction	Number of Responses Received	Total by Province / Territory Responses Received	Total Possible	Sample Size
QC	Ville de Gatineau	1	5	96	5%
	Ville de Montreal	4			
	Ministére des Transports du Québec	-			
SK	City of Yorkton	1	1	2	50%
YK	City of Whitehorse	3	3	3	100%
		Totals	**103**	**237**	**43%**

3.2 SURVEY FINDINGS

The key findings obtained from the responses to the questions contained in the survey are summarized below and represented in the following graphs (**Figures 3-1** to **3-9**).

- 43% of the roundabouts were constructed at new intersections and the majority (57%) were upgrades to existing intersections;
- 91% incorporated landscaping into the design;
- 77% were located in urban locations;
- 73% included a truck apron;
- 75% had right-turn slip lanes present;
- 89% were located in locations that had high speed approaches;
- 83% accommodated bikes in the circulatory lane and 17% had separated bike pathways; and,
- Only 1% were not illuminated with street lights.

Figure 3-1 Reasons for Installation

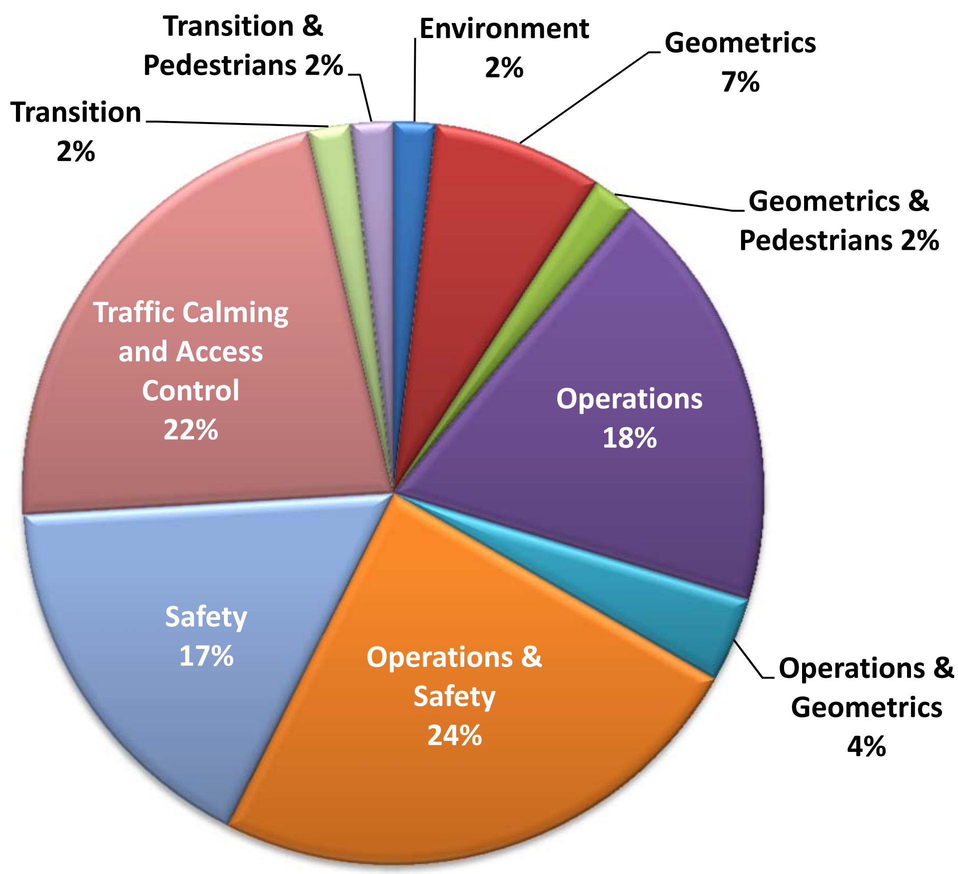
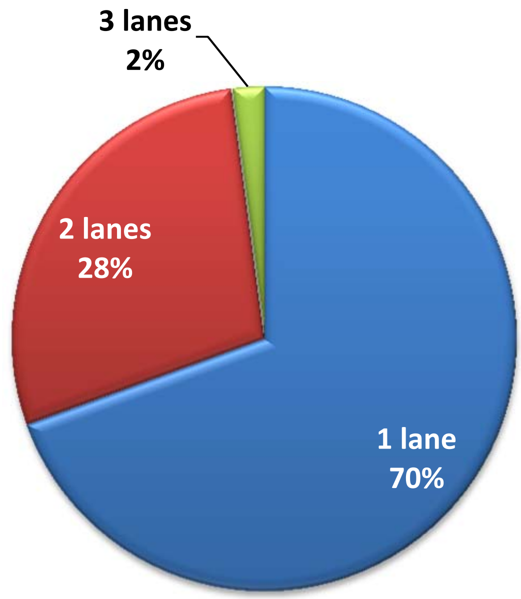
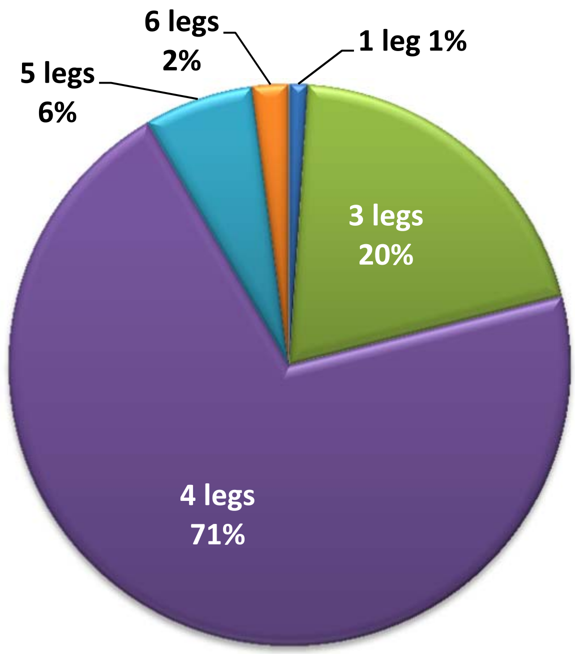


Figure 3-2 Design Inputs

a) *Number of Circulatory Lanes*



b) Number of Legs



c) Design Vehicle

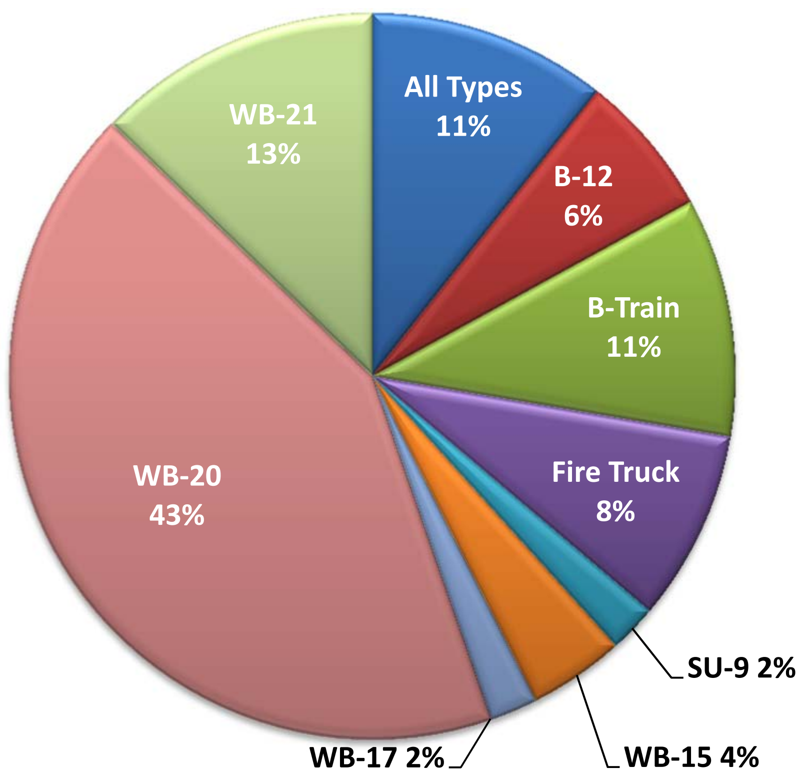
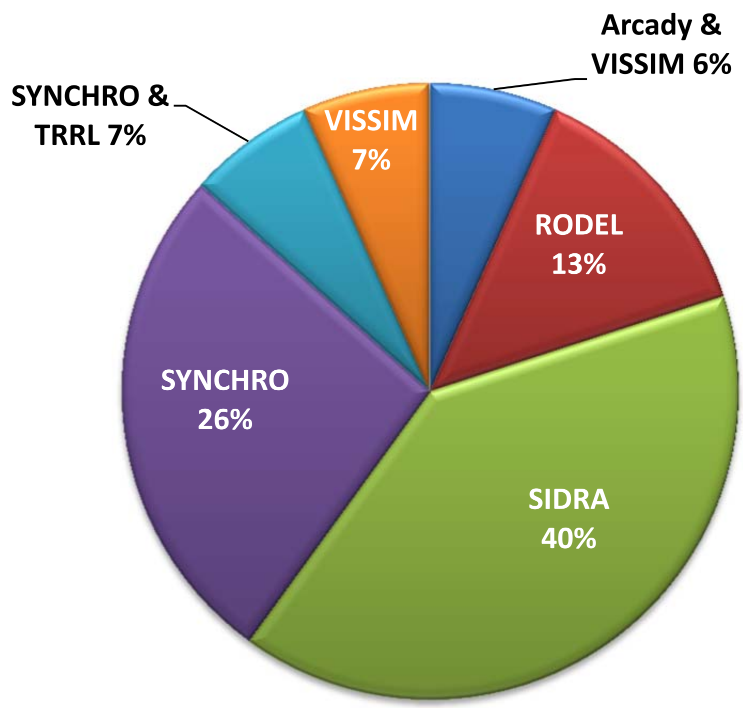
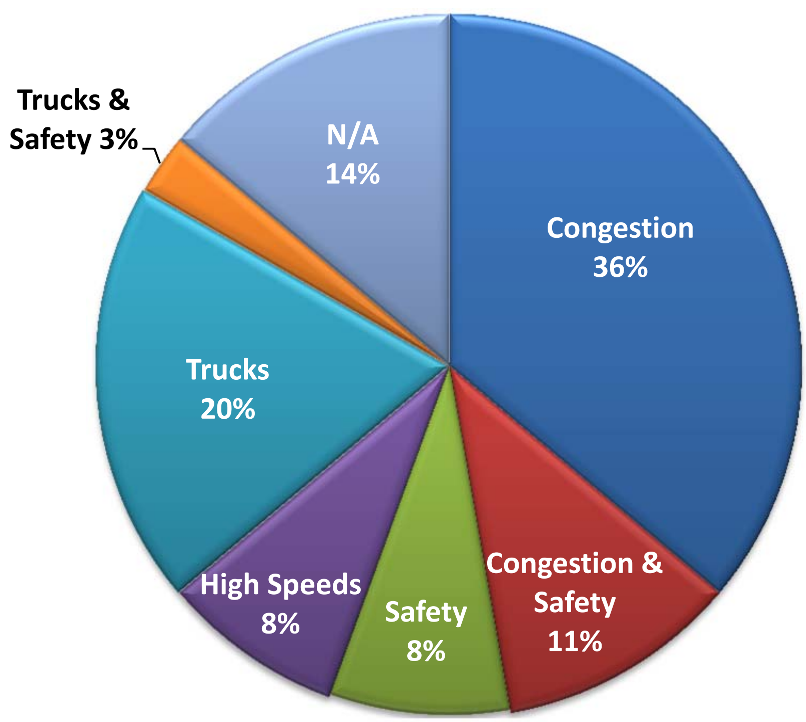


Figure 3-3 Operations

a) Software Used



b) Known Operational Issues



c) Design Changes Required After Installation

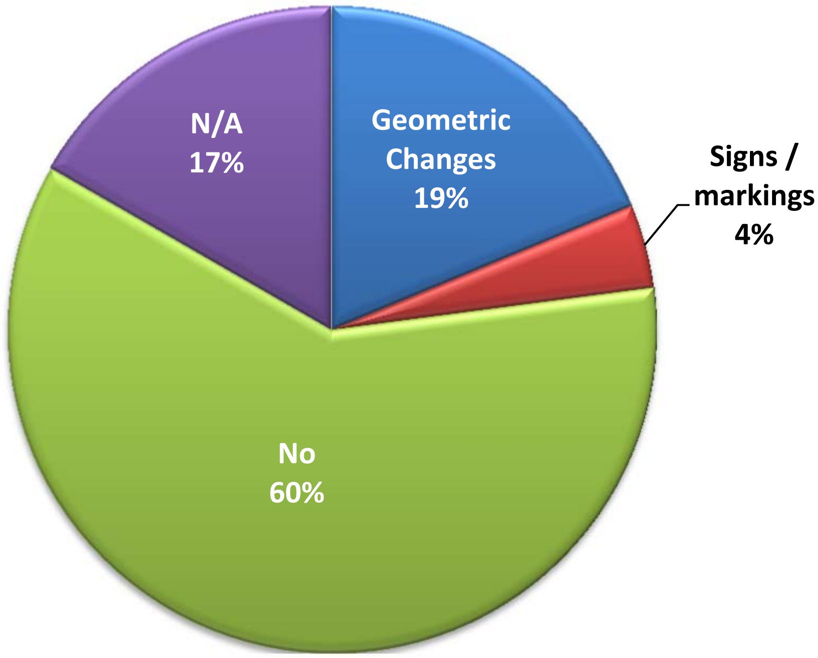
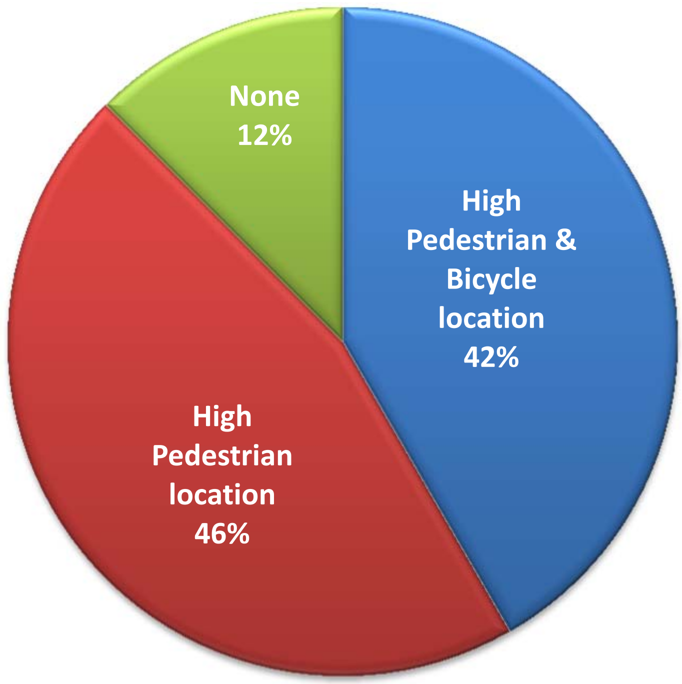
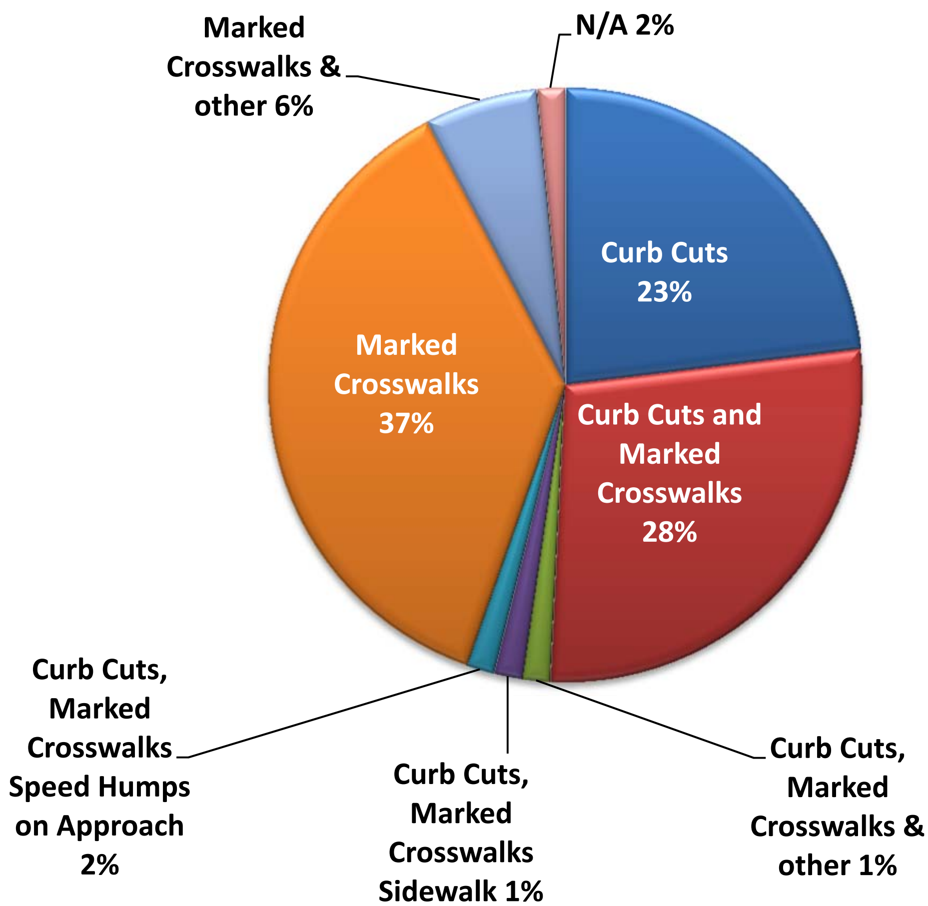


Figure 3-4 Pedestrians and Bicycles

a) High Pedestrian or Bicycle Usage



b) Pedestrian Accommodation



c) Any Special Signs / Markings for the Disabled & Visually Impaired

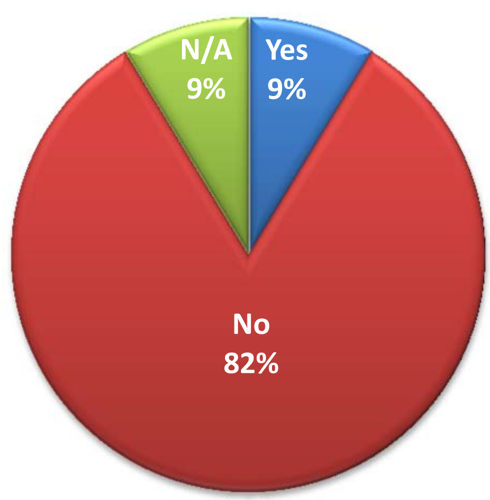


Figure 3-5 Safety Issues

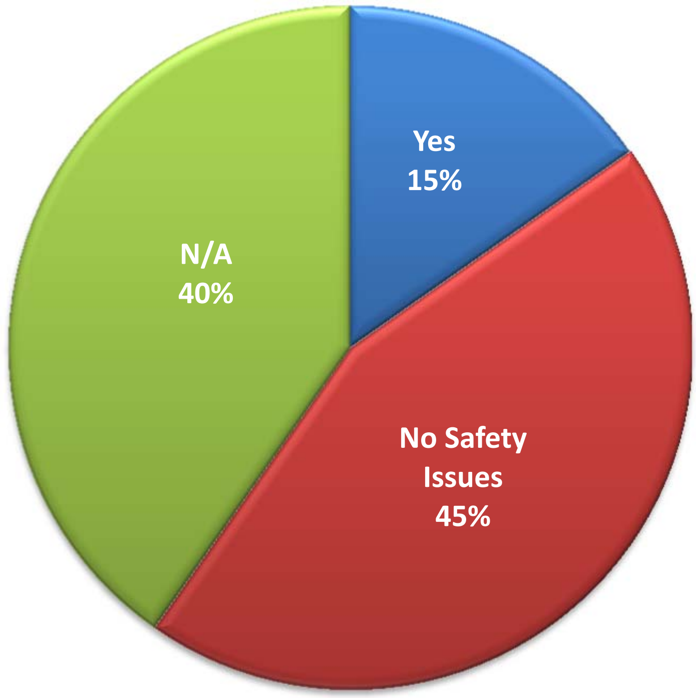


Figure 3-6 Snow Removal & Maintenance Issues

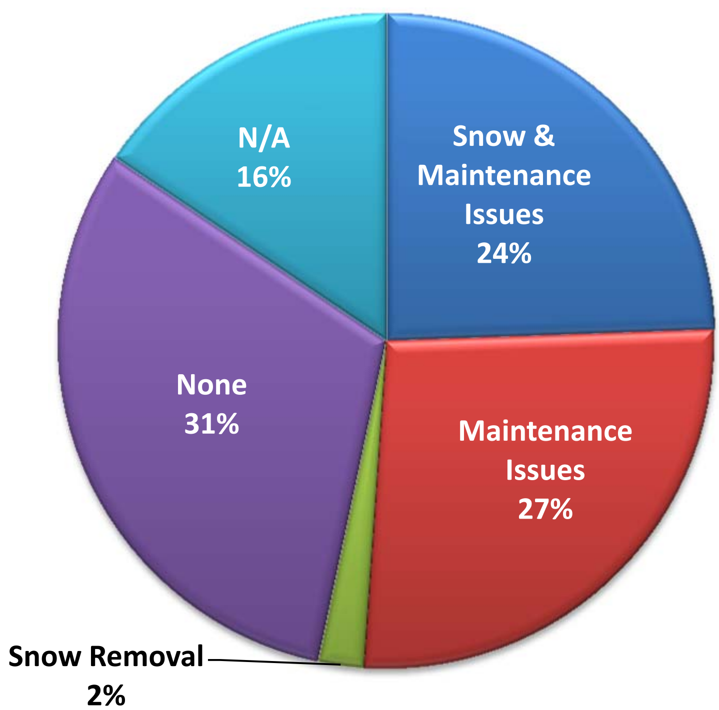


Figure 3-7 Criteria for Installing Roundabouts

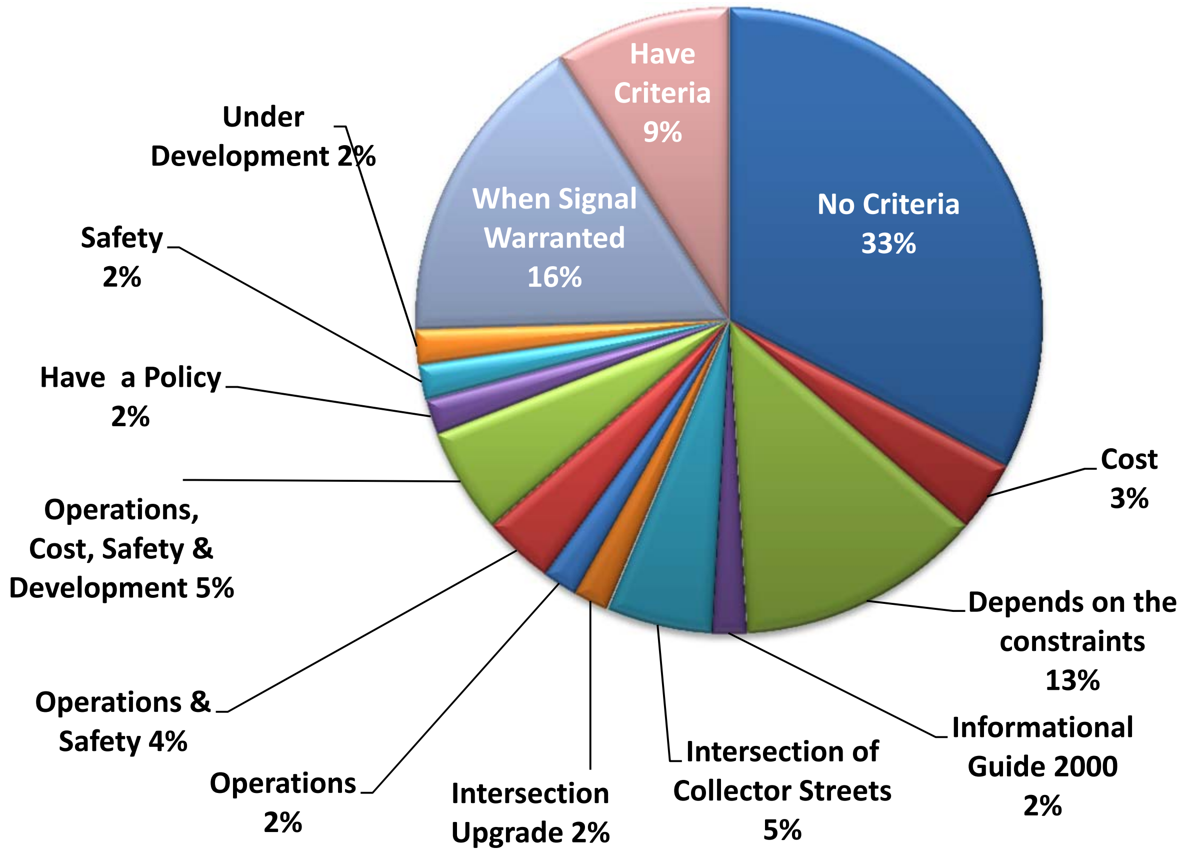
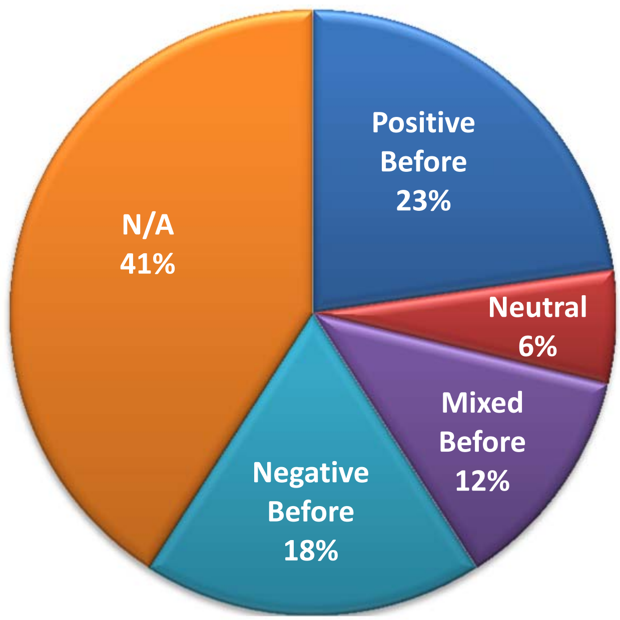


Figure 3-8 Public Acceptance

a) *Before*



b) After

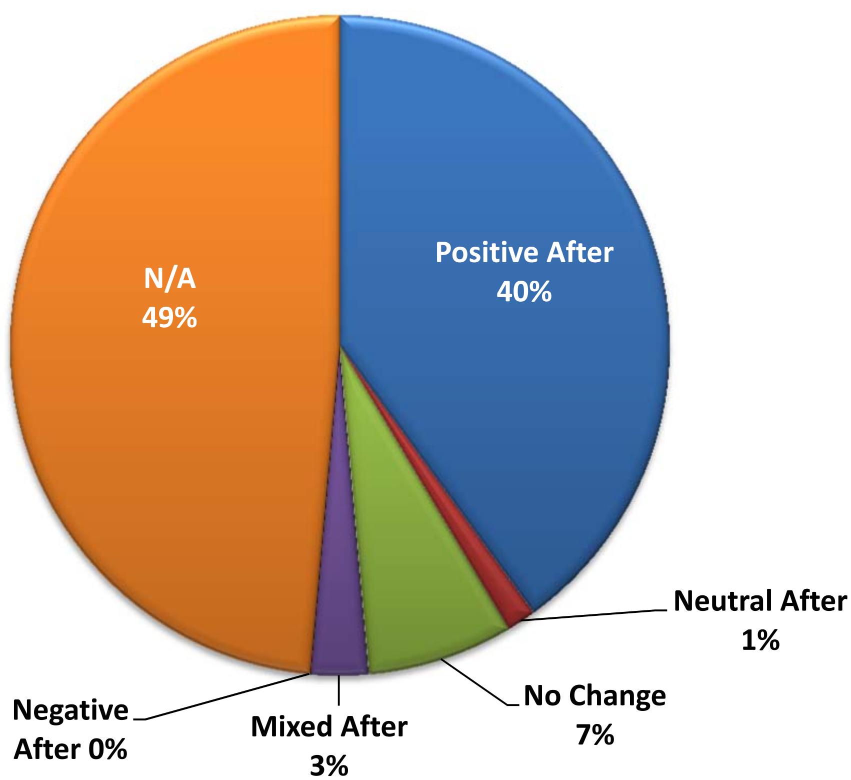
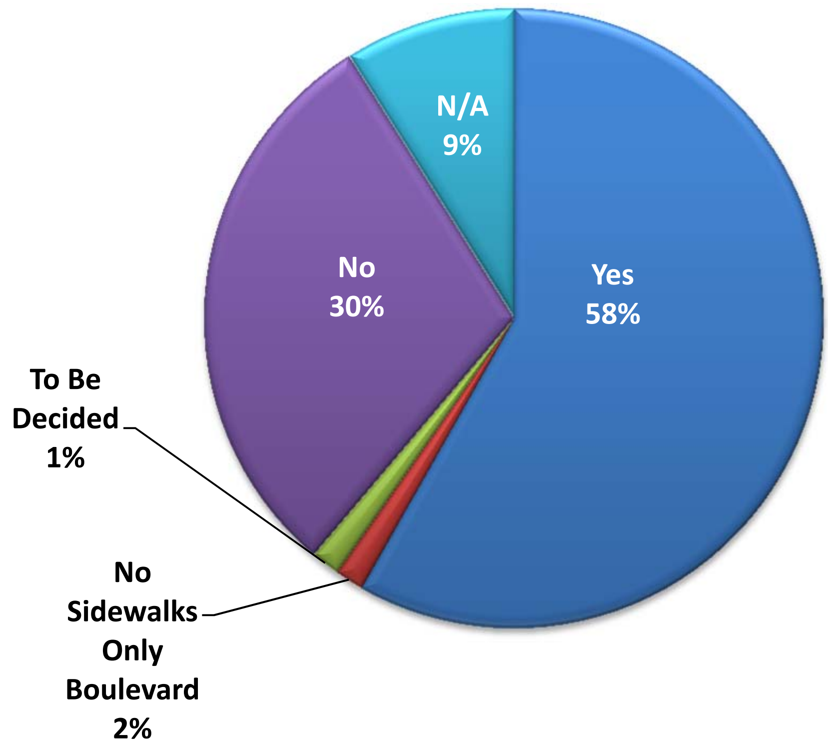


Figure 3-9 Boulevard Between Sidewalk and Vehicle Travel Paths



Summary of Survey Results

An updated database was developed based on final responses and trends. The survey results from the "Traffic Operational Characteristics" questions had a large percentage of no responses. The significant trends were as follows:

- A large proportion of roundabouts were upgrades of existing intersections rather than new roundabouts;
- In the majority of cases, the reason for installing a roundabout was operational and/or safety concerns, with a smaller proportion due to complex intersection geometry;
- The majority of roundabouts were in urban areas and had low speed approaches (less than 80 km/h);
- While truck aprons were provided on a majority of the roundabouts, right-turn slip lanes were not that common;
- The majority of respondents reported the design vehicle as a WB-20 tractor-trailer;
- A substantial majority of roundabouts had marked crosswalks for pedestrian accommodation but not separate bike paths;
- Very few of the responses mentioned any specific provisions for accessibility. However, subsequent follow-ups established various strategies used in various jurisdictions in Canada; and
- Snow removal was reported as a significant problem, as was heavy vehicle access for maintenance purposes;

- There were some reports of damage to roundabouts by trucks;
- Very few of the respondents had a formal policy in place for considering roundabouts. However, informally, some jurisdictions are considering roundabouts whenever a traffic signal control is warranted, and at least one considers roundabouts for any new collector level intersection. Some reported that formal policies were in process that would consider roundabouts first whenever traffic signal control was warranted; and
- A significant finding was that public opinion was consistently positive after installation of roundabouts. There were some complaints from users on main roads who had to slow down after the installation of roundabouts while, at the same time, the minor road users of the same intersections liked it because they had less delay. Overall, there was decidedly positive public response to roundabouts.

3.3 ROUNDABOUT IMPLEMENTATION POLICIES

Roundabout policies that are implemented in various Canadian jurisdictions have similar traits as to the implementation and design characteristics. A call for information was completed and many representatives from various Canadian jurisdictions responded with valuable policy information. Policy information received is summarized below.

Provincial Policies

Alberta

1. Roundabouts shall be considered as the first option for intersection designs where, in the exclusive judgment of the department, a greater degree of traffic control than a two-way stop is required on a paved roadway e.g. a signalization or all-way stop control. If a different intersection treatment is recommended, the project documentation should include a reason why a roundabout was not selected for that location. Roadway design, capacity analysis and traffic engineering with respect to roundabouts shall be carried out.
2. Roundabouts shall be considered on all roadways including high speed (70 km/h or greater) corridors. Roundabouts may be considered for intersections with interchange ramps.
3. Locations where roundabouts may be favoured:

    a) Where there is a need for traffic calming such as at the boundary between urban and rural environments, in low speed urban environments, between high speed and lower speed roadways and/or between divided highways and undivided highway (such as interchange ramp terminals).

    b) Where there is a desire to provide a corridor with a series of consistent intersection layouts (all roundabouts) such as at all interchange terminals along a route or at all at-grade intersections along an arterial roadway. This type of corridor is frequently used in Europe especially for arterial roadways by-passing urban centres.

4. Locations where the department would not wish to use roundabouts. This list is intended to save unnecessary analysis and debate:

    a) Existing freeways.

    b) Divided highways which are identified as "future freeways" unless the use of a roundabout for an interim stage is compatible with the staging plan.

    c) National highway core routes where the posted speed is expected to be at least 90 km/h unless the roundabout with lower speed is considered compatible with a staged plan. For example, in a low speed urban environment where the ultimate plan is to bypass the urban centre.

d) Where the preservation of a high speed through highway is both highly desirable and feasible.

e) Where geometric conditions are unsuitable, e.g. where gradients on the through alignments or approaches are unacceptably steep.

5. The timing of roundabout installation may be triggered by:

   a) The need to provide a higher degree of traffic control than a "two-way stop control".
   b) A clear economic benefit based on safety and other considerations under current traffic conditions.
   c) Implementation of a traffic calming measure based on sound engineering judgment.

6. If an intersection warrants a signal or an all-way stop control within 10 years of the proposed project, the modern roundabout shall be evaluated. Where there is an existing all-way stop control or signalized intersection and there are operational and safety problems with the current traffic control, then the roundabout shall be considered.
7. If a capacity analysis shows a heavy right-turn volume and a Level of Service (LOS) analysis shows the LOS will be lower than D for this segment of the roundabout, a right-turn channelized turning roadway may be considered. Other special circumstances may also be considered to warrant a separate right turning roadway.
8. There is no change in Access Management Guidelines as a result of using a roundabout.

British Columbia

1. Roundabouts shall be considered as the first option for intersection design where all-way stop control or traffic signals are supported by traffic analysis. If an intersection treatment other than a roundabout is recommended, the project documentation should include a reason why a roundabout solution was not selected for that location. The “roundabout first" policy supports the province's Climate Action Program of 2007.
2. Roundabouts shall be considered on all roadways including intersections at interchange ramps.
3. All roundabout designs must be reviewed by the Chief Engineer's Office for provincial consistency. The review starts at the Conceptual Design stage allowing for HQ engineering input prior to any roundabout drawings being developed.

Newfoundland and Labrador

1. The Province of Newfoundland and Labrador has no roundabout policy or research reports conducted by the provincial jurisdiction related to roundabouts.

Ontario

1. For planning and geometric design of roundabouts on provincial highways Ontario uses the FHWA “Roundabouts: An Informational Guide” (2000) along with Appendix A – MTO Design Exceptions, Appendix B – MTO Glossary of Terms, and Appendix C – MTO Roundabout Categories.

Saskatchewan

1. The Ministry of Highways and Infrastructure in Saskatchewan currently does not have any policies or research on roundabouts.

Municipal Policies

Calgary

1. The City of Calgary will use roundabouts as the preferred option of traffic control on arterials and collectors in greenfield areas where a new intersection is planned that warrants or may warrant a future traffic signal or all-way stop.
2. In existing developed areas, a roundabout should be examined where a traffic control upgrade is warranted, capital improvements are being considered, or safety or capacity issues have been identified. The use of roundabouts in these circumstances will be at the discretion of the General Manager, Transportation.
3. Intersection control evaluations will be conducted to ensure roundabout suitability. If a roundabout is found to be inappropriate, an alternate method of intersection control may be used as justified by the evaluation. The General Manager, Transportation shall be the approving authority for roundabouts.

Halifax

1. Halifax currently has no formal policy in place for roundabouts. They do, however, use the UK Design Standard TD 16/07 as their reference standard for roundabout design. As far as usage of roundabouts, Halifax considers all options available for all situations, including roundabouts for intersection treatments.

Hamilton

1. The conditions which will be considered as preferred locations for roundabout implementation in the City of Hamilton are as follows:

    a) Where capacity or safety problems have been identified at an existing intersection.
    b) Where traffic signals or all-way stops are warranted or expected to be warranted in the near future at existing or proposed intersections. If feasible, implementing properly designed roundabouts rather than all-way stops or traffic signals provides safety, efficiency and environmental benefits for all users.
    c) Where, as part of a larger capital project, suitable intersections are identified as potential sites. There is a potential significant cost savings associated with this Key Roundabout Features option as planned roadway re-construction usually requires removal of existing asphalt, granular material, curbing, sidewalks, etc.
    d) Where, through the development process, new intersections are introduced. The biggest challenge to roundabout installation normally is the land requirement. Development submissions can be approved subject to conditions such as provision of sufficient property to accommodate construction of a roundabout. In most cases there would be no or little cost to the City under this process.

Ottawa

1. The Environmental Advisory Committee recommends that the Transportation Committee and Council direct staff to consider roundabouts:

    a) As part of new development areas or as part of new transportation proposals complemented by a public education program.
    b) As an alternative to traffic control signals at existing intersections complemented by a public education program.

Waterloo

1. The Region of Waterloo has a Roundabout policy states that an Intersection Control Study be conducted when design work is being considered for:

   a) A new intersection on a regional road.
   b) An existing intersection where traffic signals are warranted.
   c) An existing regional road intersection which is programmed for improvements to address an identified safety or capacity problem.
   d) Any other location as determined by regional staff or regional councillors.

ITE Policy

The Institute of Transportation Engineers has a policy that recognizes the safety, operational and sustainability benefits of well-designed roundabouts and recommends the use of roundabouts be considered when intersections are being planned, designed, or modified.

3.4 SELECTED CANADIAN CASE STUDIES

Selected case studies are presented in the following pages to provide decision-makers with examples of actual roundabout installations across Canada. Each case study includes an aerial image or photograph, key design characteristics and technical information. The case studies serve to highlight some of the typical design features and issues related to operations, maintenance and public perception.

1 Abbotsford — BC

Trans Canada Highway / Clearbrook Road

Multi-Lane Roundabout

General

Constructed in 2011 as part of a $21M interchange upgrade, replacing an unsignalized intersection. Right turn slip lanes on three approaches. ICD = 54m, WB20 design. Project included realignment of highway westbound lanes, ramp improvements, 6-lane overpass, signal upgrade to north ramp intersection.

Traffic Operations

Occasional back-ups into the roundabout occur due to approximately 1,500 vehicles per hour on highest volume approach (in 2010), increasing to 2,000 vehicles per hour in 2034 design year, with 2% trucks. Use of overhead guide signs, painted truck gore, spiral circulatory road markings, and marked crosswalks.

Pedestrians / Cyclists

Cyclists travel in-lane or on the separated path. Marked crosswalks with flush let-downs in splitter islands for wheelchair access.

Safety

Pre-installation collision rate of 0.73 collisions / MVE (Million Vehicles Entering).

Maintenance

Extended truck apron provided in central island for maintenance vehicle.

Public Acceptance

Public opinion generally positive.

Other Information

Raspberry statue erected in the central island to celebrate local agriculture. Coloured concrete placed on splitter islands.

2 Abbotsford BC

Trans Canada Highway / McCallum Road

Multi-Lane Roundabout Interchange

General

Two multi-lane roundabouts in a diamond interchange constructed in 2011 to replace a former partial cloverleaf configuration on Highway 1 at McCallum Road. The south roundabout is BC's first six-legged, two-lane roundabout.

Background

The BC Ministry of Transportation & Infrastructure decided to replace the aging interchange due to congestion and safety issues. Detailed traffic analyses led to the conversion of the south ramp terminal to a 6-leg roundabout incorporating a connection from King Street and Hawthorne Avenue. A park and ride lot has been constructed on the southeast side of the south roundabout.

Other Information

The north ramp terminal roundabout is a four-leg design, while the south ramp terminal roundabout is a six-leg design with a northbound channelized right-turn lane and two-lane spiral circulatory road markings to facilitate optimal lane utilization.

3 North Saanich

BC

Highway 17 / McTavish Road

Multi-Lane Roundabout Interchange

General

Double lane diamond roundabout interchange with single lane roundabout access to transit exchange / park-and-ride. Completed in 2011. Installed at a cost of $28M, including the transit exchange and park-and-ride to improve intersection performance on this key link to Victoria International Airport. WB-20 design vehicle.

Traffic Operations

Designed for 2035 horizon for 3,405 peak hour volume. Operational issues included sign clutter, guide sign text not large enough, motorists failing to yield at entry on southbound Lockside approach and motorists entering roundabout in opposing lane due to perception of overhead guide sign on curvilinear approach. Guide sign text / boards were increased, a radar activated Yield Ahead sign placed on the northbound off-ramp approach and delineators placed along yellow line on southbound Lockside.

Pedestrians / Cyclists

Shared with vehicles through circulatory lanes. Separated pathways provided, including pedestrian / cyclist overpass to integrate transit exchange and park-and-ride with RapidBus stop on opposite side of highway. Special markings applied for airport and highway route shield.

Safety

6 PDO in first 6 months since April 2011 opening (an improvement from the "Before" condition).

Public Acceptance

Public perception less favourable immediately after opening (April 2011), but affected by circuitous routes during construction phasing and operational issues stated above, which are being addressed. Public perception expected to become more favourable after design changes. Complaints related to motorists failing to yield and sign issues. Because roundabouts are elevated, difficult to see exits from approaching ramps – must rely on signage. Difficult to process decisions due to proximity of roundabouts to each other. Also lessons learned related to signing.

Other Information

Mostly natural vegetation and boulders; use of coloured treatment for raised islands.

4 Port Moody — BC

David Avenue / Heritage Mountain Boulevard

Single-Lane Roundabout

Photo: City of Port Moody

General

This is a low volume single lane roundabout constructed in 2002 / 2003.

Traffic Operations

Occasional back-ups into the roundabout occur due to congestion at a secondary school access located about 40m away on the north leg.

Pedestrians / Cyclists

A two way bike path is provided on south side of David Avenue and east side of Heritage Mountain Boulevard. The path bypasses the roundabout. Marked crosswalks are provided.

Safety

Insurance Corporation of BC Data – 9 reported incidents in 6 years (1.5 / year) after implementation.

Maintenance

Truck apron may not be cleared of snow regularly. Quiet pavement open graded asphalt was used, which was worn out fairly quickly at intersections along David Avenue.

Public Acceptance

Concern was expressed regarding back-ups from the school access on the north leg. However, general perception was positive, as a similar roundabout project was approved in principle several years after this construction was completed. The public still seems concerned with multi-lane roundabouts.

5 Calgary

26 Avenue SE / Highfield Road SE / Dartmouth Rd SE

Single-Lane Roundabout

AB

General

Double lane roundabout with 25m radius and CPR rail running through the central island. A roundabout was suggested by CPR to: replace an awkward intersection with poor intersection performance and geometry; to complement planned CPR track upgrades; and to accommodate projected traffic increases. Constructed in 2010 for $2.3M. WB-20 design vehicle.

Traffic Operations

10,000 to 12,000 ADT on approach legs, with 4-6% trucks. Complaints related to length of construction, as project was delayed over winter due to weather; complicated signal timing with rail gate operation. Rail tracks installed at incorrect elevation (1½" elevation difference created bump in circulatory lanes between tracks), which required some reconstruction.

Pedestrians / Cyclists

Cyclist share lanes with vehicles.

Safety

Rail gate arms at each approach.

Public Acceptance

Mixed public perception before construction, but it was positive afterwards. Complaints related to motorists failing to yield and sign issues. Roundabout operation and rail gate system operates well. Queues after rail delay clear quickly.

Other Information

Landscaping is mostly natural vegetation. Use of inlaid dyed concrete for truck apron.

6 Sylvan Lake

Highway 20 / Highway 11A

Single-Lane Roundabout

AB

General

This roundabout is located on the east side of the tourist town of Sylvan Lake, west of Red Deer, in a speed transition area. It has a two-lane entry with a dedicated right-turn lane westbound and a channelized right-turn lane northbound.

Background

The roundabout was constructed in 2008 by Alberta Transportation at a cost of $1.0 million to relieve long traffic queues during the summer tourist season. It can be expanded from a single-lane to a two-lane design with minimal throw-away cost by expanding outwards when warranted by traffic growth.

Other Information

Shortly after the roundabout opened a westbound driver lost control of his vehicle and crashed into the central island of the roundabout, destroying a civic feature installed there by the Town of Sylvan Lake.

7 Cold Lake

Highway 55 / Highway 892

Single-Lane Roundabout

AB

Photo: Alberta Transportation

General

A large single-lane roundabout constructed in 2012 on Highway 55 west of Cold Lake, Alberta. It was designed to accommodate very large oil service vehicles for all movements, the largest of which is over 90 metres long.

Background

The intersection was originally under two-way stop control on Highway 892 and experienced a poor collision history. As per Alberta Transportation policy, a roundabout was considered as the first option in upgrading to a greater degree of control. At first the roundabout was to accommodate two specific oil service vehicles for movements to/from the west and north. Several alternatives were developed, including a by-pass of the roundabout in the northwest quadrant. It was decided that the roundabout should accommodate several heavy construction vehicles that can potentially travel anywhere in the Provincial road network. From there, it involved marginal additional cost to ensure the roundabout could accommodate all movements of the largest oil service vehicles currently on the Alberta road network.

Other Information

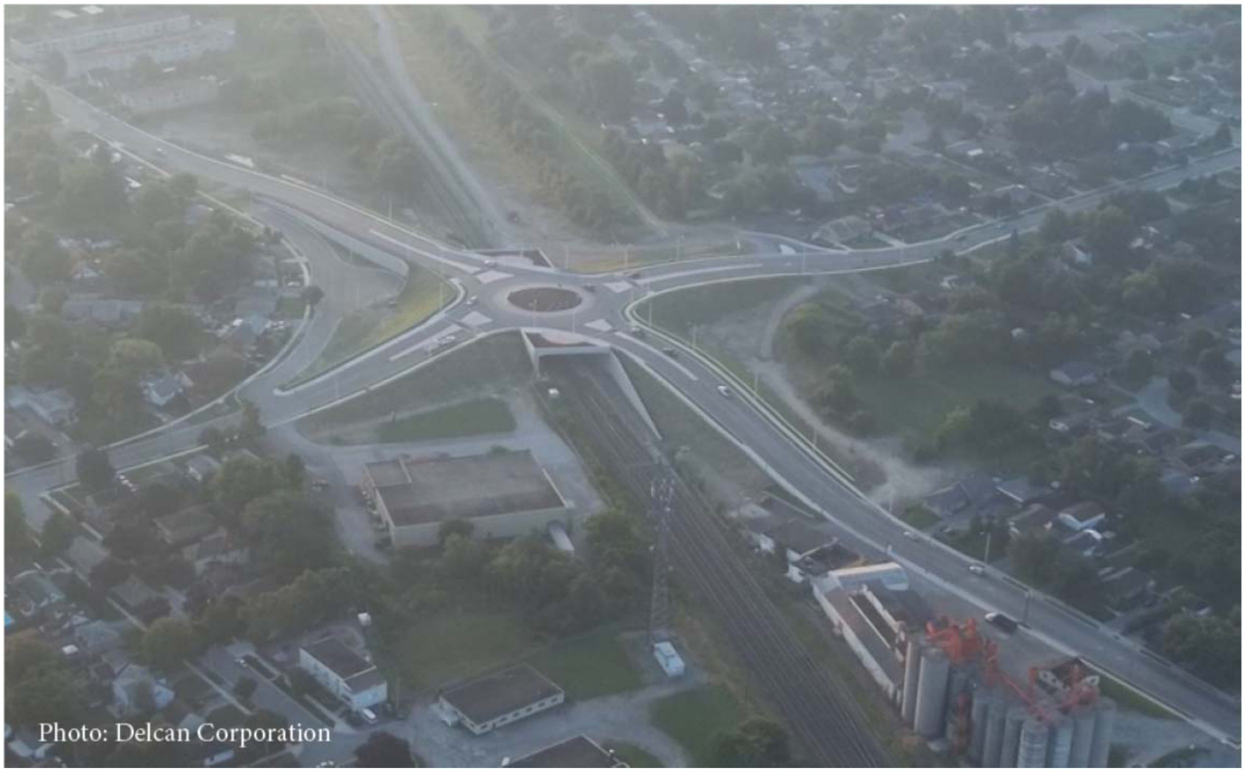
The roundabout has an oversize truck apron around the central island and along the splitter islands. They make the intersection traversable for large platform trailers and other over-dimensional loads. The roundabout also has oversize truck aprons around the outside that allow it to be overrun by multi-platform trailers hauling large oil fields modules. The central island is not traversable, as a prominent central island is important at roundabouts with high-speed rural approaches.

8 London

Trafalgar Road / Hale Road

Single-Lane Roundabout

ON



General

This single-lane roundabout on an overpass replaced two closely-spaced T-intersections split by a CN Rail mainline crossing in the east end of the City of London. The railway line is on one of the most heavily-used corridors in Canada, and is adjacent to a nearby rail-marshalling yard.

Background

Busy conditions along the railway line, along with area traffic growth, had led to increasingly congested conditions at the intersections. The roundabout and overpass was completed in 2010 at a cost of $16 million. This represented a savings of over $4 million compared to a signalized intersection and overpass, which would have required a longer structure because of the need for straight approaches and auxiliary lanes.

Other Information

A memorial to Charley Fox, a local World War II flying ace, was unveiled in the central island of the roundabout shortly after it opened.

9 Waterloo

Ira Needles Boulevard

Multi-Lane Roundabout Corridor

ON

General

A corridor of multi-lane roundabouts along Ira Needles Boulevard, a new arterial road on the west side of the Cities of Kitchener and Waterloo. The first roundabout at Erb Street opened in 2004, while the remainder, at University Avenue, Victoria Street, Highland Road and Highview Drive opened between 2005 and 2007. A sixth roundabout opened in 2011, and others along the corridor are being considered.

Background

A study undertaken early in the planning process by the Region of Waterloo led to the decision to implement roundabouts at all the major intersections along Ira Needles Boulevard, with no traffic signals. Since its construction the corridor has seen considerable commercial development. Transit routes exist in the corridor, and there is now significant pedestrian and cyclist activity at some of the roundabouts.

Other Information

The roundabouts have entries that flare from one lane to two and exits that taper from two lanes back to one. No significant changes to the roundabouts will be necessary when Ira Needles Boulevard is widened from 2 lanes to 4 and the roundabouts have full two-lane entries and exits.

10 St. Jacobs

Arthur Street / Sawmill Road

Multi-Lane Roundabout

ON

General

This multi-lane roundabout east of the tourist village of St. Jacobs was completed in 2006 at a cost of $1.5M by the Region of Waterloo. The intersection handles a high percentage of peak commuter, off-peak tourist and large truck traffic, plus horse-and-buggy traffic from a nearby Mennonite community.

Background

The roundabout is located on a two-lane undivided highway under the jurisdiction of the Region of Waterloo. It represents an extension of provincial Highway 85, a divided freeway running through the Cities of Waterloo and Kitchener. An Intersection Control Study was originally undertaken to compare widening the existing signalized intersection versus implementing a roundabout. A roundabout was selected because of its potential capacity and safety advantages, as well as a lower cost and smaller overall footprint than a widened signalized intersection. The roundabout is an oval shape to address the existing intersection skew.

Traffic Operations

This location experiences high peak-hour commuter traffic volumes. Design changes after construction included lengthening a flare to add capacity and adjusting pavement markings for better lane utilization.

Other Information

Speed studies conducted after the roundabout was opened have confirmed that, although average traffic speeds are over 90 km/h upstream of the intersection on Arthur Street (former Highway 85), they are about 40 km/h through the roundabout.

11 Kitchener (Region of Waterloo) ON

Bridge Street / Lancaster Street

Partial Multi-Lane Roundabout

General

A partial multi-lane roundabout completed in 2009 for $2.5M to reduce peak hour traffic delays and contribute to district revitalization.

Background

The Region of Waterloo decided to make this roundabout the central feature in their revitalization of the Bridgeport district in the City of Kitchener. The historic bridge on the south side of the site was refurbished and several properties were purchased and buildings demolished to make way for the roundabout and an associated park area.

Other Information

The geometric design of the roundabout was a challenge given property constraints, a fixed alignment of the historic bridge, and a major culvert crossing to the north. The result was a compact design with spiral circulatory road markings. The roundabout accommodates a full-size tractor semi-trailer for all movements, and an oversize load for through movements on Bridge Street.

12 **Kitchener** (Region of Waterloo) ON

Homer Watson Boulevard / Block Line Road

Multi-Lane Roundabout

General

A multi-lane roundabout with a three-lane entry southbound, located near a high school on a major arterial road in the Region of Waterloo.

Background

This roundabout was the sixteenth constructed by the Region of Waterloo. The roundabout has a three-lane entry on the north leg in anticipation of a future connection to the east bringing significantly higher traffic volumes through the intersection. Prior to construction the intersection was under traffic signal control and free-flow vehicle speeds averaged over 80 km/h. Concern was expressed about the safety of high school students crossing the north leg, sometimes on red against high-speed traffic.

Other Information

A couple months after opening in August 2011 a high school student walking across the west leg exit of the roundabout was struck by a transit bus. In response the Region of Waterloo designated the right entry lane southbound as a right-turn-only lane, and installed flexible bollards in the downstream section of circulatory road to reduce it to two lanes. Other measures included crossing guards present on the north leg during high school peak periods, larger Yield signs at the entries, enhanced pavement markings, and a reduction in the posted speed limit.

13 Hamilton

ON

Wilson Street / Meadowbrook Drive

Single-Lane Roundabout

Photo: GHD / Ourston Roundabout Engineering

General

This single-lane roundabout is located between the low-speed village of Ancaster and the high-speed approach (posted 80 km/h) from the Highway 403 interchange. It was constructed in 2002 at a cost of $0.65 million.

Although traffic signals were soon to be warranted at the intersection, it was decided to implement a roundabout to control speeds on Wilson Street and act as a gateway to the village. This represented the first application of a roundabout on an arterial road in Ontario.

Other Information

Speed studies conducted before and after the roundabout was opened have shown a reduction in motor vehicle speeds both into and out of downtown Ancaster, at certain locations by as much as 25 km/h.

14 Hamilton

Wilson Street / Shaver Road

Partial Multi-Lane Roundabout

ON

Photo: GHD / Ourston Roundabout Engineering

General

This roundabout acts as a gateway treatment between the Highway 403 interchange and a developing commercial corridor. It was constructed in 2008 at a cost of $1.25 million.

Background

The City of Hamilton's first multi-lane roundabout is located on a high-speed road on the west side of the Wilson Street interchange from the village of Ancaster. The project started in 2004 as an Intersection Control Study to compare a signalized intersection and a roundabout. A roundabout was selected because of its potential capacity and safety advantages at this high-volume intersection.

Other Information

The roundabout is a partial two-lane design. The east-west approaches on Wilson Street have two-lane entries and exits while the north-south approaches have single-lane entries and exits.

15 Hamilton — ON

Stone Church Road West / Omni Boulevard

Single-Lane Roundabout

General

This single-lane roundabout was constructed by the City of Hamilton in 2009 to slow traffic on Stone Church Road and facilitate access from a residential community. The roundabout encroaches on an adjacent environmentally sensitive area.

Background

Traffic signals were not warranted due to low off-peak demand from Omni Boulevard; however, residents requested improved peak-period access at the intersection. Concerns were also raised about high traffic speeds past several residences fronting Stone Church Road east of the intersection. A roundabout was implemented to address both problems.

Other Information

The roundabout accommodates a WB-20 tractor semi-trailer for east-west movements along Stone Church Road and a WB-17 for turning movements. The latter vehicle may represent the occasional “lowboy” trailer contractor vehicle.

16 Picton ON

Highway 13 / County Road 1

Single-Lane Roundabout

General

The first roundabout constructed on a provincial highway in Ontario. This single-lane design west of the tourist town of Picton was completed in 2009 by the Ministry of Transportation Ontario (MTO).

Background

The original intersection was under stop control on County Road 1 and had a 55-degree skew. A number of serious motor vehicle collisions (including 1 fatality) led to a Class Environmental Assessment study in 2005 to examine alternatives to the existing configuration, including offsetting it, realigning it to reduce the skew angle, and introducing traffic signal or roundabout control. The study recommended realigning the intersection to form a 70-degree skew and implementing a roundabout.

Other Information

According to the latest information from the MTO, no crashes have been reported at the intersection since the roundabout opened.

17 North Bay

Gormanville Road / College Drive/ McKeown Avenue

Multi-Lane Roundabout

ON

General

This multi-lane was constructed in 2009 at a cost of $1.0 million. A community college is located on the northwest corner of the intersection, generating significant bus transit and pedestrian activity.

Background

This roundabout is located in the northwest section of the City of North Bay, about 100 metres from the Trans-Canada Highway (Highway 17). It was selected over a signalized intersection because of less potential for queue spillback between it and the nearby signalized intersection at the highway.

Other Information

The roundabout is a multi-lane design with spiral circulatory road markings to facilitate heavy left-turn movements from consecutive approaches.

Trees planted on approach from interchange to limit sight distances and, indirectly, to decrease approach speeds.

18 Ottawa — ON

Boulevard Jeanne D'Arc / Boulevard St. Joseph

Multi-Lane Roundabout

General

A two-lane roundabout constructed in 2011 by the City of Ottawa at a major intersection in the community of Orleans. It accommodates a peak hour service volume of 3,600 vehicles.

Background

The idea of a roundabout was originally suggested as a means of enhancing the streetscape and contributing to the revitalization of the downtown Orleans area. The roundabout has a compact footprint due to a number of property and utility constraints at the intersection.

Other Information

The roundabout is a two-lane design with channelized right-turn lanes eastbound and westbound. The right-turn lanes are yield-controlled rather than free-flow. Although this type of right-turn treatment has less vehicle capacity, it makes the roundabout more compact and creates better conditions for pedestrians.

19 Gatineau QC

Boulevard des Allumettières / Rue Demontigny

Multi-Lane Roundabout Corridor

Photo: GHD / Ourston Roundabout Engineering

General

A corridor of 3 multi-lane roundabouts along Boulevard des Allumettières, linking Autoroute 50 with the west side of the City of Gatineau. The roundabouts are at Rue Labelle, Rue Demontigny and Boulevard Saint Joseph. A fourth roundabout is to the south on Boulevard Saint Joseph at Rue Montcalm. The roundabouts are unique in Canada in that the east leg of each has pedestrian-activated traffic signals.

Background

This location experiences a moderate volume of pedestrians. The pedestrian-activated signals were installed when the roundabouts were constructed out of concerns with access for pedestrians with vision loss. The signals rest on green for motor vehicle traffic, and change to amber and then red upon activation.

There are regulatory pedestrian crosswalk signs, and auxiliary signal heads are in place at driver eye height so that drivers do not have to stop well back of the pedestrian crosswalks to see the signals. Standard pedestrian signals let pedestrians know when drivers have a red signal indication. The entry and exit have separate sets of signals, which accommodate shorter cycle lengths. The pedestrian refuge in the splitter island is staggered to separate the audible signals and provide more vehicle storage on the exit side, as drivers are exiting the roundabout.

Other Information

The remaining legs of each roundabout feature overhead regulatory pedestrian crosswalk signs, supplemented with full-time amber flashers.

20 Montréal

Rue Notre-Dame / Rue Sherbrook

Multi-Lane Roundabout

QC

General

A two-lane roundabout with channelized right-turn lanes eastbound and westbound, constructed in 2006 on the east side of the island of Montréal.

Background

The City of Montréal decided to replace an aging grade-separated intersection on the island of Montréal with a roundabout. Rue Notre-Dame is a busy commuter corridor that links the east side of the island to the mainland via le Pont de Gardeur. The westbound lanes overpass Rue Sherbrooke. The desire was to reconnect the north and south sides of the intersection to pedestrian traffic, and provide a greener and more inviting public realm for all users. A feasibility study established that a roundabout could provide similar traffic capacity, but with a much more compact and urban footprint.

Other Information

Initially a four-leg roundabout was contemplated to split the heavy traffic volumes from Rue Notre-Dame westbound. A three-leg roundabout with two channelized right-turn lanes was ultimately designed and constructed to eliminate the need for a 3-lane entry and provide a simpler and more compact design.

21 Halifax

Armdale Roundabout

Multi-Lane Roundabout

NS

General

A retrofit of the former Armdale Rotary, originally constructed in the 1970s at a key five-leg intersection in the southern Halifax peninsula (Chebucto Road, Quinpool Road, Herring Cove Road, St. Margaret's Bay Road, and Joseph Howe Drive).

Background

Originally the rotary operated on a "courtesy" rule where entering and circulating drivers exchanged priority. In 2008 a combination of geometric, signing and marking changes were applied by the Halifax Regional Municipality to resolve congestion and safety deficiencies, and convert the rotary to modern roundabout operation. The project cost $2.9 million. More extensive geometric modifications would have been desirable to reduce the size of the roundabout and maximize safety, but they were not possible given the tight urban conditions and area road network impacts.

Pedestrians / Cyclists

Cyclists travel in-lane or with pedestrians. There are moderate pedestrian volumes at the intersection, and bus stops are present on several entries or exits.

Other Information

The roundabout accommodates a peak hour service volume of over 5,300 vehicles.

It has two three-lane entries, two-lane spiral circulatory road markings, and a lane reversal system at one exit.

22 Halifax

Larry Uteck Boulevard (Highway 102 Interchange / Nine Mile Drive / Starboard Drive)

Multi-Lane Roundabout Interchange / Corridor

NS

General

A corridor of 3 multi-lane roundabouts constructed as part of a new diamond interchange along Highway 102 north of Halifax. Two roundabouts at the ramp terminals were completed in 2010; the third, at Nine Mile Drive / Starboard Drive, was completed in 2011. This roundabout interchange was one of several constructed by the Nova Scotia Department of Transportation and Infrastructure Renewal as part of reconstruction and widening projects along Highway 102 and Highway 104 from 2010 to 2012.

Background

An initial traffic study concluded that, compared to signalized intersections, roundabouts at the ramp terminals would result in lower peak and off-peak delays for drivers, and realize significant construction cost savings due to fewer lanes across the overpass structure (4 lanes as opposed to 8).

Further investigation concluded that a single five-leg roundabout would be less costly than two closely-spaced four-leg roundabouts at the west ramp terminal and nearby service road. In total, the 3 roundabouts were estimated to have a construction cost savings of over $3 million compared to four signalized intersections.

Other Information

The east ramp terminal roundabout has two channelized right-turn lanes and spiral circulatory road markings. The west ramp terminal roundabout is a five-leg design with a three-lane entry and spiral circulatory road markings. It was designed to accommodate a peak hour service volume of 4,800 vehicles.

3.5 A CANADIAN MUNICIPAL EXPERIENCE INTRODUCING ROUNDABOUTS: VERNON, BC

Vernon is a medium sized city with a population of 38,150. It is the commercial hub of the North Okanagan, providing employment, shopping and leisure facilities to the surrounding rural communities. Nestled in grassland hills and surrounded by three lakes, Vernon boasts year round recreation opportunities that make it an attractive location for residents and tourists alike. Until 2005, all intersections were 2, 3 or all-way stops or had traffic signals. Being unfamiliar with roundabouts as a method of intersection control, the level of public resistance met staff's expectations. The experience of the first two roundabouts built and the lessons learned are described below.

30 Avenue at 35 Street – 2005	32 Avenue at Pleasant Valley Road – 2009
Description	
Proposed to replace a stop-controlled intersection, surrounded by seniors' housing. On one corner was the highly popular Schubert Seniors Centre. It was designed to address the above-average number of injury accidents in the area of a type that would be addressed by a roundabout.	As part of an underground utility upgrade project, the crash data of the all-way stop at the intersection of 32 Avenue with Pleasant Valley Road was reviewed and found to have an above average number of injury accidents of a type that could be addressed by a roundabout. In addition, it was experiencing excessive congestion in peak periods.
Municipal Staff Outreach to the Community	
With the assistance of the Insurance Corporation of British Columbia (ICBC), a pamphlet was produced explaining roundabout control and how to use one. Municipal staff held open house sessions in the adjacent seniors centre with a three dimensional representation of the roundabout scaled to suit toy cars. This enabled people to "drive" a toy car around it to see when and where to yield. Due to the high level of concern for senior pedestrians using the roundabout, two crosswalks had pedestrian activated signals installed.	Again in collaboration with ICBC, a pamphlet was produced that was widely distributed to residential properties and many other public buildings. Links to instructional driving videos were placed on the municipal website. Public open house sessions were held, but these were largely attended by the residents who lived on the streets due to be reconstructed as part of the simultaneous capital sewer replacement project.
Public Reaction	
The general public, in particular nearby seniors, were strongly opposed to it. The general perception was that roundabouts wouldn't work in Canada, let alone Vernon. Objectors considered it would cause more crashes than it would prevent. It was their opinion that that traffic signals would have greater capacity, be safer for vehicles and suited to winter snow and ice conditions.	Despite the crash reduction and efficient traffic flow without peak period congestion being demonstrated daily at the first roundabout, this was still perceived to be the least desirable method for controlling traffic. Its location in the middle of an established heritage residential area lead to large numbers of people feeling they were going to be unacceptably affected by it. The timing of this project was unfortunate as it was just before a municipal election and the intersection became one of the election

30 Avenue at 35 Street – 2005	32 Avenue at Pleasant Valley Road – 2009
	issues. Council discussed the advantages and disadvantages of roundabouts and traffic signals at this location. Another important factor was that ICBC would contribute no funding towards traffic signals at this location but would contribute a significant Road Improvement Program grant towards a roundabout. Council evaluated the information and passed a resolution to support the construction of the roundabout.

Current Public Perception

Eight years after the construction of the first roundabout, the public's anticipated problems have not manifested at either location, delivering a reduction in collisions and removed all traffic congestion from the 32 Avenue intersection. The vocal opposition has, in the light of the success of the roundabouts, recanted and requests for roundabouts to be built at other intersections are increasing every year.

Lessons Learned

If possible, showcase examples of roundabouts in nearby communities and publicize any grant funding that has been obtained, demonstrating that other road safety agencies fully support and are prepared to contribute funds to such projects.

Do not underestimate the resistance to change and the importance of consultation, education and community involvement required to implement projects that include elements new to that community.

Finally, read Dan Burden's "My Toughest Challenge"[13] about a design charrette in Clearwater, Florida, into demands for the removal of a recently constructed roundabout, when what was needed were some minor alterations. As Dan Burden summarizes, this roundabout had become the lightning rod of change for this community that was being faced with its future; growth was a certainty and he hoped that, through public engagement events like this one, even the most fearful and angry would realize that they, like this intersection, must change.

[13] Dan Burden, My Toughest Challenge…Clearwater Roundabout Charette, Walkable Communities, July 28, 2000.

3.6 CURRENT CANADIAN RESEARCH, STUDIES

Research Reports and Studies

There have been several research reports completed by Canadian jurisdictions regarding the benefits of using roundabouts as an alternative to a conventional four-legged intersection. Several of the research reports and their summary are outlined below.

Synthesis of North American Roundabout Practice (TAC, 2008)

This synthesis was developed by TAC and features current practices and experiences with roundabouts. It forms an expanded counterpart to National Cooperative Highway Research Program (NCHRP) Synthesis 264, “Modern Roundabout Practice in the United States”, published in 1998. The TAC synthesis provides a review of literature, research and case studies, and is supplemented with selected international experience. An outline of responses from a web-based survey of public road agencies in Canada and the United States on roundabout planning, design and operating practices is included, and resulting conclusions and best practices are summarized.

Tools for Estimating the Safety and Operational Impacts of Roundabouts (TC, 2010)

The conversion from a stop or signal controlled intersection to a roundabout has major cost implications. To assist in the decision making, a research project jointly funded by Transport Canada and the Ministry of Transportation, Ontario, was undertaken to develop a formalized warrant process to assess the cost-effectiveness of a contemplated roundabout, with the aim of producing results that could be referenced nationally.

Chapter 5 of the Synthesis of North American Roundabout Practice (TAC, 2006)

In 2006, a "Synthesis of North American Roundabout Practice" was developed through TAC. The synthesis consisted of a literature review of roundabout guides and current practice, research and case studies, supplemented with selected experience in other countries where appropriate. The synthesis determined that roundabouts are usually constructed the safety, capacity, or environmental benefits. Currently the main reason for constructing roundabouts in North America is improved intersection safety. The document explains why roundabouts have such a high potential for safety. It discusses the studies undertaken in North America, and in other countries where North American data is insufficient, to evaluate the effects of roundabouts on the safety of motorists, pedestrians and bicyclists. Finally, it describes what measures can be taken in the design of roundabouts to maximize their safety potential.

Modern Roundabouts, Global Warming, and Emissions Reductions: Status of Research, and Opportunities for North America (Author, Date?)

This document provides literature on roundabouts and pollution emissions; describes the Australian intersection model and the lack of a comparable U.S. model; reviews applications of the Australian model to U.S. intersections; and concludes by evaluating the impact of installing roundabouts in the City of Burlington, Vermont, as a strategy to implement its plan for global warming gas reduction to below 1990 levels.

Study of the Environmental, Economic, Safety & Social Benefits of Roundabouts – Transport Canada (TC, 2009)

Roundabouts have environmental, economic and social benefits in addition to those of safety. This report addresses the various impacts of roundabouts through literature review and brief telephone interviews with transportation practitioners in Canadian and U.S. jurisdictions. Knowledge gaps are identified and policy recommendations are made.

Accommodating Commercial and Over Dimensional Vehicles at Roundabouts (TAC, 2010)

This paper builds upon one submitted for the 2009 conference that discussed “small” users (pedestrians and cyclists) and “large” users (trucks) of roundabouts. It covers the topic of large commercial vehicles at roundabouts in more detail. Several horizontal design treatments exist to accommodate large commercial vehicles at roundabouts. This paper examines the use of widened entries and exits, partially traversable truck aprons, gated pass-throughs, and right-turn by-pass lanes. This paper discusses whether to allow for trucks to over track adjacent lanes in a roundabout and whether to install lane lines in the circulatory road.

Comparative Evaluation of Roundabout’s Operational Performance (Author, Date?)

Currently, roundabouts are gaining popularity in different Canadian cities, where they are being constructed in increasing numbers as an alternative to stop control or traffic signal. However, many Canadian jurisdictions find it difficult to establish the feasibility of roundabouts given the lack of information on driver behaviour at roundabouts compared to other types of intersections in Canada. To address this gap, this study was conducted to compare vehicular delay as an operational performance measure on three types of intersections and to evaluate driver speed and deceleration behaviour when approaching a roundabout under Canadian driving conditions. Video recording and automatic traffic counters / classifiers were used to collect speed, traffic volume, and delay data on three main intersection types used in residential areas in the City of Ottawa: (1) roundabout, (2) all-way stop control, and (3) signal control. It was found that the roundabout produced less delay compared to all-way stop sign and signal controlled intersections. In addition, drivers were more comfortable and aware of their environment, as demonstrated by the speed reduction as drivers proceed into and through the roundabout. These findings represent a first step towards calibrating the warrants for using a roundabout based on Canadian conditions and examining the feasibility of upgrading a stop-controlled intersection to a roundabout or a roundabout to a signalized intersection.

Capital Cost Analysis of Nova Scotia Roundabout Program to 2010

This paper addresses the historical context of roundabouts in Nova Scotia and discusses, in brief, the evolution from the merge on entry design philosophy of the 1950s through to legislative changes of 2005 that resulted in yield on entry operation. The change in legislation and philosophy led to the introduction of fourteen roundabouts in the first five years since their introduction in Nova Scotia.

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APPENDIX A

Additional Pedestrian Information

It is recognized that there are challenges in providing roundabout features that offer an adequate level of safety for pedestrians with vision impairment. The US National Cooperative Highway Research Program (NCHRP) has released a comprehensive report identifying potential crossing solutions at roundabouts to address crossing issues associated with people with vision loss (Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities, NCHRP Report 674, 2011, 152 pages,

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_674.pdf)

The NCHRP report identifies the four principal tasks that need to be mastered for a visually-impaired pedestrian to cross a road:

1. Finding the crosswalk and identifying the intended crossing location at an unknown intersection;
2. Aligning to cross to establish a correct initial heading at a crosswalk that may or may not be aligned perpendicular with the sidewalk;
3. Deciding when to cross in an environment of largely uninterrupted traffic flow requiring the identification of appropriate gaps in traffic or crossing opportunities in front of yielding vehicles; and,
4. Maintaining alignment while crossing multiple lanes over the length of the entire crosswalk until the far side of the roadway is reached.

The Canadian National Institute for the Blind (CNIB) has summarized their recommendations for design components at roundabouts in a report (*Clearing Our Path – Universal Design Recommendations for People with Vision Loss, 2009*), including the use of Tactile Walking Surface Indicators (TWSIs). The document details various types of TWSIs, with the “Guidance TWSI” being the equivalent of the truncated-dome detectible warnings that have been used in the United States since 2001 to meet American with Disabilities Act requirements. The CNIB document also supports pedestrian crossings being 20 – 30 metres in advance of the roundabout.

The CNIB published a document relating to pedestrian signals (*Position on Accessible Pedestrian Signals*), which should be reviewed when considering any pedestrian crossing:

http://www.cnib.ca/en/about/who/believe/Documents/CNIB%20APS%20position.doc)

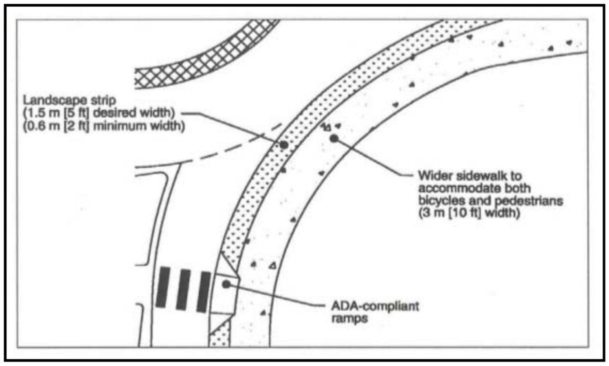
Mitigation Options

To enable a person with vision loss to cross the road at a roundabout, the following can be implemented:

1. Finding the crosswalk

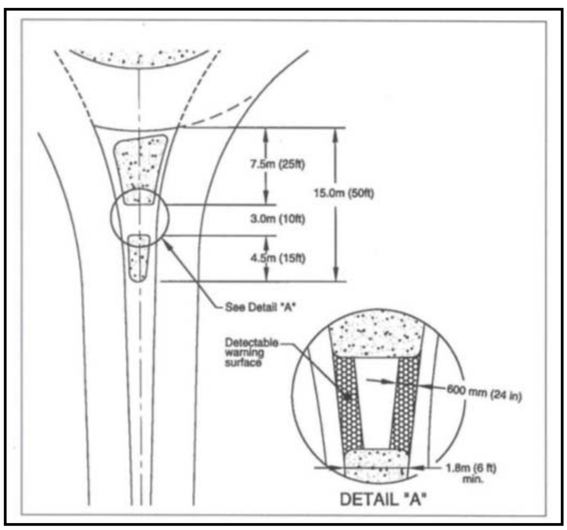
   Physically channel users to the crosswalks by installing curbside landscaping and providing perpendicular alignment, such as planted boulevards leading up the crosswalk. Pedestrians with low or medium vision loss can identify different areas if they have a strong colour contrast and blind users can identify different areas by their texture. Crosswalks can be further identified by the use of ramps and zebra stripe pavement markings. Various types of detectable warning surfaces have been used across Canada although they are not required through legislation.

The US FHWA Informational Guide identifies pedestrian convenience, pedestrian safety and vehicular operations in the roundabout as some of the primary factors warranting consideration in locating pedestrian crossing treatments. A typical example is shown in **Figure A-1**. The minimum splitter island dimensions for a single lane roundabout are shown in **Figure A-2**. The splitter island provides pedestrian refuge during a crossing movement, helps channelize approaching traffic, impedes wrong-way movements, and separates the directional streams of traffic. As shown in the figure, the recommended minimum offset from the yield line to the beginning of the crossing location is identified as 7.5 metres.



"Roundabouts: An Informational Guide", FHWA-RD-00-67, June 2000

Figure A-1 Roundabout Sidewalk Treatment



"Roundabouts: An Informational Guide", FHWA-RD-00-67, June 2000

Figure A-2 Recommended Splitter Island Dimensions

High-contrast markings and pedestrian routes that are well-lit at night will be useful to pedestrians who use residual vision to travel, and are the larger proportion of pedestrians who have vision impairment. Municipal and/or provincial regulations dictate lighting levels required for pedestrian crossings, which will also enhance pedestrian visibility to drivers.

2. Aligning to the crosswalk

If the crosswalk and the central splitter island are not ramped, curbed, or equipped with detectable surface warnings or signs, they will not be identified by a pedestrian with vision loss.

As the crosswalks are often positioned where the curb is curve, the use of ramp score lines or truncated dome detectable warning surface can be laid such that people with vision loss can establish the direction of travel they must take to cross that portion of the road. The user can feel either the score lines or the line of the truncated domes, indicating the direction they need to travel. This does require the score lines and warning surface are laid accurately to ensure the user sets out in the correct direction.

3. Identifying a crossing opportunity

While some roundabout crossings have signals at the pedestrian crossings, this is not a common design practice across Canada. However, without signals it can be difficult to be sure that an approaching car has stopped, especially on multi-lane crossings where cars may have only stopped in the near lane and continue to travel across the crosswalk in the far lane.

When crossing the exit leg of the roundabout, it is difficult for the pedestrian to ascertain if the approaching vehicle is going to travel across the pedestrian crosswalk or continue around the roundabout. As vehicles within the roundabout are on a circular travel lane and not moving in a straight line, the approaching speed can be more difficult to determine.

At unsignalized crosswalks this opportunity is created by large gaps in the traffic or a yielding driver. Maintaining slow vehicle speeds by keeping travel lane widths narrower or the crosswalk raised increases yielding. Depending upon the size and location of the roundabout, people with vision impairment may have difficulty differentiating the sound of approaching traffic vehicles from those in the roundabout. Landscaping in the splitter island, designed not to block the driver's view of pedestrians, has been found to help with this differentiation.

Sound or rumble strips will have the least amount of impact for driver and will give an audible clue to people with vision loss of approaching vehicles. Due to uniform spacing of the strips, the pedestrian will be able to judge if the vehicle is decelerating to a stop, maintaining a constant speed or accelerating to the crosswalk. The application of these treatments on more than one leg of the roundabout would increase the negative and positive attributes linearly as the audible clues at two different crosswalk locations may become confusing to discern. However, some recent studies have found that the devices weren't generating the desired sound warning effect and didn't significantly increase the numbers of vehicles yielding. Research is continuing into more automated yield and gap detection methods.

At a multi-lane approach with an increase in the number of crossing lanes, there are lower available gaps and yield rates by drivers, and possibly higher vehicle speeds. To reduce crossing distance and provide more vehicle storage, two vehicle-length storage between the circulatory lane and the crosswalk could be considered. This distance gives some benefits to pedestrian with vision impairment from increased crosswalk spacing away from the roundabout, i.e., crossing alignment can be more perpendicular to the lane and approach simultaneously.

4. Maintaining alignment during crossing

If the alignment of the crosswalk remains unchanged across the full width of the road the curbs in the splitter island can be laid to match the crosswalk alignment.

A detectable warning surface can be laid such that the pedestrian can establish the direction in which he/she needs to travel. This does require that the warning surface is cut and laid accurately on both sides and in the splitter island and not simply perpendicular to the curb as this will misdirect the user. This is extremely useful when the alignment of the crosswalk changes at the splitter island.

In a multi-lane approach, the splitter island design should provide pedestrians a two-stage crossing due to the relatively reduced opportunity to obtain an acceptable gap (more traffic or longer crossing time); a wider crosswalk width and more space with protection / detection facility may be needed. Should a high number of pedestrians need to be accommodated on the splitter island, the crosswalks can be staggered to create space.

Sample photos of the implementation of tactile walking surface indicators are provided below.

City of Pitt Meadows

Figure A-3 TWSI Installed to Provide Directionality Across Crosswalk

City of Pitt Meadows

Figure A-4 TWSI Installed at Signalized Intersection Pedestrian Crosswalk

Vancouver Ramp Detail

The City of Vancouver has adopted the use of score lines in ramps to lead pedestrians across and in line with the crosswalk as per the details shown at the end of this appendix. Comments on the use of this system include:

Pros

- Provides directionality
- Ease of construction

Cons

- Scores may fill up with snow or other debris
- Not easily detected under foot
- Do not necessarily indicate to a pedestrian that they are at a crossing ("not detectable in the sidewalk and roadway environment because of the similarities to other surface textures and defects", FHWA Memorandum HIPA-20, May 6, 2002)
- Score lines may be confused with expansion or contraction joints in concrete sidewalks near the crosswalk location
- Not supported by CNIB

City of Courtenay

Figure A-5 Score Lines Near the Crosswalk Location

District of Summerland

Figure A-6 Score Lines Near the Crosswalk Location

Other jurisdictions, and as required for all hazardous vehicular ways, transit platform edges, and curb ramps in the United States under the Americans with Disability Act (ADA) requirements, use truncated domes[14].

USA

The truncated domes come in tiles made of precast concrete, recycled rubber, cast iron or even as studs that can be installed into existing paving.

Pros

- Provides directionality if laid properly
- Easily detected under foot
- Meets current FHWA / ADA requirements
- Can provide a visual cue (for people without total vision loss) due to use of contrasting colors

Cons

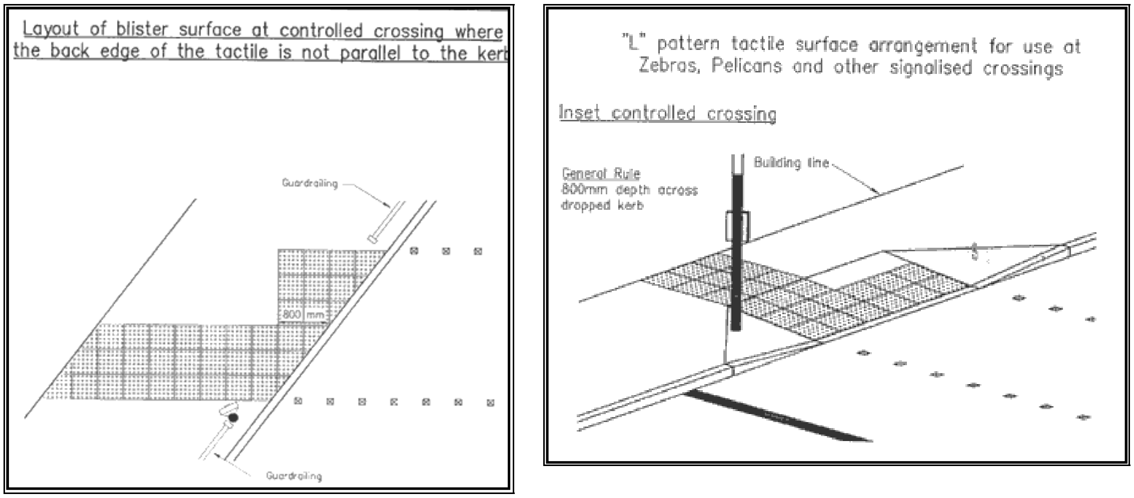
- Does not provide directionality when simply laid perpendicular to the curb
- Domes can be subject to damage from snow clearing equipment

UK Tactile Paving Surfaces

A UK Department for Transport document covers the use of tactile paving surfaces, known as truncated domes in North America. Tactile paving, in different forms, provides a surface for people with vision impairment to feel using their feet, or to a limited degree with their canes, informing them of crosswalk locations and other hazards. At crosswalks the paving oreintation informs the pedestrian of the presence of a crosswalk and, by its ‘T’ or ‘L’ shape, whether it is signalized or not. It is laid across the full width of the sidewalk to ensure all pedestrians notice it. See **Figure A-7**. The tactile surface next to the curb is cut and laid at an angle matching the direction the crosswalk takes over the road. This is particularly useful at roundabouts, intersections with non-standard geometry, or in cases where the crosswalk direction changes in the central / splitter island.

When used at a signalized crosswalk, it is laid out in an `L` shape, again with the stalk across the full width of the sidewalk and the bar directing pedestrians to one side to access the signal push button.

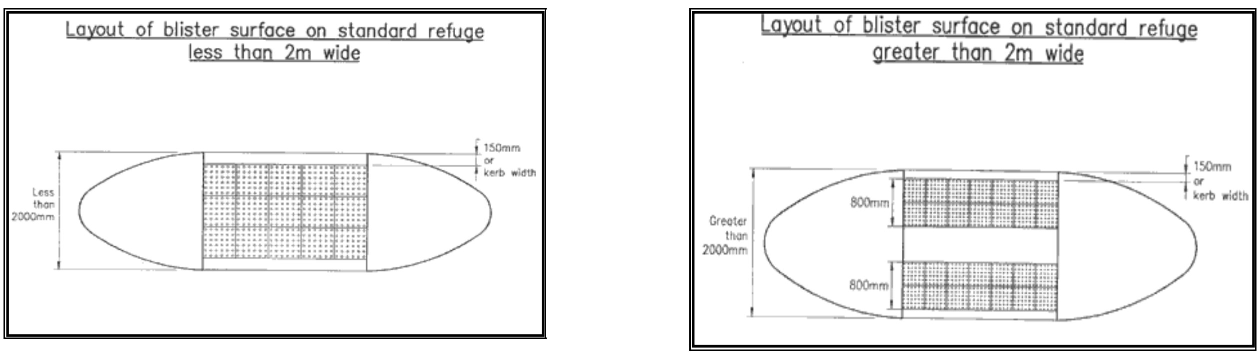
[14] *“Detectable warnings were required in 1991 by the Americans with Disabilities Act Accessible Guideline (ADAAG) (regulatory standards) for hazardous vehicular ways, transit platform edges, and curb ramps”, FHWA Memorandum HIPA-20, May 6, 2002.*



UK Department for Transport Guidance on the Use of Tactile Paving Surfaces

Figure A-7 Examples of Tactile Paving Surfaces

The tactile paving in the central splitter island is also laid out such that the user can determine whether it is above or below 2m in width and whether the next crosswalk is on a different angle to the first **(Figure A-8)**.



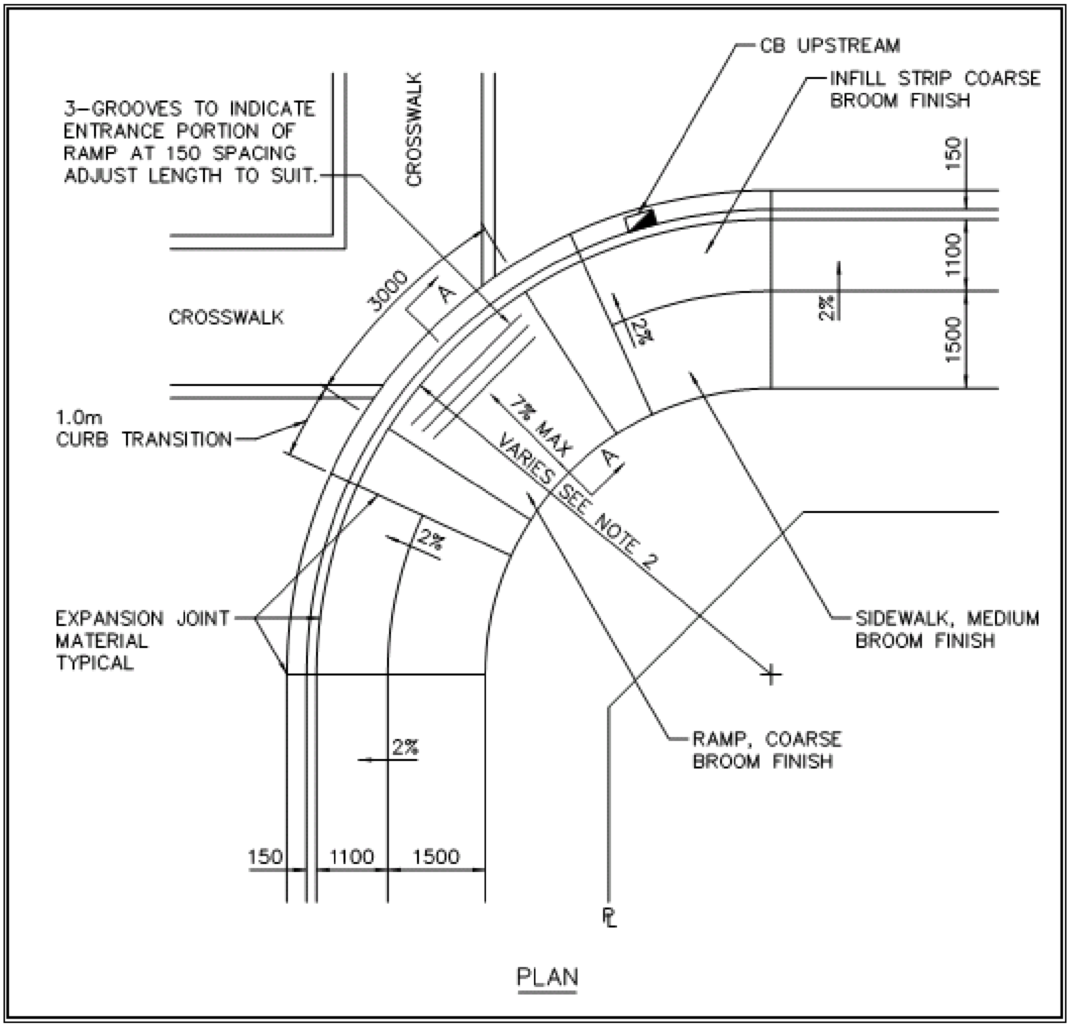
UK Department for Transport Guidance on the Use of Tactile Paving Surfaces

Figure A-8 Tactile Paving in the Central Splitter Island

Other Canadian Practices

Municipalities and provincial road authorities across Canada reported a wide range of measures that have been implemented at roundabout pedestrian crossings to accommmodate people with vision loss. The summary of these treatments include:

- Score lines in concrete parallel to the pedestrain crosswalks direction of travel;
- Score lines in concrete parallel to the curb line at the sidewalk/road interface (refer to excerpt below from Master Municipal Construction Documents, Platimun Edition, Volume II, Printed 2009, Standard Detail Drawing C8, www.mmcd.net);
- Tactile walking surface indicators; and,
- No treatment for grandfathered roundabouts.



Master Municipal Construction Documents, Platimun Edition, Volume II, Printed 2009, Standard Detail Drawing

Figure A-9 Score Lines

Summary

The safety benefits of roundabouts for vehicle and pedestrian traffic are considerable and, because of this, they will continue to be constructed across Canada. A road authority may apply established pedestrian traffic signal warrants that utilize pedestrian / vehicle volume thresholds to decide whether pedestrian crossings should be signalized at or near a roundabout.

Until specific standards are adopted, engineers and jurisdictions must rely on existing related research and professional judgment to design pedestrian features so that they are usable by pedestrians with disabilities. Possible design remedies for the difficulties faced by pedestrians include tight entries, crosswalks raised on a traffic calming table with detectable warnings, treatments for people with vision impairment to locate crosswalks, raised pavement markers with pedestrian activated yellow flashing warning lights to alert drivers to crossing pedestrians, pedestrian crossings with actuated signals set sufficiently upstream of the yield line..

Individual provincial guidelines provide for road authority direction on the type of crosswalk to be implemented. These guidelines are based on available gap calculations and, therefore, take into consideration physical limitations, traffic volumes, pedestrian volumens and pedestrian age / walking speed.

Finally, introducing a training program would be helpful for people with vision loss to cross safely at roundabouts. In the United States, it was reported that there are some experts who have successfully trained people with vision loss to use pedestrian crossings at roundabouts.

CURB RAMP DESIGN STANDARDS

GENERAL CONSIDERATIONS

Curb ramps are designed for the access of wheelchairs (they also accommodate scooters, strollers and people with poor mobility).
Ramps should land wheelchair users safely in the crosswalk and in the desired direction of travel.
The preferred design is to install 2 ramps per corner with directional score lines wherever possible.
The scoring pattern is designed to assist people with visual impairments.

- Directional score lines shall guide someone safely into the crosswalk, lining up with the ramp across the street and be parallel with the crossing or marked crosswalk.

DOUBLE CURB RAMP DESIGN (Preferred)

- The ramp and the directional score lines shall lead into the crosswalk, lining up with the ramp across the street and be parallel with the crossing or marked crosswalk.
- Where a greener treatment is desired grass can be installed between the two ramps where there is a reasonable expectation that the adjacent property owner will mow the additional grass.
- Minimum 1 meter full curb between the two ramps.

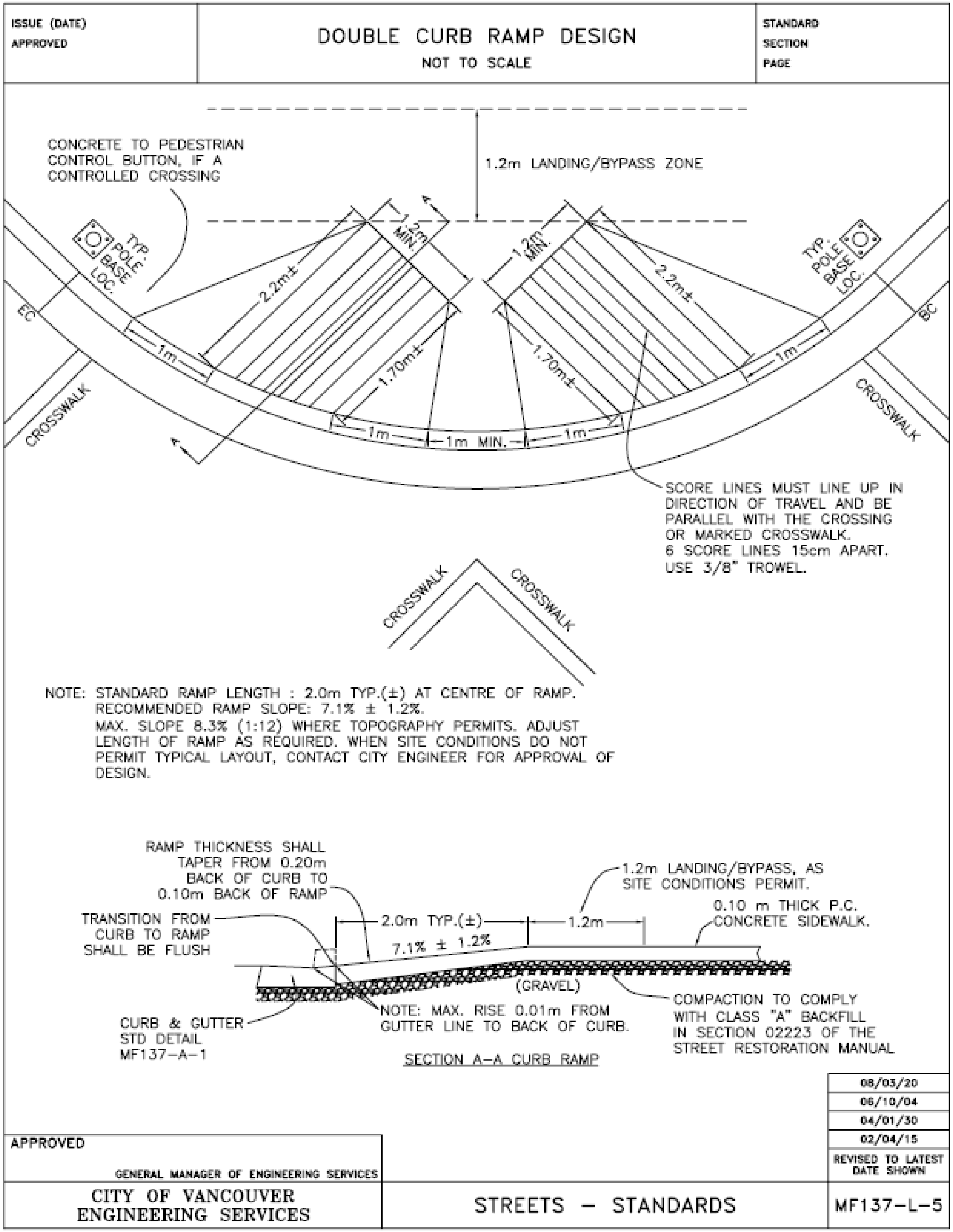
LARGE SINGLE CURB RAMP DESIGN (Alternative)

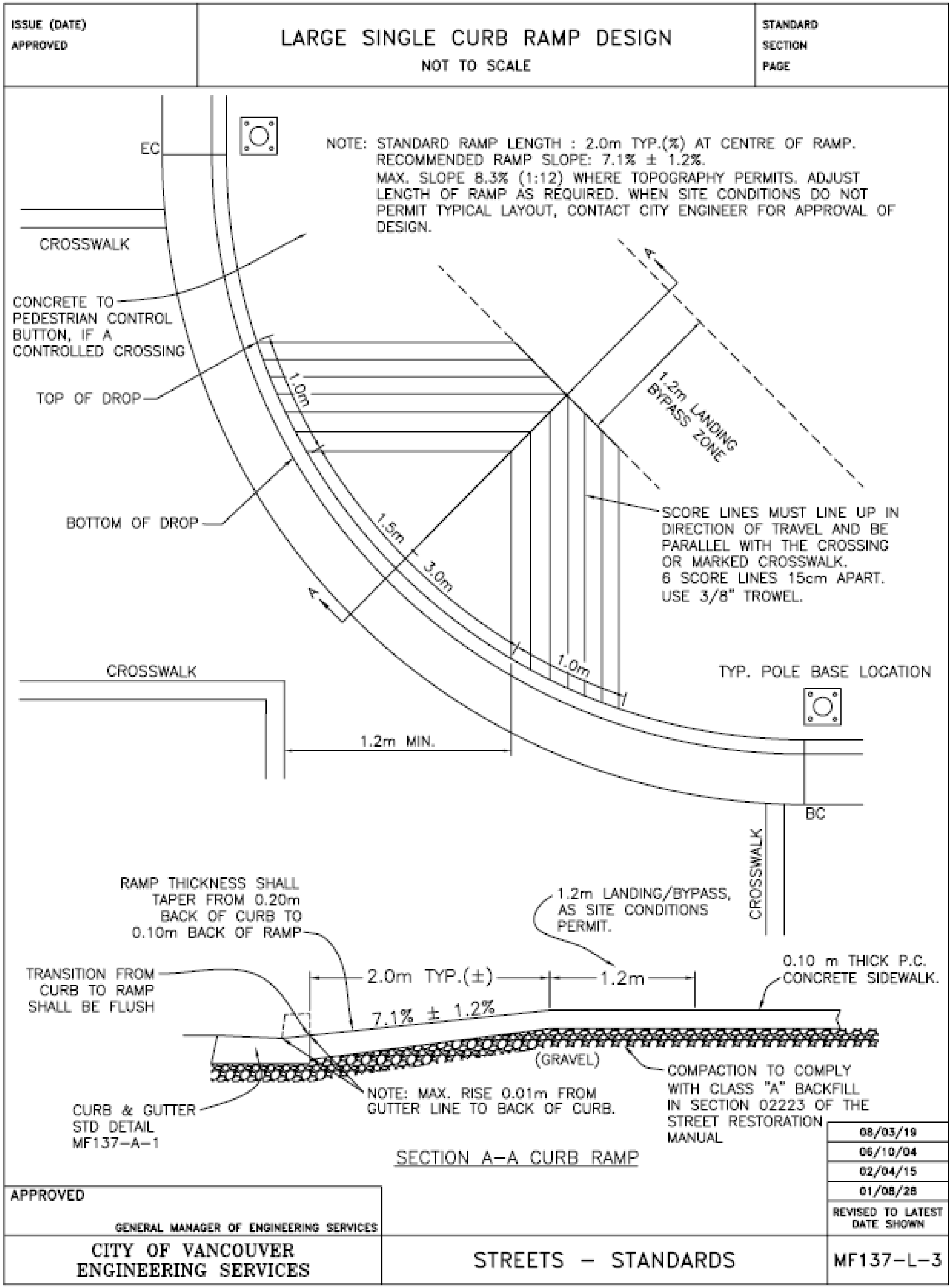
- Used when double curb ramps cannot be accommodated due to obstructions such as poles, utility boxes, property lines, etc. that would result in less than 1 meter full curb between the two ramps.
- The ramp must adequately land a pedestrian in either crosswalk.
- Directional score lines shall lead the user over the curb and into the crosswalk, lining up with the ramp across the street and be parallel with the crossing or marked crosswalk.

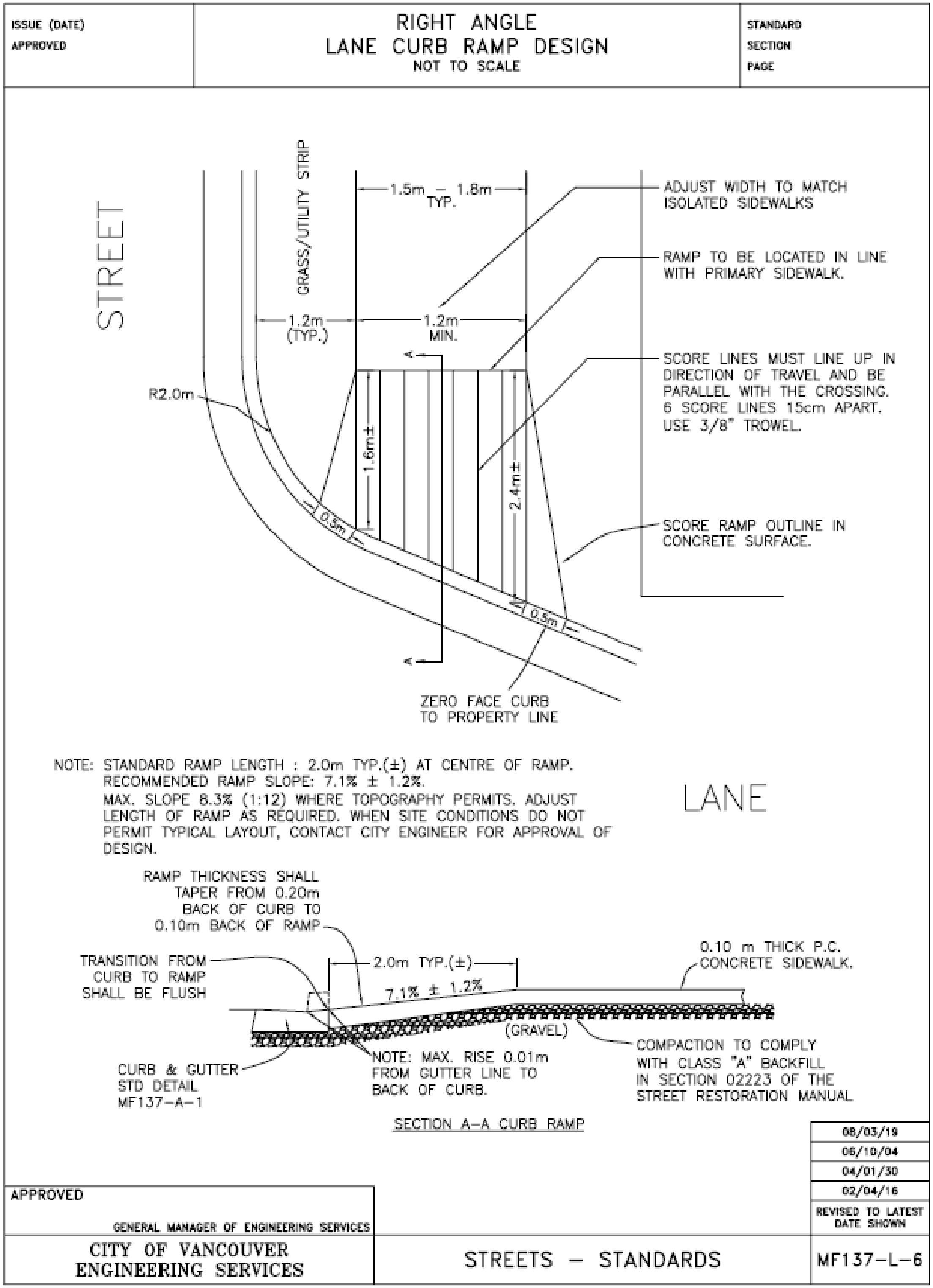
LANE CURB RAMP DESIGN

- Used at lane intersections. However, consideration can be given to running the sidewalk through the lane (this would generally be a crossing as opposed to a raised sidewalk).
- The ramp and the directional score lines shall line up with the ramp across the lane and be parallel with the crossing.
- In residential areas, the flares may be installed in grass to match the boulevard treatment.

In the event that none of these designs can be implemented please contact the Project Coordinator in Streets Design or Eileen Curran (604.871.6131) in Streets.


ISSUE (DATE)
APPROVED
DOUBLE CURB RAMP DESIGN
NOT TO SCALE
STANDARD
SECTION
PAGE
CONCRETE TO PEDESTRIAN CONTROL BUTTON, IF A CONTROLLED CROSSING
1.2m LANDING/BYPASS ZONE
TYP. POLE BASE LOC.
1.2m MIN.
2.2m±
1.70m±
1m
1m MIN.
EC
BC
CROSSWALK
SCORE LINES MUST LINE UP IN DIRECTION OF TRAVEL AND BE PARALLEL WITH THE CROSSING OR MARKED CROSSWALK.
6 SCORE LINES 15cm APART.
USE 3/8" TROWEL.
NOTE: STANDARD RAMP LENGTH : 2.0m TYP.(±) AT CENTRE OF RAMP.
RECOMMENDED RAMP SLOPE: 7.1% ± 1.2%.
MAX. SLOPE 8.3% (1:12) WHERE TOPOGRAPHY PERMITS. ADJUST LENGTH OF RAMP AS REQUIRED. WHEN SITE CONDITIONS DO NOT PERMIT TYPICAL LAYOUT, CONTACT CITY ENGINEER FOR APPROVAL OF DESIGN.
RAMP THICKNESS SHALL TAPER FROM 0.20m BACK OF CURB TO 0.10m BACK OF RAMP
TRANSITION FROM CURB TO RAMP SHALL BE FLUSH
1.2m LANDING/BYPASS, AS SITE CONDITIONS PERMIT.
0.10 m THICK P.C. CONCRETE SIDEWALK.
2.0m TYP.(±)
1.2m
7.1% ± 1.2%
(GRAVEL)
CURB & GUTTER STD DETAIL MF137-A-1
NOTE: MAX. RISE 0.01m FROM GUTTER LINE TO BACK OF CURB.
COMPACTION TO COMPLY WITH CLASS "A" BACKFILL IN SECTION 02223 OF THE STREET RESTORATION MANUAL
SECTION A-A CURB RAMP
08/03/20
06/10/04
04/01/30
02/04/15
REVISED TO LATEST DATE SHOWN
APPROVED
GENERAL MANAGER OF ENGINEERING SERVICES
CITY OF VANCOUVER ENGINEERING SERVICES
STREETS – STANDARDS
MF137-L-5


ISSUE (DATE)
APPROVED
LARGE SINGLE CURB RAMP DESIGN
NOT TO SCALE
STANDARD
SECTION
PAGE
NOTE: STANDARD RAMP LENGTH : 2.0m TYP.(±) AT CENTRE OF RAMP. RECOMMENDED RAMP SLOPE: 7.1% ± 1.2%. MAX. SLOPE 8.3% (1:12) WHERE TOPOGRAPHY PERMITS. ADJUST LENGTH OF RAMP AS REQUIRED. WHEN SITE CONDITIONS DO NOT PERMIT TYPICAL LAYOUT, CONTACT CITY ENGINEER FOR APPROVAL OF DESIGN.
EC
CROSSWALK
CONCRETE TO PEDESTRIAN CONTROL BUTTON, IF A CONTROLLED CROSSING
TOP OF DROP
1.0m
1.2m LANDING BYPASS ZONE
BOTTOM OF DROP
1.5m
3.0m
SCORE LINES MUST LINE UP IN DIRECTION OF TRAVEL AND BE PARALLEL WITH THE CROSSING OR MARKED CROSSWALK. 6 SCORE LINES 15cm APART. USE 3/8" TROWEL.
CROSSWALK
1.0m
TYP. POLE BASE LOCATION
1.2m MIN.
BC
CROSSWALK
RAMP THICKNESS SHALL TAPER FROM 0.20m BACK OF CURB TO 0.10m BACK OF RAMP
1.2m LANDING/BYPASS, AS SITE CONDITIONS PERMIT.
TRANSITION FROM CURB TO RAMP SHALL BE FLUSH
2.0m TYP.(±)
1.2m
0.10 m THICK P.C. CONCRETE SIDEWALK.
7.1% ± 1.2%
(GRAVEL)
COMPACTION TO COMPLY WITH CLASS "A" BACKFILL IN SECTION 02223 OF THE STREET RESTORATION MANUAL
NOTE: MAX. RISE 0.01m FROM GUTTER LINE TO BACK OF CURB.
CURB & GUTTER STD DETAIL MF137–A–1
SECTION A–A CURB RAMP
08/03/19
06/10/04
02/04/15
01/08/28
REVISED TO LATEST DATE SHOWN
APPROVED
GENERAL MANAGER OF ENGINEERING SERVICES
CITY OF VANCOUVER ENGINEERING SERVICES
STREETS – STANDARDS
MF137–L–3



City of Vancouver

Figure A-10 Curb Ramp Design Standards

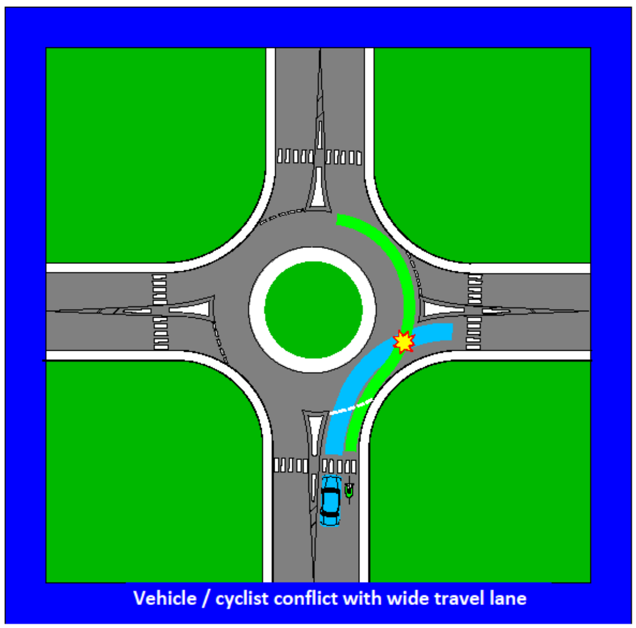
APPENDIX B

Accommodating Cyclists

Roundabouts and Cyclists – The Lessons Learned in Europe

Roundabouts have been constructed since 1905 in Europe, the UK, Australia and New Zealand. British roundabouts have a good accident record overall. However, bicycle accident rates at roundabouts were found to be 14 times those for cars. In continental Europe, designs reflect their use on more lightly travelled roads; for traffic calming purposes and to improve conditions for the generally higher numbers of cyclists on the local road network.

The diagram below shows the conflict point between cyclists and vehicles with a wide lane that allows them to travel side by side. This geometry is the cause of the above average injuries for cyclists at roundabouts in the UK. To address this, the European Roundabout Design that does not provide enough room for vehicles to pass cyclists has been adopted.



Source: A Watson, City of Vernon

Figure B-1 Point of Conflict With Cyclist on Outer Edge of Travel Lane

Summary of Key Features of Roundabouts of a Continental Design

- Arms that are radial / perpendicular to the roundabout centre (rather than tangential).
- A circulatory carriageway width of between 5m and 7m.
- An external (inscribed circle) diameter of between 25m and 35m.
- Overrun areas in the centre of the roundabout (sloped if possible), to accommodate larger vehicles.
- Single lane entry and exits.
- Minimal flare on entry and substantial deflections.

The most common accident type for cyclists at roundabouts involves a motor vehicle entering the roundabout and colliding with a cyclist on the circulatory travel lanes. This often occurs because the driver does not see or register the presence of the cyclist. Drivers tend to concentrate on detecting more frequent and major conflicts at the expense of smaller, less common conflicts such as those involving cyclists. This may explain why cycle accident rates tend to decrease with increased bicycle flows at roundabouts, and also suggests that a modified geometry that increases the prominence of cyclists may be of value.

Other accident types comprising a significant minority of bicycle accidents at roundabouts are rear-enders, and a motor vehicle exiting the intersection collides with a cycle continuing on the circulatory travel lane.

Various treatments have been retrofitted to existing roundabouts as seen below.

Nottinghamshire County Council Cycling Design Guide 2006

(NOTE: Clockwise vehicle direction)

Figure B-2 Heworth Green, York, UK

In an attempt to highlight the presence of cyclists in the roundabout the cycle lanes were painted around the outer edge of the roundabout combined with signs to warn drivers of bike presence. On the approach to each exit, lanes split in two so it is more clear whether cyclists are turning off or continuing around the roundabout.

Nottinghamshire County Council Cycling Design Guide

(NOTE: Clockwise vehicle direction)

Figure B-3 Heworth Green, York, UK

Nottinghamshire County Council Cycling Design Guide

(NOTE: Clockwise vehicle direction)

Figure B-4 Painted Outer Lane for Cycles in Victoria Embankment, Nottingham, UK, and Sign to Highlight Cyclist Presence.

Source: Fiestberaad Online Knowledge Bank (Dutch Cycling Embassy)

Figure B-5 Lelystad, Museumweg, Netherlands, Bicycle Roundabout

Local authorities in Lelystad constructed a “bicycle roundabout” at Bataviastad in October 2006. On this particular roundabout, the red asphalt lane for cyclists is not located on the outside, but in the middle of the road. This location is a pilot project that is still under evaluation. No separate bike paths have been constructed on this roundabout, as space would not allow it. The advantage of a bicycle lane in the middle of the roundabout is that bicycles and mopeds avoid the blind spots of trucks. Car drivers, too, have a better view of cyclists. Local authorities have observed actual practices a number of times. Cyclists have no issues with these operating conditions; however, they can no longer enter the roundabout conflict-free.

Results of Treatments

A study of 210 roundabouts in the Netherlands by Schoon and Van Minnen, 1994, found that roundabouts with a circulatory bicycle lane were not safer for cyclists. It is suggested by some that circulatory bicycle lanes actually place cyclists directly into the area of the roundabout where they are most at threat from vehicles either entering or leaving the roundabout. Therefore, care needs to be applied when circulatory bicycle lanes are considered. However, there were found to be a number of measures that could be taken to make both existing and proposed roundabouts safer for cyclists.

If Not on the Roundabout, Then Where?

Large multi-lane roundabouts can be extremely daunting for cyclists as there are many opportunities for conflict with traffic and they require cyclists to be fast, alert and confident of their abilities to accelerate out of conflict. In contrast, the recommended standard for Dutch roundabouts is for a physically separated circular bicycle track running around the outside of the main circulatory travel lane. The track is separated from the rest of the roundabout by about 5m (this distance will need increasing to 7.5m considering larger Canadian vehicles), allowing space for a single car to stop without blocking the passage of bikes.

Clearly marked pedestrian crossings usually run alongside the bike tracks, making both more visible. These crossings have traffic islands to make crossing easier and are raised onto a flat top speed hump, starting 5m before the crossing itself, to make them more obvious to cars. Larger two lane roundabouts generally have two entry lanes per leg of the roundabout, but only a single exit lane, increasing the visibility of bikes and pedestrians using the crossings. Some roundabouts, known as 'turbo roundabouts' have spiral lane markings removing the necessity for cars to change lanes as they negotiate it. There are raised markers between the lanes to prevent corner cutting, giving drivers fewer distractions as they exit the roundabout. Most bicycle tracks are one-way, running in the same direction as the rest of the traffic on the roundabout, but some busy roundabouts have two-way lanes which can increase conflicts and accidents. In one such case, warning lights alert motorists to the presence of bikes. More traffic islands have also been used to mitigate these conflicts. On the whole, roundabouts have been found to be much safer than traditional four-leg intersections, and separated tracks safer than lanes on the roundabout itself.

Shared space roundabouts, such as the one in Drachten, Netherlands, also have a bicycle track around the outside, giving bikes right of way over drivers entering or exiting. The main difference is that there is no marked lane separating bikes from pedestrians, fewer warning signs, no traffic islands, and the bike track is less clearly distinguished from the carriageway (a flush paved area rather than raised red asphalt), in line with the shared space principle of minimum regulation. Despite this, a study found that 95% of bikes using the roundabout were able to proceed without stopping as drivers mostly gave way to them. It was also shown to be safer than the intersection which preceded it, but perception by people using it was that it was less safe although they did feel that it had improved the area and traffic flow through the junction.

Should Cyclists have Priority Over Vehicles?

Roundabout design varies enormously in the Netherlands, as do priority regulations. Outside the urban area, cyclists do not have priority on roundabouts; within the urban area, various regulations exist. A rough estimate reveals that within the urban area there are between 600 and 800 roundabouts with separate bicycle paths, 60% of which have cyclist priority.

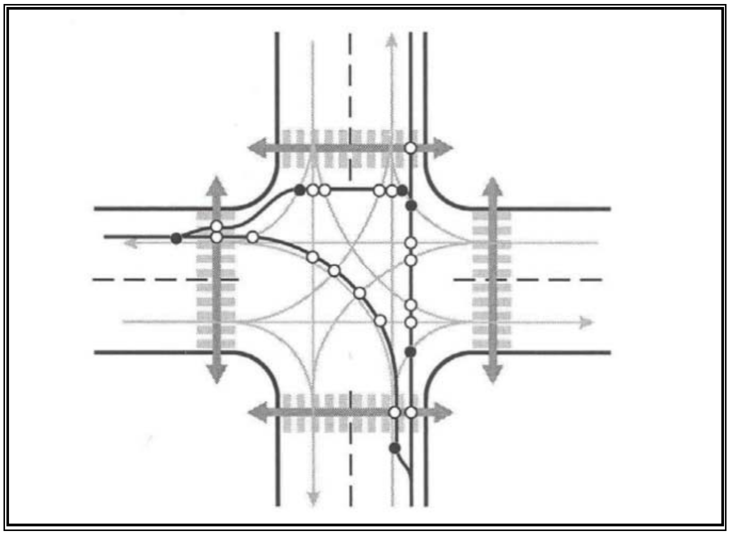
Sitichting Wetenshappelijk Onderzoek Verkeersveiligheid (SWOV, translated into English is the Netherland Institute for Road Safety Research) studied the effects of a uniform priority regulation on all these roundabouts in the Netherlands: priority or no priority for cyclists. It appears that on roundabouts "with cyclist priority", there are more accidents between motor vehicles and cyclists than on roundabouts "without cyclist priority".

The reasons are unclear. Based on its analysis, SWOV concluded that roundabouts without cyclist priority are safer, but could not decide why this should be. The accident statistics do not shed any light on the difference.

There are two possible explanations. The first possibility is that motorists wrongly assume they have priority over cyclists. This assumption may be partly due to the lack of any uniform priority regulation in the urban area in the Netherlands. The second possibility is that motorists have to make so many observations in such a short space of time when entering and leaving a roundabout that they fail to see cyclists. Behaviour studies should provide more insight into this. Overall the final recommendation was not to provide cyclist priority in roundabouts.

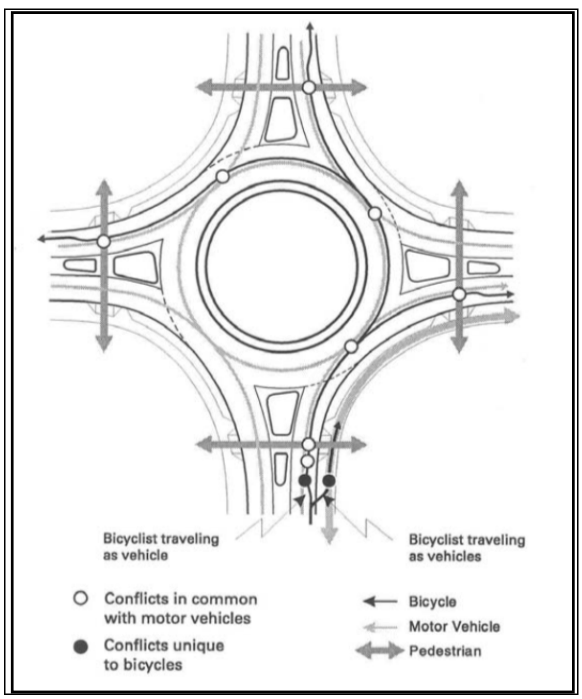
Benefits of Roundabouts for Cyclists

The major benefit of a roundabout for cyclists either travelling as a vehicle or using a shared pedestrian / bicycle route is the reduced number of conflict points (see **Figures B-7** and **B-8**).



"Roundabouts: An Informational Guide", FHWA-RD-00-67, June 2000

Figure B-7 Bicycle Conflicts at a Conventional Intersection



"Roundabouts: An Informational Guide", FHWA-RD-00-67, June 2000

Figure B-8 Bicycle Conflicts at a Roundabout

Key Design Features for Cyclist Safety

- Reducing the width of the circulatory travel lane so bicycles are in the same travel lane as all vehicles;
- Increasing the deflection on entry and limiting the number of arms;
- Reducing entry speeds of traffic with traffic calming features on the approaches if necessary;
- Providing signs to raise driver awareness of the presence of cyclists in the roundabout;
- Providing alternative bike routes to avoid the roundabout completely if considered appropriate;
- Providing a shared use facility for pedestrians and cyclist around the edge of the roundabout if the roundabout has more than one circulatory travel lane and/or flows on the circulatory carriageway are 8,000 vehicles / day or over; and,
- Ensuring that the centre median at the crosswalks is at least 2.0m wide to accommodate cyclists who have dismounted and are travelling around the roundabout as a pedestrian walking their bicycle.

APPENDIX C

The Survey Form

Figure C-1 Survey Form in Excel

Survey of Canadian Roundabout Practices

*Please complete this survey for **each** roundabout location in your jurisdiction.*

1. General

1.1	Location (names of intersecting streets)		
1.2	Jurisdiction (Town/ Municipality/City, Prov.)		
1.3	Implementation date (month, year)		
1.4	New facility or upgrade to existing intersection	☐ New ☐ Upgrade	
1.5	Reason for roundabout installation.		
1.6	Construction cost	$	
1.7	Are digital photos or aerial images available?	☐ Yes ☐ No	If available, please include digital file with survey submission or contact Technical Liaison Committee at Tel: 416-252-5311 Fax: 416-231-5356 Email: sajjad.rasheed@snclavalin.com
1.8	Design PDF or other format available?	☐ Yes ☐ No	

2. Design Inputs

2.1	Highest Number of circulatory lanes	☐ 1 lane ☐ 2 lanes ☐ 3 lanes
2.2	Number of legs	
2.3	Inscribed circle diameter (outside diameter)	
2.4	Design vehicle	
2.5	Truck apron present?	☐ Yes ☐ No
2.6	Right turn slip lanes present? On how many approaches?	
2.7	Rural or urban setting	☐ Rural ☐ Urban
2.8	Any high speed approaches (i.e. 80 km/h or higher)?	☐ Yes ☐ No

3. Traffic Operational Characteristics

3.1	Design year	
3.2	Level of Service / Capacity Software	LOS = Capacity Software =
3.3	Traffic volumes, hourly (vph) if available or daily (vpd) for each leg (please specify directions with volumes) and/or total AADT	Dir Vol Dir Vol Dir Vol Dir Vol Dir Vol Dir Vol Total Entering AADT =
3.4	Truck percentage by leg (in the same order as above)	% % % % % % Total = %
3.5	Known operational issues related to:	☐ Delays or queuing ☐ High speeds ☐ Path overlap ☐ Truck access ☐ Other; please specify
3.6	Were any design changes required after implementation to address deficiencies? If so, please explain (i.e. deficiencies related to geometrics, signing, pavement markings, etc.)?	

4. Pedestrians / Cyclists

4.1	High pedestrian or cyclist location?	☐ High pedestrian location ☐ High cyclist location
4.2	Cyclist accommodation	☐ Shared with vehicles through circulatory lane(s) ☐ Separate pathway ☐ Other; please specify
4.3	Pedestrian accommodation	☐ Curb cuts ☐ Marked crosswalks ☐ Other; please specify
4.4	Are any special signs markings installed for the physically disabled or visually impaired?	

5. Safety

5.1	Collision rate or number of "Before" collisions per year	
5.2	Collision rate or number of "After" collisions per year	
5.3	Is it illuminated?	☐ Yes ☐ No
5.4	Any safety issues?	

2

6. Maintenance

6.1	Any snow removal issues?	
6.2	Any other maintenance issues?	

7. Policy

7.1	Does your jurisdiction have an existing policy for roundabout installation (i.e. when should a roundabout be considered)?	
7.2	What installation warrants criteria is applied?	

8. Public Acceptance

8.1	Was public perception generally positive or negative before installation?	
8.2	Has public perception changed since implementation?	
8.3	Have specific public complaints or compliments been received? Please explain.	
8.4	Has public perception affected your jurisdiction's desire to install new roundabouts? If so, why?	

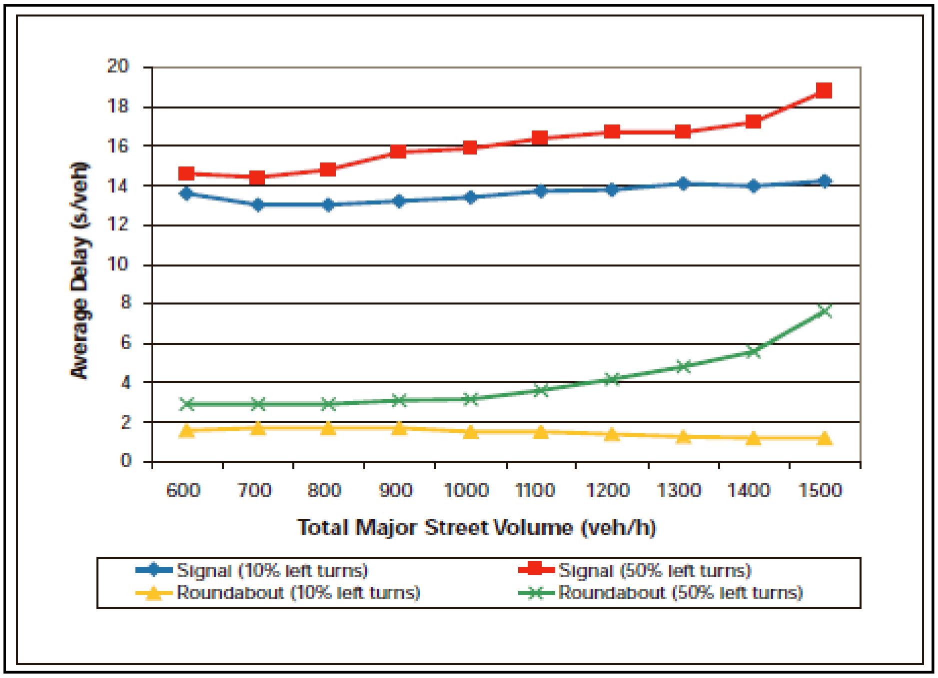
9. Other

9.1	Landscaping incorporated into design?	☐ Yes ☐ No
9.2	Boulevard present between sidewalks and vehicle travel paths?	
9.3	Any unique landscaping or aesthetic features (please explain)?	
9.4	Other unique features?	

3

APPENDIX D
Roundabout Capacity

Generally, a roundabout causes less delay to drivers than a traffic signal control, as shown in **Figure D-1**.



"Roundabouts: An Informational Guide", FHWA-RD-00-67, June 2000.

Figure D-1 Comparison of Delay between Signalized Control and a Roundabout

Similarly, the Kentucky Transportation Cabinet (KYTC) has thresholds as summarized in **Table D-1**.

Table D-1 Planning Level Maximum Roundabout Capacities

	Single Lane	Double Lane	Triple Lane
Peak Hour (Vehicles / Hour)	<2,000	2,000 – 4,000	4,000 – 7,000
Daily (Vehicles / Day	<20,000	20,000 – 40,000	40,000 – 70,000

KYTC Roundabout Interim Requirements and Guidelines 2006

The impact to adjacent intersections should also be accounted for in determining roundabout feasibility. Generally, it is not desirable to include a roundabout within a coordinated traffic signal system. However, replacing a high-turn volume intersection within a coordinated system may actually improve system efficiency and progression.

Traffic Operations Evaluation

The NCHRP Report 672, "Roundabouts: an Informational Guide", Second Edition, 2010, has guidelines for analyzing roundabouts for various stages, as summarized in **Figure D-2**.

Application	Typical Outcome Desired	Input Data Available	Potential Analysis Tool
Planning-level sizing	Number of lanes	Traffic volumes	Section 3.5 of this guide, HCM, deterministic software
Preliminary design of roundabouts with up to two lanes	Detailed lane configuration	Traffic volumes, geometry	HCM, deterministic software
Preliminary design of roundabouts with three lanes and/or with short lanes/flared designs	Detailed lane configuration	Traffic volumes, geometry	Deterministic software
Analysis of pedestrian treatments	Vehicular delay, vehicular queuing, pedestrian delay	Vehicular traffic and pedestrian volumes, crosswalk design	HCM, deterministic software, simulation
System analysis	Travel time, delays and queues between intersections	Traffic volumes, geometry	HCM, simulation
Public involvement	Animation of no-build conditions and proposed alternatives	Traffic volumes, geometry	Simulation

From NCHRP Report 672, "Roundabouts: an Informational Guide", Second Edition, 2010

Figure D-2 Guidelines for Analysis of Roundabouts

The current HCM™ and SYNCHRO™ include analysis capabilities for roundabouts. Several methods of roundabout modelling have been developed, most of them in other countries where roundabouts are common intersection treatments. The Australian methods are gap based as in the HCM and are implemented in the SIDRA software. Gap acceptance parameters can be modified based on local conditions.

The Australian method is based on analytical models while other methods, such as the British method, tend to be more empirical in nature, such as ARCADY and RODEL. The analytical models depend more on mathematical relationships while the empirical models are based on observed driver behaviour. The empirical models are largely based on observation of UK roundabouts and can be calibrated to existing conditions.

In addition, roundabouts can be analyzed using micro-simulation packages such as VISSIM and PARAMICS. Micro-simulation is data intensive and costly in comparison.

Comparison of Results

A number of studies have compared results from various analysis models using North American roundabout data. The studies consistently show lower capacities for North American studies as compared to roundabouts in Europe and other countries where roundabouts have a long history. This is primarily due to the relative novelty of roundabouts in North America and thus drivers are somewhat tentative driving around roundabouts and do not utilize their full capacity potential.

In addition, due to most roundabouts being relatively new in North America, almost none of them may have reached their full capacity and thus it is hard to gauge what the real capacity of a North American roundabout is.

Currently RODEL and SIDRA are the two popular packages for roundabout analysis.

<u>RODEL</u>:

- Regression equations based on observations of UK intersections
  - Strongly relates design elements and geometry to approach capacity (diameter, entry width, etc.)
  - Interactive design / operations analysis
  - Limitations
    - o Empirical data includes experimental observations
    - o Uses equations calibrated to UK drivers and UK vehicles
    - o Capacity is reached with small increases in volumes
    - o Ignores circulatory or exit capacity
    - o Ignores bypass lanes

<u>SIDRA</u>:

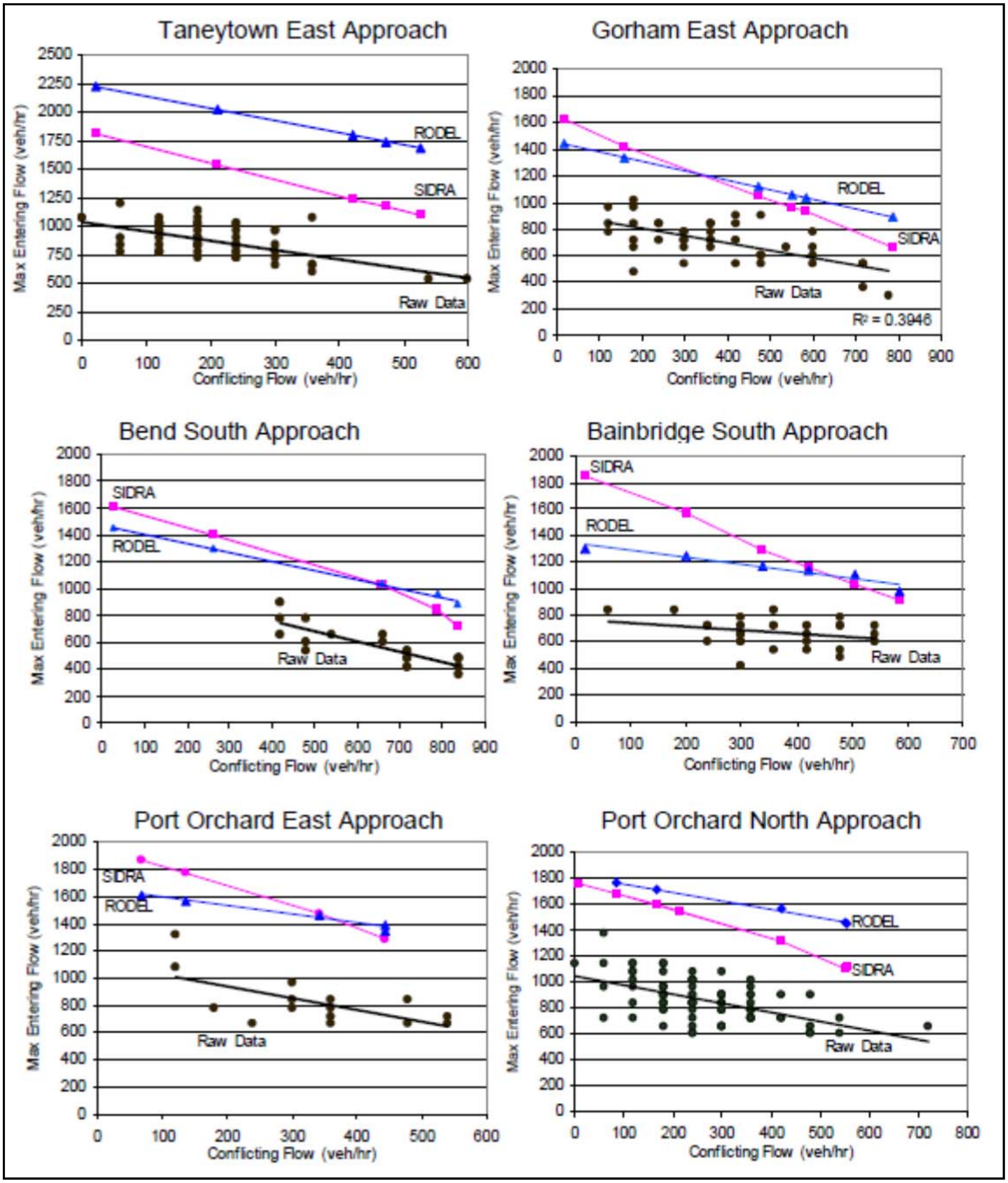
- Uses gap acceptance and lane utilization to determine capacity
- Can change headway values to calibrate to local conditions – Environmental Factor
- Limitations
  - o LOS results not always consistent with predicted V/C or queues
  - o Ignores bypass lanes

A comparison of the two popular methods, RODEL and SIDRA, was completed for various roundabouts in North America in 2004 with various approach lanes. The comparison of predicted capacity with actual capacity for six-lane approaches is summarized in **Figure D-3**.

The following were the findings from the study:

- The observed entry capacities are lower than either of the two models predict. RODEL as well as SIDRA tend to overestimate capacity.
- The slope of the RODEL capacity estimates better reflect the data, and hence RODEL may be calibrated by adjusting the intercept to reduce the magnitude of the estimate.

Micro-simulation has also been emerging as a viable means to analyze roundabouts. The major packages are VISSIM and PARAMICS, which have been found to be useful for congested conditions and also for system-wide analysis. Simulation is also useful for complex geometry, such as weaving within the roundabout and at freeway ramps. Paramics and VISSIM are most flexible in modeling driver behaviour and the benefit is the level of detail that can be modeled. However, they are more complex difficult to apply compared to RODEL or SIDRA as there are more parameters affecting driver behaviour.



Source: "Information for the Highway Capacity and Quality of Service Committee", NCHRP 3-65, July 2004

Figure D-3 Capacity for RODEL and SIDRA for Six-Lane Approaches