Roundabout Experience in the Region of Waterloo

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Executive Summary

The Region of Waterloo is located in southern Ontario, Canada, and has a population of over 450,000. The Region has implemented 11 roundabouts on its arterial road system, 8 of which are multi-lane. Five of the roundabouts are along an arterial road corridor with no traffic signals. One roundabout replaced a major signalized intersection and accommodates a high percentage of trucks and horse-drawn vehicles.

Roundabouts are implemented through a feasibility process that starts with an Initial Screening Tool and ends with a detailed Intersection Control Study at warranted locations. The process tends to favour roundabouts over traffic signals where traffic volumes are high and there would be greater societal savings realized through reduced injury crashes. This favouring of higher volume and higher crash-prone intersections distinguishes the Region from many other jurisdictions who tend to initially implement single-lane roundabouts at lower-volume locations.

There have been some ongoing design issues at the Region's roundabouts. The first relates to the use of fishhook markings and signs, which are being reconsidered at future roundabouts for maintenance reasons. The second has to do with circulatory road striping. Initially the circulatory road was striped at all multi-lane roundabouts, but then the striping was removed because of concerns with the lane positioning of large trucks and Regional transit buses. Circulatory road striping may be reinstated at certain roundabouts, and will be required at some future roundabouts that will have exclusive left turn movements. The third design issue involves winter maintenance, where mountable maintenance pads were introduced at multi-lane roundabouts to assist snow plows in clearing snow next to the central island.

As is the case elsewhere, there continues to be a need for public education on proper lane utilization at multi-lane roundabouts. Some motorists still do not understand that left turns at roundabouts are to be made from the left lane of the entry unless otherwise indicated. Ideally this public education would be accomplished at a higher level, with provincial or state programs aimed at motorists and law enforcement officers. Despite this the Region's roundabout program has been an unqualified success, and dozens more roundabouts are being planned.

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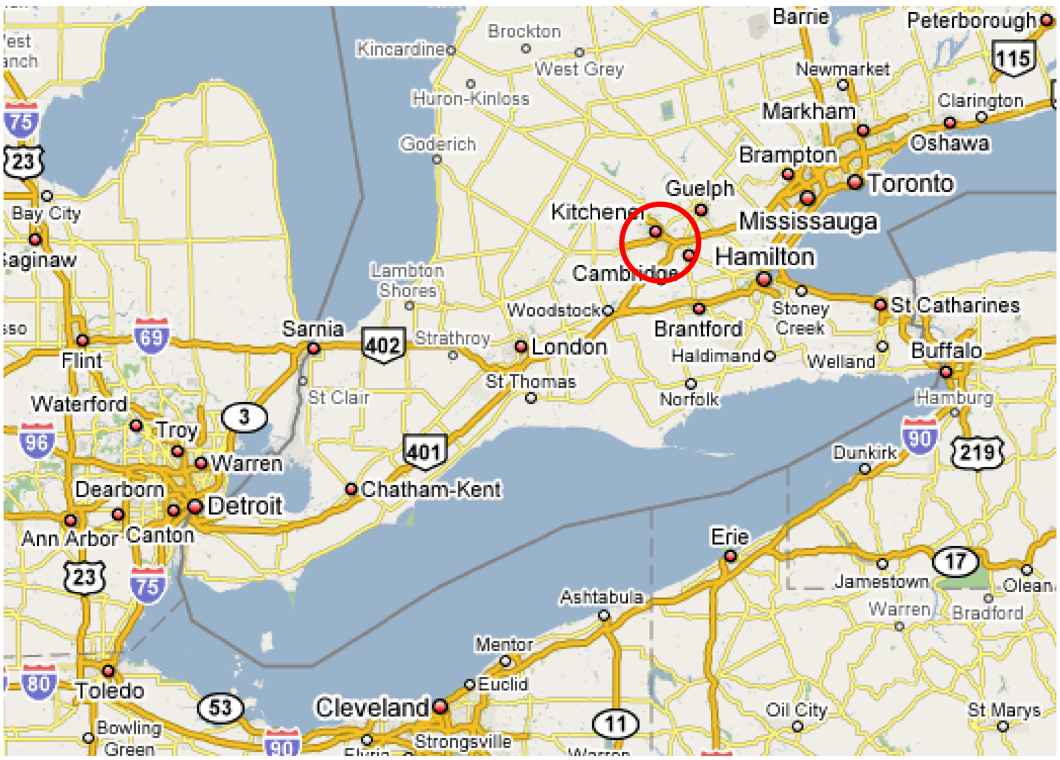
1.0 Background

Waterloo Region is located in southern Ontario in the centre of the triangle formed by three Great Lakes: Ontario, Erie and Huron, as shown in Figure 1.1. It is made up of three urban municipalities: Cambridge, Kitchener and Waterloo, and four rural townships: North Dumfries, Wellesley, Wilmot and Woolwich. With a combined population of over 450,000, Waterloo Region is one of the fastest growing areas in Ontario. The Region is responsible for the major road network including all arterial and some collector roads with a total road network of 700 kilometres (435 miles) and over 450 traffic signals.

Figure 1.1
Location of the Region of Waterloo



Source: Google Maps

Waterloo Region transportation staff became interested in roundabouts in the late 1990's and the Region implemented its first roundabout in 2004 at the intersection of Ira Needles Boulevard and Erb Street. Supportive public policy as well as direct support from the public has increased the demand for roundabouts on local and regional roads in the area. Waterloo Region now has 11 roundabouts in operation on arterial roads with dozens more being planned.

2.0 Roundabout Feasibility

2.1 Regional Roundabout Policy

Prior to the implementation of the Erb Street roundabout the idea of a modern roundabout was not familiar to many staff and public officials in the Region. Staff believed that due to this unawareness of roundabouts public officials and the general public would have some difficulty agreeing to the concept of a roundabout at a specific location. Therefore it was decided to bring forward a report to Regional Council that provided background information on roundabouts and recommended general direction be given to staff to consider the implementation of roundabouts on regional roads. Council approved the report and passed a by-law stating that roundabouts must be considered on the Region's arterial road system when:

- A new intersection is proposed.
- Traffic signals are warranted.
- Modifications are programmed at an existing intersection to address safety or capacity problems.

In 2008, as part of Regional Council's review of Strategic Objectives for the coming political term and following the success of the initial roundabouts and continued support for roundabouts from the general public, Regional Council directed staff to continue to implement roundabouts as an action to support the strategic objective of improving air quality through reduced emissions.

2.2 Roundabout Feasibility – General

The staff report was approved in April 2003, whereupon the Region was inundated with requests to consider roundabouts at various locations to support development growth in the area. Initially, the decision to undertake a roundabout feasibility study was often the result of a somewhat subjective process and the development of the feasibility study and final decision on a particular location was often delayed. Local developers and their consultants became concerned with this "ad hoc" process and cited several problems:

- Development approvals were being delayed beyond normal timeframes.
- The current process was not clearly understood and was perceived to be unpredictable regarding whether or not a particular location would be favoured for a roundabout.

It was decided to develop a more rigorous, predictable and defendable approach to the selection of candidate roundabout sites. As a first step, a Roundabout Coordination Committee (RCC) was created consisting of Regional transportation and planning staff as well as transportation staff from the local area municipalities. The mandate of the RCC was to guide and direct the effective implementation of roundabouts by making recommendations to senior management. RCC members review technical reports and make decisions regarding the feasibility of roundabouts at particular locations, develop technical standards and specifications for their implementation and provide direction regarding needed public education for roundabouts.

Another problem with the early roundabout feasibility process was that in order to meet Council's direction to consider a roundabout at all locations where road modifications were being considered, the Region was directing consultants to prepare detailed feasibility studies. This was being done for every location even though some of these locations were not good candidates for roundabouts and as a result, time and money were being wasted in some cases on locations that should have been "screened out". In response the RCC developed an Initial Screening Tool. Transportation planning staff also developed revised guidelines for the preparation of Traffic Impact Studies (TIS) by developers. The revised TIS guidelines clearly describe the process to be followed by the consultant to determine the feasibility of a roundabout.

2.3 Pre-Screening

The first step in determining the suitability of a roundabout at a particular location is to undertake an initial screening. The initial screening provides a relatively quick assessment of the feasibility of a roundabout in comparison to other forms of traffic control (i.e. traffic signals, all-way stop) or road modifications (i.e. auxiliary lanes).

The Initial Screening Tool requires the following information:

- The location and description of intersection.
- Whether traffic signals are warranted for the horizon year under consideration.
- Whether the intersection is new or a retrofit.
- Whether there are nearby intersections or railroad crossings.
- Whether the intersection is part of a coordinated signal system.
- If there is an identified collision problem that needs to be addressed.
- Whether persons with disabilities or horse-drawn vehicles are frequent users of the intersection.
- What road modifications are otherwise proposed at the intersection.
- What size of roundabout (i.e. two-lane entries, etc.) would be necessary for the horizon year under consideration.
- The present value of injury collisions over a 20-year life cycle.
- The estimated implementation cost (capital plus property, illumination, etc.).

The intended outcome of the screening is to have enough information to assist staff in deciding whether or not to proceed to a more detailed investigation to determine the feasibility of a roundabout.

2.4 Intersection Control Studies

An Intersection Control Study (ICS) is a more detailed investigation that looks at the following quantitative criteria to compare traffic control alternatives such as traffic signals and a roundabout:

- Safety performance for all users.
- Operational performance for motorists.
- Estimated implementation costs.
- Life cycle costs (including the implementation cost and the 20-year present value of injury collision, operating and maintenance costs).

A 20-year life cycle is used in the ICS to be consistent with Regional capital works programs. This sometimes causes conflicts when trying to get developers to fund all or part of a conversion to traffic signals or a roundabout because development traffic studies are usually conducted for shorter life cycles such as 5 years.

Also discussed in the ICS, but on a more qualitative level, are various other criteria such as vehicle noise, fuel consumption and emissions; speed control; effects on pedestrians, bicyclists, transit and emergency services; truck accommodation; road and utility maintenance; construction and staging; compatibility with adjacent land uses and site accesses; public acceptance; and aesthetics.

Traffic signal and roundabout functional design concepts are developed to facilitate the comparison. Care is taken to ensure the roundabout concept, in particular, is functional in terms of design checks such that capital costs and property impacts can be determined with a fair degree of confidence they would not change substantially should the concept proceed to further design.

It is important to note that the comparison of the 20-year life cycle costs for the alternatives being considered is the main criterion in determining the preferred type of traffic control for a particular location. Typically, the alternative with the lowest overall 20-year life cycle cost is recommended on a technical basis.

2.4.1 Injury Collision Performance

One of the most important criteria used in comparing traffic signals and a roundabout is injury collision performance. A procedure is used that looks at injury crashes only. It is difficult to get an accurate reading on property-damage-only crashes in a given location because not all of them are reported.

The steps are as follows:

1. Determine the current injury crash rate under traffic signal control. If the intersection exists and is already signalized then this is the existing rate. If the intersection is planned or is under a different type of control then the rate is obtained by looking at typical rates for other similar intersections within the Region. Other jurisdictions may have safety performance functions (SPF's) specific to a given location.

2. Predict the future 20-year injury crash frequency under traffic signal control by factoring the rate by the forecast average annual daily traffic (AADT). This future AADT may be obtained by local growth or by long-range modelling.

3. Predict the future injury crash frequency under roundabout control. At this time the Region averages the results obtained using three methods:

    - The intersection-level model from NCHRP Report 572.[1]

[1] *Roundabouts in the United States*, NCHRP Report 572, National Cooperative Highway Research Program, Transportation Research Board, 2007. The intersection-level model is used for single-lane and two-lane roundabouts, but find it predicts very high crash frequencies for three-lane roundabouts. The approach-level model is not used because it only reports total collisions.

- The empirical Bayes before-after results from NCHRP Report 572, disaggregated by logical group where appropriate.
- The output from the safety analysis tool RD2. RD2 is an empirical-based method based on U.K. research into the relationships between roundabout geometry and injury collisions.[2] It should be cautioned that the procedures used in the research are based on U.K. collision reporting methods, and may not be directly transferable to roundabouts in North America.

2.4.2 Injury Collision Costs

Once future injury collision frequencies for the traffic signal and roundabout alternatives are predicted, they are converted to present costs (PC) using economic analysis methods. An alternative method would be to use a present value (PV) comparison, say in comparing the safety benefits of traffic signals or a roundabout to an existing stop control. However usually the Region is committed to reconstructing the intersection to replace a stop control, or the intersection is already signalized.

In these studies the Region uses a standard cost to society of $30,000 per injury crash from research by the Transportation Association of Canada.[3] Some provinces have their own injury crash costs, which are similar, and standard costs to society for fatal or property-damage-only crashes as well. Sources for standard rates in the US include the National Safety Council website at http://www.nsc.org/lrs/statinfo/estcost.htm, and the FHWA web document at http://www.tfhrc/gov/safety/pubs/05051/index.htm. The latter has crash costs disaggregated by intersection control, operating speeds, impact types, etc.

The Region uses a discount rate in the economic analysis of 6 percent. This is a typical rate for multiple-year project cost comparisons as it covers both the cost of borrowing plus about 1.5 to 2 percent for future inflation.

2.4.3 Other Costs and Criteria

In addition to the costs to society of injury crashes, other costs incorporated into the ICS are:

- The implementation cost (capital plus property, illumination, etc.).
- A present cost for annual traffic signal maintenance, and a present cost to do a complete re-build at the 20-year horizon.
- Maintenance for any additional street lighting and landscaping that would be required for a roundabout.

Life cycle costs or benefits associated with reduced delay for a roundabout are not determined quantitatively but are considered qualitatively. The rationale is firstly that the costs of delay are difficult to assess and can be quite subjective and controversial, and secondly that if the delay cost was factored in to the total life cycle cost comparison between traffic signals and roundabouts the Region would no longer be installing traffic signals.

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[2] Maycock, G and RD Hall, *Accidents at 4-Arm Roundabouts*, Transport Research Laboratory (TRL) Report LR1120, U.K. Department for Transport, 1984.

[3] Default Values in Collision Costs, *Canadian Guide to 3R/4R*, Transportation Association of Canada, August 2001.

Life cycle costs or benefits associated with reduced fuel consumption and emissions are also not determined quantitatively but are considered qualitatively. Appropriate models do exist, but they are intensive in terms of data requirements. This may change in the future as environmental benefits become more important.

Tables 2.1 and 2.2 summarize typical qualitative values for a multi-lane roundabout. Often a roundabout will be estimated to cost more to construct, but to cost less over a 20-year life cycle due to societal savings from fewer injury crashes.

Table 2.1
Comparison of Capital and Life Cycle Costs (Typical Values)

Item	Traffic Signals	Roundabout
Total Construction Cost	$1,095,000	$1,262,000
Property Acquisition	$140,000	$320,000
Injury Crash Cost (PC)	$905,000	$316,000
Traffic Signal Annual Maintenance and Replacement (PC)	$184,000	-
Additional Street Lighting and Annual Maintenance (PC)	-	$33,000
Total Cost	**$2,324,000**	**$1,931,000**

Table 2.2
Summary of Operational, Safety and Cost Evaluation (Typical Values)

Evaluation Criteria	Traffic Signals	Roundabout
Annual Injury Crashes by 2027	2.6	0.9
Traffic Operations by 2027	LOS ‘C’ to ‘D’	LOS ‘B’
Total Capital Costs	$1.1 million	$1.3 million
Capital plus Life Cycle Costs	$2.3 million	$1.9 million

Table 2.3 lists typical qualitative comments associated with traffic signals and roundabouts at a particular location.

Table 2.3
Summary of Qualitative Comments (Typical)

Evaluation Criteria	Comments	
	Traffic Signals	**Roundabouts**
Vehicle Noise, Fuel Consumption and Emissions	Status quo.	Expect reductions in proportion to reductions in average delay – about 60 percent in the AM and PM peak hours.
Speed Control	Traffic speeds controlled only during red phase. Higher operating speeds likely on minor road.	Potential to control speeds at all times.

Table 2.3 Cont'd

Summary of Qualitative Comments (Typical)

Evaluation Criteria	Comments	
	Traffic Signals	**Roundabouts**
Pedestrians and Persons with Disabilities	May require push-button actuation. Audible signals possible.	Shorter crossing distances, and splitter islands provide refuge. Audible signals possible on individual legs.
Bicyclists	Crossing and left turn movements not accommodated under actuated control.	Lower motor vehicle speeds good for bicyclists.
Emergency Services, Transit	Pre-emption equipment may be required.	Comparable to traffic signals having pre-emption.
Truck Movements	Provides optimal operations on green, but lower operating speeds otherwise.	Good operations for all turning movements.
Road and Utility Maintenance	Status quo. May require lane closures.	Work in circulatory road may require larger vehicles to detour around intersection.
Construction and Staging	Status quo.	More complex and unfamiliar to contractors, and likely to require road closures or temporary widenings.
Compatibility with Area Land Uses and Site Accesses	No restrictions for driveway access. Higher operating speeds likely near residential driveways on minor road.	No restrictions for driveway access. Lower operating speeds in vicinity.
Public Education and Acceptance	Seldom necessary due to familiarity.	Will require careful planning and public education. Area-wide policy recommended before first roundabout is implemented.
Aesthetic Value	Decorative paving materials possible.	Decorative paving materials possible. Central island can be landscaped or features used to provide a gateway feature.

There are a number of uncertainties inherent in forecasting traffic growth, predicting injury collision frequencies for traffic signals and roundabouts, using societal injury crash costs, and estimating construction costs. Therefore, if the final life cycle costs are reasonably close to each other (i.e. within the range of the accumulated errors of the various evaluation criteria) then selection of the preferred alternative may come down to the importance placed on the more qualitative criteria.

Based on a lower 20 year life-cycle cost and consideration of other qualitative factors a roundabout may be recommended as the preferred alternative at a particular location. If so then the location is carried forward for public consultation and a recommendation is brought forward through a report to Regional Council for final approval. Locations that are part of a larger road project may be subject to a more comprehensive environmental assessment process and would follow that process as dictated by the scope and potential impacts of the overall project. Once approved the location is programmed for implementation based on funding and other capital works priorities.

2.5 Discussion

As noted earlier, the 20-year life cycle cost is the main criterion for determining the suitability of a roundabout compared to other forms of traffic control. A key consideration is the inclusion of the expected injury collision cost in the total life cycle cost. Based on the Region's experience to date, the implementation cost for a roundabout is in every case higher than the implementation cost for traffic signals. Although the cost of personal injuries is not a direct Regional cost but is a societal cost, the Region considers it essential to consider this cost in the evaluation.

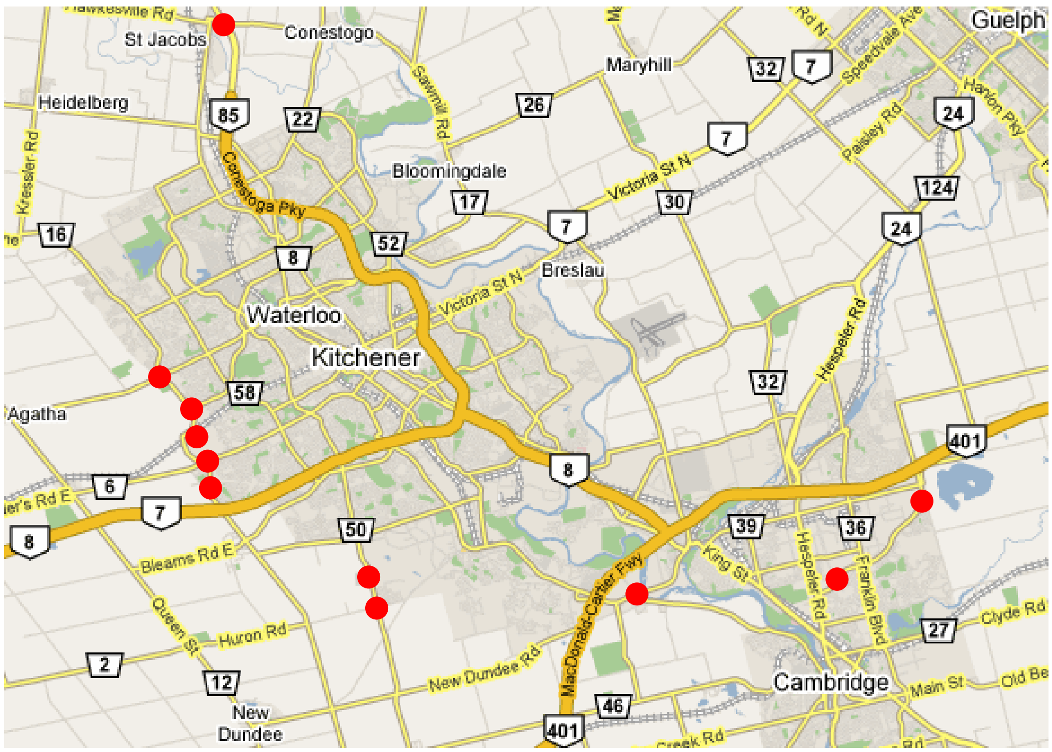
Regional staff believe the current feasibility process is working well in that it is bringing forward good locations for roundabout implementation and is also helping to prioritize locations based on their expected cost/benefit. The feasibility process tends to favour roundabouts over traffic signals at intersections with 4 legs and high volumes where more injury collisions would be expected as opposed to intersections with 3 legs where, due to less conflicts or lower volumes, fewer severe collisions would be expected. This favouring of higher crash-prone locations assists the Region in focusing the available transportation program funds on locations where the potential exists to obtain the most "bang for the buck". This prioritizing is critical as insufficient funds exist to construct a roundabout at every suitable location.

3.0 Roundabouts in the Region of Waterloo

3.1 Overview of Existing Roundabouts

There are currently 11 roundabouts on the Region's arterial road system: 8 are multi-lane, 1 is single-lane, and 2 are sized as multi-lane but initially striped as single-lane. Their locations are shown in Figure 3.1. Other roundabouts exist within the Region on collector or local roads.

Figure 3.1
Existing Roundabouts in the Region of Waterloo



Source: Google Maps

The first roundabouts were constructed in 2004. There is limited collision data since only 7 have been in operation for over a year, but collectively as of late 2007 based on the first 9 roundabouts there have been:

- No major injuries and 13 minor injuries.
- 67 property-damage-only crashes.
- 43 non-reportable crashes.
- No pedestrian or bicyclist collisions.

3.1.1 The Ira Needles Corridor

The first roundabout to be constructed in the Region, and the first multi-lane roundabout on an arterial road in Ontario, is at Ira Needles Boulevard and Erb Street. It has an inscribed circle diameter (ICD) of 55 metres (180 feet), with flared two-lane entries on Ira Needles Boulevard and on west leg of Erb Street and a full two-lane entry on the east leg of Erb Street. See Figure 3.2.

Figure 3.2
Roundabout at Ira Needles Boulevard and Erb Street

Photo: Ourston Roundabouts Canada

Ira Needles Boulevard is a new arterial road on the west side of the Region. The Erb Street roundabout was completed in 2004 as part of Stage 1 of the entire project. In 2006 and 2007 as parts of Stages 2 and 3 four more roundabouts were built at University Avenue, Victoria Street, Highland Road, and Highview Drive to form the first roundabout corridor in Canada. The new 6 km (4 mile) road has 5 back-to-back roundabouts and no traffic signals. Ultimately, this corridor may have 7 roundabouts as 2 additional roundabouts are being considered at the north limit of the road. The existing roundabouts have ICD's ranging from 50 to 55 metres (165 to 180 feet), and are designed with flared two-lane entries that can accommodate the eventual widening of Ira Needles Boulevard to four lanes with no changes required at the roundabouts.

3.1.2 Arthur Street and Sawmill Road

In 2006 a multi-lane roundabout was constructed at Arthur Street and Sawmill Road to replace a signalized intersection as per the recommendation of an ICS. The ICS was triggered because the intersection was experiencing long peak hour delays northbound and southbound, and was scheduled to be widened in response to traffic growth. The average injury collision frequency was 4.4 crashes per year. In the first 9 months of operation, there has been only one personal injury at the roundabout.

Arthur Street is the extension of former provincial Highway 85. It is a high-speed rural road at the north end of the Region. The intersection at Sawmill Road is near the village of St. Jacob's, a significant heritage site and local tourist destination. The roundabout is an ellipse in response to the skew of the intersection with an ICD that varies between 57 and 62 metres (187 and 203 feet). See Figure 3.3.

Figure 3.3
Roundabout at Arthur Street and Sawmill Road

Photo: Region of Waterloo

The roundabout carries a high percentage of trucks (10 percent). It also accommodates large farm equipment and horse-drawn vehicles (wagons and buggies), some of which are operated by members of the local Mennonite community. The horse-drawn vehicles typically travel on the lower volume Sawmill Road and cross Arthur Street mostly during non-peak traffic periods.

Representatives from the local Mennonite community were consulted during the planning phase of the project to get input on how they believed the roundabout would work for the horse-drawn vehicles. There was concern expressed that during peak traffic times the horse-drawn vehicles would have trouble finding adequate gaps to enter the roundabout and that motorists would not yield to buggies. The Sawmill Road approaches were designed with flared two-lane entries to provide buggy operators a lane to wait for a gap while allowing motorists to use the other entry lane without being held up behind the buggy. The Region also made use of a large existing culvert located under Arthur street north of the intersection which was currently used by buggy drivers to pass under Arthur Street during trips to and from the village of St. Jacobs. The design of the roundabout included a gravel pathway from the roundabout to the culvert to allow horse-drawn vehicle operators to by-pass the roundabout during periods of high traffic volumes on Arthur Street. After opening of the roundabout staff observed that although some buggy operators are using the bypass culvert, most of them are using the roundabout and are having no problems entering and circulating with motorized traffic. See Figure 3.4.

Figure 3.4
Horse and Buggy Crossing Arthur Street

Photo: Region of Waterloo

Several large local trucking firms were opposed to the roundabout during the planning phase. A representative from the Ontario Trucking Association appeared before Regional Council and claimed the roundabout would be unsafe. Since the opening of the roundabout in June 2006 the Region has not received any comments from the local trucking firms and an informal discussion with a dispatcher from one large firm revealed that the drivers in the company think the roundabout is working well, despite their earlier doubts.

3.2 Planned Roundabouts

The Region of Waterloo currently has about 30 roundabouts in various stages of planning and design. Two of them will be in areas with high pedestrian activity. Most are two-lane, and some are being designed for widening to three lanes once traffic volumes warrant. Two are currently being designed with spiral truck aprons to accommodate exclusive or dual left turn movements.

Many of the roundabouts are planned along arterial road corridors. The largest project currently underway involves assessing the feasibility of up to 12 roundabouts to replace traffic signals along a major arterial to defer the need to widen the road from four to six lanes.

4.0 Ongoing Issues

4.1 Roundabout Design Issues

4.1.1 "Fishhook" Markings and Signs

When the first roundabouts opened in the Region, staff observed the occasional motorist making a left turn by turning left at the entry in front of the central island. They may have been conditioned into traveling clockwise around the central island when the roundabouts were under construction. In response, as has been the practice in some other jurisdictions, staff replaced the standard lane use signs and pavement markings with those having "fishhook" arrows. See Figure 4.1.

Figure 4.1
"Fishhook" Pavement Markings

Photo: Ourston Roundabouts Canada

There is some debate as to whether fishhook arrows improve motorist understanding of how to make left turns at roundabouts, or whether they simply result in more confusion. They are not yet in the MUTCD so assigning fault when wrong-way turns or improper lane utilization occurs may be problematic. Regional pavement marking staff have had difficulty implementing the fishhook pavement markings as they are quite large and require a multi-piece template that takes about twenty minutes to set up for one marking. Due to installation time and expense, staff are not currently using the fishhook pavement markings but may reconsider their use in the future.

4.1.2 Circulatory Road Striping

Another issue that has arisen in the Region is whether to stripe the circulatory road of multi-lane roundabouts. When the first two roundabouts were constructed in 2004 they had striping in the circulatory roadway. The main reason at the time was that they were to help keep motorists in their lane and educate them on correct lane use. It was recognized that the striping may lead to some ambiguity about the positioning of large trucks as they navigate the roundabouts.

In 2006 the striping came under scrutiny because of concerns raised by a Regional transit bus operator on a route that turned left at the roundabout and had a bus stop near the exit. The Region reviewed videotaped operations of the roundabout with and without the circulatory striping and concluded there was little difference between the operations at low volumes although the operation without the striping appeared to be more like a single-lane roundabout. As a result of this review staff decided to leave out the circulatory roadway striping at all the Region's roundabouts but will continue to monitor operations as volumes increase over time.

Most multi-lane roundabouts in Canada and the US have striping in the circulatory road. Table 4.1 lists generally accepted advantages and disadvantages.

Table 4.1
Advantages and Disadvantages of Striping the Circulatory Road

Advantages	Disadvantages
Lessens potential for path overlap by reminding drivers to stay in lane while circulating	Where design does not allow for trucks to maintain own lane, can encourage passenger car drivers to circulate next to trucks
May result in slower circulating speeds during off-peak times	Where design does allow for trucks to maintain own lane, requires that roundabout be larger and have wider lanes for swept paths
Educates drivers on how to correctly turn left (but only if approach markings and signs correctly assign lane choice)	May necessitate truck aprons where not normally required
A must for multi-leg configurations with consecutive left turns and spiralled exit paths	May accentuate inherent path overlap problems
	May lessen potential to yield at entry as striping reinforces lane use mentality

The Region recognizes that striping in the circulatory road will be advisable with some future roundabouts because they will have spiral truck aprons to accommodate exclusive left turn movements.

4.1.3 Maintenance

There have been no major problems with maintenance of the roundabouts despite many concerns they would pose problems for snow plowing. Minor design modifications have evolved to accommodate the plow equipment including a semi-mountable curb on the central island of all roundabouts (including multi-lane roundabouts) with a full-depth heavy-duty concrete pavement behind the curb to allow plow rear wheels to over track so that the left edge of the circulatory road way can be properly plowed. Tight exit geometry at some of the early roundabouts caused some difficulties for plow operators and this resulted in some of the two-lane exits not being cleared completely of snow. Discussions are underway with maintenance staff to avoid this problem through better education of plow operators and through the design of flatter exits.

4.2 Public Education

The Region's first roundabouts were constructed over three years ago. At the time an extensive public education campaign was initiated for the benefit of pedestrians, bicyclists and motorists. That campaign has since been reintroduced in advance of several larger and more complex roundabouts that will be implemented over the next few years. The backbone of the Region's education program is the Region's roundabout website which contains frequently asked questions, a history of roundabouts, upcoming new roundabout projects, interactive animations and a training video. The animations show each type of user (pedestrian, bicyclist, motorist and truck driver) how to perform various movements at a roundabout including examples of "what not to do".

Making sure entering motorists yield to circulating traffic is an issue at all roundabouts. Although compliance rates are generally good, it remains an issue in the Region of Waterloo as well. Poor yield compliance seems to be most prevalent in cases where traffic enters a roundabout in platoons.

The other issue relates to correct lane utilization. Some motorists still do not understand that left turns at roundabouts are to be made from the left lane of the entry unless otherwise indicated. They enter from the right lane and stay to the outside of the circulatory road when making a left turn. The connection needs to be established with motorists, here and in other jurisdictions, that at roundabouts left turns are made from the left lane, just as at other intersections. Ideally this would be accomplished at a higher level, with provincial or state programs aimed at motorists and law enforcement officers. This is in its early stages in some provinces in Canada.

5.0 Conclusions

The Region of Waterloo has implemented 11 roundabouts on its arterial road system, 8 of which are multi-lane, and is planning dozens more because of the success of its roundabout policy and feasibility process. The feasibility process starts with an Initial Screening Tool and ends with a detailed Intersection Control Study at warranted locations. It tends to favour roundabouts over traffic signals where traffic volumes are high and there would be greater societal savings realized through reduced injury crashes over a 20-year life cycle. This favouring of higher volume and higher crash-prone intersections distinguishes the Region from many other jurisdictions who tend to initially implement single-lane roundabouts at lower-volume locations.

There have been some ongoing design issues at the Region's roundabouts. The first relates to the use of fishhook markings and signs, which are being reconsidered at future roundabouts for maintenance reasons. The second has to do with circulatory road striping. Initially the circulatory road was striped at all multi-lane roundabouts, but then the striping was removed because of concerns with the lane positioning of large trucks and Regional transit buses. Circulatory road striping may be reinstated at certain roundabouts, and will be required at some future roundabouts that will have exclusive left turn movements. The third design issue involves winter maintenance, where mountable maintenance pads were introduced at multi-lane roundabouts to assist snow plows in clearing snow next to the central island.

As is the case elsewhere, there continues to be a need for public education on proper lane utilization at multi-lane roundabouts. Some motorists still do not understand that left turns at roundabouts are to be made from the left lane of the entry unless otherwise indicated. Ideally this public education would be accomplished at a higher level, with provincial or state programs aimed at motorists and law enforcement officers.