APPENDIX E

DRAFT INTERSECTION CONTROL POLICY

IBI GROUP

City of Waterloo

POLICY PAPER: TRAFFIC CONTROL

SECOND DRAFT

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1. PURPOSE OF TRAFFIC CONTROL MEASURES

Driving, cycling and walking require constant assessment and reassessment of the travelling environment and responding to potential conflicts and conditions. A road user's reaction to "unexpected" events or situations is generally slower and thus provides them with less time to recognize the eminent decision and to properly react to it. The uniform application of traffic and pedestrian control devices (hereafter, collectively referred to in this paper as traffic control devices) simplifies road user tasks as it aids in the timely recognition and understanding of the situation.

Accordingly, standards and guidelines have been developed to provide uniform implementation and application of traffic control devices. The Manual of Uniform Traffic Control Devices for Canada (Canadian MUTCD) provides standards and guidelines concerning the design and use of traffic control devices, including signs, markings and devices. The use of a "standard" traffic control device or sign does not by itself constitute uniformity or a typical installation. In fact, a standard device used in an inappropriate application or location may cause confusion among the various road users, contribute to poor decisions and increase conflict potential.

For specific control devices such as traffic signals, all-way stops, stop and yield signs, marked and unmarked crosswalks, speed limits signs, roundabouts and other traffic calming devices, warrants or guidelines have been created on a national, provincial and/or jurisdictional level. Historically, warrants were minimum criteria that needed to be met before a specific traffic control or roadway device would be installed. Today, a warrant provides qualitative and quantitative threshold conditions to transportation professionals to evaluate the potential operational or safety benefits (and disbenefits) of traffic control devices, based on average conditions.

Warrants assist in determining the need for a particular control device to guide:

Logical and Consistent Application - the best means to achieve effective and safe traffic and pedestrian control is through the uniform application of realistic policies and standards within a municipality, region and/or province;

Priority Installations – As with other infrastructure and capital improvements, the available funding for traffic control devices is often limited. For more costly devices such as traffic control signals, roundabouts and pedestrian signals, a jurisdiction may need to prioritize their installation based on available capital funds, staff resources and on-going maintenance resources. The City of Waterloo and Region of Waterloo make use of traffic control warrants to determine potential needs and responsibilities for overall growth. Distinguishing between warranted and unwarranted traffic control devices is an additional tool in these decision processes;

Installation Responsibility – A main objective of traffic control is to achieve safe driving behaviour by creating a predictable roadway environment through the consistent, appropriate application of traffic control devices. In Ontario, this is achieved through the application of road design and traffic control guidelines from the Ontario Traffic Manual (OTM) consistent with the intent of the Highway Traffic Act, and to provide a basis for road authorities to generate or update their own guidelines and standards.

Fundamental Responsibility - The traffic practitioner's fundamental responsibility is to exercise engineering judgment and experience on technical matters in the best interests of the public and workers. Guidelines are provided in the OTM to assist in making those judgments, but are not used as a substitute for experienced judgment. Design, application and operational guidelines and procedures for roads are also applied in the context of each application (called "context-sensitive) with proper consideration of the prevailing circumstances.

Funding Responsibilities – There are many circumstances where changes in land use, access or the area road network will change traffic or pedestrian volumes at a particular location, thus creating a warranted traffic control device. The City of Waterloo and Region of Waterloo can make use of traffic control warrants to determine potential needs and responsibilities.

It is important to stress that regardless of the location, the best means to achieve effective and safe traffic control is through the uniform application of realistic policies and standards within a municipality. Warrants for traffic control devices assist in attaining these goals.

2. REVIEW OF TRAFFIC CONTROL WARRANTS

2.1 Traffic Signal Warrants

According to Highway Traffic Act section 144(31), traffic control signals can only be installed in accordance with an approval obtained from a person designated to give such approvals by the municipality that has jurisdiction over traffic control signal systems. In the Region of Waterloo, the Region has this jurisdiction over all traffic controls, including those on local municipal roads.

In past years, Regional staff would support the installation of unwarranted signals IF a developer or the local municipality paid for the installation. More recently, the Region has changed this practice and no longer supports installation of unwarranted signals no matter who pays. Furthermore, the Region now requires that if a local municipality is prepared to proceed with any unwarranted signal installation, then to meet legislative requirements, the local municipal Council must; 1) designate a person to approve it, 2) the local municipality must enter into an agreement with the Region to accept 100 percent responsibility for all costs associated with installing, operating and maintaining the unwarranted signals and most importantly, 3) the local municipality must indemnify and hold harmless the Region from the installation. None of these conditions are advisable for the City of Waterloo from a cost and a corporate and professional liability perspective.

The reasons for this strong stance against unwarranted traffic control signals can be summarized as follows:

- While the public often equate traffic signals to enhanced intersection safety, Regional collision data shows that at least twice as many collisions occur at signalized intersections compared to stop-controlled intersections;
- Studies show that signals generally do not improve pedestrian safety, and in the Region their studies show that the majority of pedestrian collisions occur at signalized intersections. Rather than installing unwarranted signals, the Region is making increased use of raised pedestrian refuge islands (without railings) and roundabouts to enhance pedestrian safety on their regional roads;
- Speed studies by the Region show that the average speed approaching a signalized intersection is higher than approaching a stop-control or uncontrolled intersection;
- Unwarranted signals cause travel delays that frustrate some drivers, resulting in decreased driver compliance through the intersection and shortcutting on other streets to avoid the unwarranted signals; and
- Unnecessary driver delays and idling at unwarranted signals increases fuel consumption, carbon emissions and noise which all have negative environmental effects.

The Region of Waterloo uses the warranting methodology from the Ontario Traffic Manual Book 12. Data is tabulated and compared to threshold levels based on gap and delay theory. There are several possible justifications, including:

- Minimum vehicle volume in which signalization can be used to minimize total average vehicle delay at the intersection;
- Delay to cross traffic, where the traffic on the side street suffers excessive delay or hazard in entering or crossing the main street;
- Collision experience, where an unsignalized intersection has an unusually high collision record; and
- Pedestrian volume and delay, where the traffic volume on the main street is so heavy that pedestrians experience excessive delay or hazard in crossing the main street or where high pedestrian crossing volumes produce the likelihood of such delays. If any of these justifications are met, then signals are warranted. Intersection pedestrian signals may be considered where the warrant is met based on pedestrian needs alone.

2.2 Intersection Pedestrian Signal/Mid-Block Signal/Pedestrian Crossings

An Intersection Pedestrian Signal (IPS) is a traffic signal designed solely to assist pedestrians in safely crossing a major roadway. An IPS only regulates the traffic on the main street. Vehicles approaching an intersection from a side street are controlled by the STOP signs. At an IPS, both motorists and pedestrians have responsibilities to ensure public safety.

According to OTM Book 12, section 4.9 Pedestrian Justification, a combined pedestrian crossing volume of at least 300 crossings over an 8 hour period is required to justify installation of IPS.

2.3 Stop Control

Because the STOP sign causes a substantial inconvenience to motorists, it should be used only where warranted. According to the Manual of Uniform Traffic Control Devises (MUTCD), a STOP sign may be warranted at an intersection where one or more of the following conditions exist:

1. An intersection of a less important road with a main road where application of the normal right-of-way rule is unduly hazardous;

2. A street enters a through highway or street;

3. An unsignalized intersection in a signalized area; and/or

4. Other intersections where a combination of high speed, restricted view, and serious accident records indicates a need for control by the STOP sign.

Prior to the application of these warrants, consideration should be given to less restrictive measures, such as the YIELD sign (see Section 2.4), where a full stop is not necessary at all times. Periodic reviews of existing installations may be desirable to determine whether, because of changed conditions, the use of less restrictive control or no control could accommodate traffic demands safely and more effectively.

Where two roadways intersect, the STOP sign or signs should normally be posted on the minor street to stop the lesser flow of traffic. Traffic engineering studies, however, may justify a decision to install a STOP sign or signs on the major street, as at a three-way intersection where safety considerations may justify stopping the greater flow of traffic to permit a left-turning movement.

2.4 All-Way Stop Control

The use of all-way stop control to address safety and security issues associated with vehicle speeds, traffic infiltration and pedestrian safety is a subject that has received considerable attention in many North American jurisdictions. The "ease" and cost of implementation in most municipalities make all-way stop control a resident and elected-official remedial solution to numerous traffic issues.

The warrants that have been developed by the Canadian, US and other local authorities have attempted to define situations where the net benefit of all-way stop control to all road users can be achieved. Misuse of all-way stop control in many jurisdictions have led to excessive motorist restrictions leading to driver frustration, low compliance, reduced pedestrian safety, increased mid-block speeds and environmental impacts. One of the primary safety concerns of all-way stop control is associated with pedestrians, cyclists and other road users expecting other road users, specifically motorists, to stop.

Given the extensive attention that all-way stop control has received, there is a wide-range of warranting factors and thresholds values included in jurisdictional guidelines. Provided below is a summary of major warranting factors identified in Exhibit 1.

Other criteria noted include cases where all-way stop control should not be used:

- Solely as a speed control device;
- Solely to protect pedestrians, especially school aged children;
- Solely to reduce traffic infiltration potential;
- Where off-set intersection, poor geometry or more than four-legs exist;
- Where progressive signal timing systems existing; and
- Higher speed roadways (posted speeds greater than 60 km/h).

2.5 Yield Control

According to the MUTCD, the YIELD sign may be warranted:

1. On a minor road at the entrance to an intersection where it is necessary to assign right-of-way to the major road, but where a stop is not necessary at all times, and where the safe approach speed on the minor road exceeds 15 km/hr;

2. Within an intersection with a divided highway, where a STOP sign is present at the entrance to the first roadway and further control is necessary to the entrance to the second roadway, and where the median width between the two roadways exceeds 10 metres;

Exhibit 1: All-Way Stop Warrant - Criteria

Criteria	Warranting Value/Measure	Jurisdiction
Minimum vehicular volumes on all approaches	Function of roadway type and hours of count. Typically 500 vehicles per hour for the peak 7 to 8 hours of the day (arterials) and 180 to 350 vehicles per hour for local roadways	All jurisdictions
Minimum vehicular volumes on minor street	Function of roadway type and hours of count. Typically 80 to 200 vehicles per hour for the peak 7 to 8 hours of the day (arterials) and 50 to 80 vehicles per hour for local roadways	All jurisdictions
Volume split between major and minor roads	70/30 to 65/35 depending on roadway type and configuration	OTM, Canada MUTCD, US MUTCD, Ottawa, Mississauga, Markham, Ajax
Collision frequency	3 to 5 collisions correctable by all-way stop control per 12 month period	OTM, Canada MUTCD, US MUTCD, Ottawa, Markham, Ajax, Winnipeg
Sight restrictions	Various	Markham, Nepean, Ottawa, Ajax, Winnipeg
Maximum number of lanes on approach	Maximum of 2 lanes	OTM, US MUTCD, Canada MUTCD, Ottawa, Nepean, Ajax
Minimum traffic control spacing	250 to 300 metres on arterial roads	All jurisdictions

3. Where there is a separate or channelized right-turn lane, without an adequate acceleration lane; and/or

4. At any intersection where a special problem exists and where an engineering study indicates the problem to be susceptible to correction by use of the YIELD sign.

YIELD signs should not ordinarily be placed to control the major flow of traffic at an intersection unless at a modern roundabout.

2.6 Pedestrian Crosswalks

Historically, warrants for pedestrian control and pedestrian crosswalks have generally been based on vehicular and crossing pedestrian volumes in the area. These criteria typically do not reflect the nature or operations of the traffic on the roadway.

2.6.1 PEDESTRIAN CROSSING CONTROL

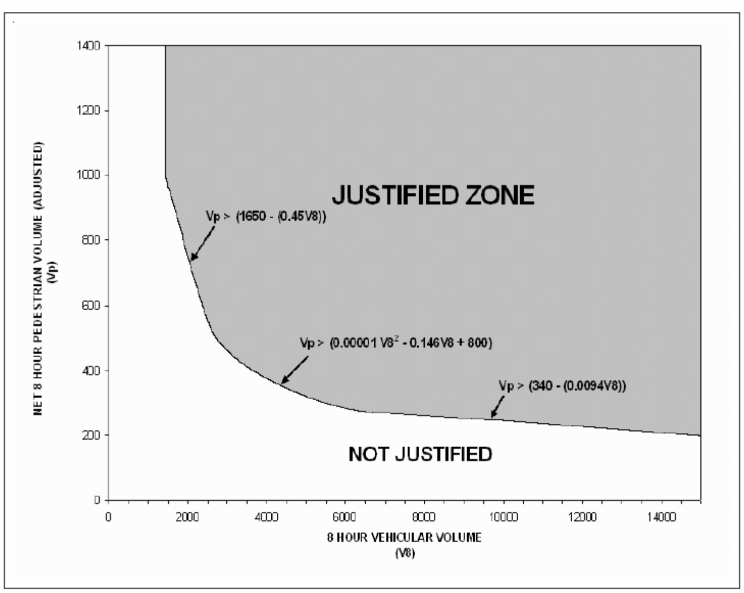
There are a number of forms of pedestrian crossing control used in North America:

- Mid-Block Pedestrian Crossings;
- Intersection Pedestrian Signals (IPS) as previously discussed in Section 2.2; and
- Pedestrian Crossovers (PXOs).

OTM Book 12 provides warrants for these devices as part of their traffic signal warrants, namely Warrant 5 and justification 5A (volume justification) and 5B (delay justification). Both the delay and volume justifications are a function of vehicle and pedestrian volumes and both must be fulfilled. Provided below is a summary of the Ontario warrants, as well as, those applied in other jurisdiction.

Jurisdiction	Pedestrian Warrant Summary
US MUTCD	• Minimum of 100 pedestrians for each of the four peak hours of the day or 190 pedestrians in the peak hour. • Shall not be considered where the distance to the nearest traffic control signal along the major street is less than 90 metres. • Considered if fewer than 60 gaps per hour are available in the traffic stream.
Canadian MUTCD	• No specific warrants for pedestrian signals, i.e., justified through the pedestrian factors in the Traffic Signal Warrant Procedure (TAC 2003)
OTM Book 12	• Justification is based on volume and delay of pedestrians. • Generally a minimum of 200 pedestrians is required in an eight hour period to justify a higher form of control, but the actual requirement also dependent on the eight-hour vehicular volume as shown on Exhibit 2.

Exhibit 2: Pedestrian Crossing Warrants



2.6.2 MARKED PEDESTRIAN CROSSINGS

The Canadian MUTCD indicates that pavement markings should not be used as stand-alone devices to indicate a pedestrian crossing, i.e., the pedestrian crossing should not be marked unless another form of traffic control, such traffic signals, overhead flashers, mid-block pedestrian signals or marked School Crossing are in place at the location. Recent research by Zegeer et al, ITE Journal, January 2004, included a safety analysis of marked versus unmarked crosswalks in 30 American cities. The major findings of the study indicated that:

- Pedestrian collisions are relatively rare at uncontrolled pedestrian crossings;
- Marked crosswalks on two-lane roadways and lower volume multi-lane roadways were not found to have a negative or positive impact on pedestrian collisions;
- Marked crosswalks alone, without other substantial treatments, are generally not recommended on three or four lane roadways with Annual Average Daily Traffic (AADTs) greater that 12,000; and
- There are some situations, such as pedestrian crossing of two-lane streets in downtown areas, where marked crossings may assist in consolidating pedestrian crossing activities.

3. MODERN ROUNDABOUTS

The modern roundabout is an unsignalized intersection in which traffic moves around a central island of varying size and design in a one-way direction. Roundabouts are engineered to offer several potential advantages over signalized and stop controlled intersections, including improved safety performance, less delay, shorter queues (particularly during lower volume periods), reduced speeds, and improved aesthetics for community enhancement. In some applications, roundabouts can avoid or prolong the need for expensive widening of an intersection approach that would otherwise be necessary under traffic signal control.

When considering introducing roundabouts in the City of Waterloo, it is first critical to distinguish their design principles from older-style circular intersections. Older style circular intersections (e.g. traffic circles or rotaries) are generally large in diameter (often greater than 100 m) with circulating speeds in excess of 50 km/h. They typically provide little horizontal deflection to the paths of entering vehicles and some intersections even operate under the principle that circulating traffic yields to entering traffic. These features have led to higher collision risk conditions and inefficient operations, and as a result, traffic circles fell largely out of favour in the 1950's.

Modern roundabouts include specific design and traffic control features to promote slower entry speeds, safer driving conditions, and smooth and continuous flow. The fundamental principles of a modern roundabout that distinguish it from other circular intersections are:

- **Yield at Entry** - Traffic within the circulatory roadway has priority and entering vehicles must yield. This creates a smooth flow and eliminates the possibility of congestion developing within circulatory roadway;
- **Traffic Deflection** - Traffic entering the roundabout is directed or channelled to the right with an appropriate curved path into the circulating roadway that avoids the central island. This deflection helps to reduce speed as it forces drivers to make a change in direction when entering the roundabout; and

- **Geometric Curvature** - The radius of the circulatory road and the angles of entry can be designed to slow the speed of vehicles. Key geometric design parameters and the fastest speed path are critical to achieve proper design.

The information contained in the following policy direction provides a high level overview of roundabout design and application. More detailed information regarding policy considerations, site-specific considerations and operational analysis is available from the roundabout design guide published by the Federal Highway Administration (FHWA).[1]

3.1 Recommended Policy Direction

Based on the findings to date regarding a number of successful roundabouts in Waterloo Region, Ontario and North America, modern roundabouts are well suited to the operating speeds, traffic volumes, and vehicle types found on many of the City of Waterloo roadways.

Following the construction of eight (8) roundabouts to date on the following City streets, the City of Waterloo remains interested in the use of modern roundabouts on City roadways as an alternative to signalized intersections where appropriate design guidelines can be met and/or the operational, safety and financial benefits are superior to alternative forms of traffic control.

1. Hagey/Wes Graham;
2. Hagey/Frank Tompra;
3. Laurelwood/Beaver Creek;
4. Laurelwood/Blue Beech;
5. Paris Blvd/Bordeaux;
6. Kraus/Conestoga;
7. Margaret/Union; and
8. University Avenue/Rim Park access.

A traffic circle that functions as a roundabout is also located at the Eastbridge/New Bedford intersection.

A modern roundabout should be considered where:

- The installation of traffic signal control at an existing intersection has met the applicable warrants;
- At a new City road intersection; and/or
- Improvements at a City road intersection to address safety or capacity concerns.

The feasibility and benefit of providing a modern roundabout should be determined through an Initial Screening and Intersection Traffic Control Study.

3.1.1 INITIAL SCREENING

An initial screening tool as currently used by the Region of Waterloo provides a relatively quick assessment of the feasibility of a modern roundabout at a particular intersection in comparison to

[1] Roundabouts: An Informational Guide, Publication No. FHWA-RD-00-067, June 2000

other appropriate forms of traffic control or road improvements including auxiliary lanes, traffic control signals, four-way stop, etc. The intended outcome of this tool is to provide enough information to assist staff in deciding whether or not to proceed to an Intersection Control Study to further investigate in more detail the feasibility of a roundabout.

3.1.2 INTERSECTION CONTROL STUDY

An Intersection Control Study includes a review of the reasonable forms of traffic control for a particular location or corridor and would include, but not be limited to, the following primary measures:

- Road user safety for all potential users including a detailed review of the societal costs of collision potential;
- Level of service and delay for all potential users;
- Environmental impacts such as fuel consumption, vehicle emissions and noise;
- Capital and operating costs;
- Compatibility with road/corridor traffic control strategies, and adjacent land use and access;
- Property impacts; and
- Effects on transit operations, emergency service provision, accommodation of persons with disabilities and farm vehicle operations.

3.2 Modern Roundabout Design

The defining characteristics of a modern roundabout are unique and should be clearly identified. Consistent definitions for each of the key features, dimensions, and terms are used as guidelines throughout the industry to maintain uniformity in roundabout planning practice. The key features of a modern roundabout are shown graphically in Exhibit 3 and described briefly in Exhibit 4.

While the following design guidelines outline a number of quantitative attributes and limits for proper roundabout design, they are guidelines and are not intended to direct the overall design of a particular roundabout application. Roundabout design is an iterative process that combines operational simulation, design experience and engineering judgement to optimize the design attributes from a capacity and safety perspective.

Engineering judgement can often be used to make context-sensitive decisions about roundabout design. The context of the roundabout can include the volume, speed and type (i.e. heavy trucks, transit buses) of vehicles approaching the intersection, the available right-of-way and type and proximity of abutting land use. These factors often influence how design guidelines are applied to specific roundabout applications.

Exhibit 3: Typical Features of a Modern Roundabout (Source: KCDOT, 2005)

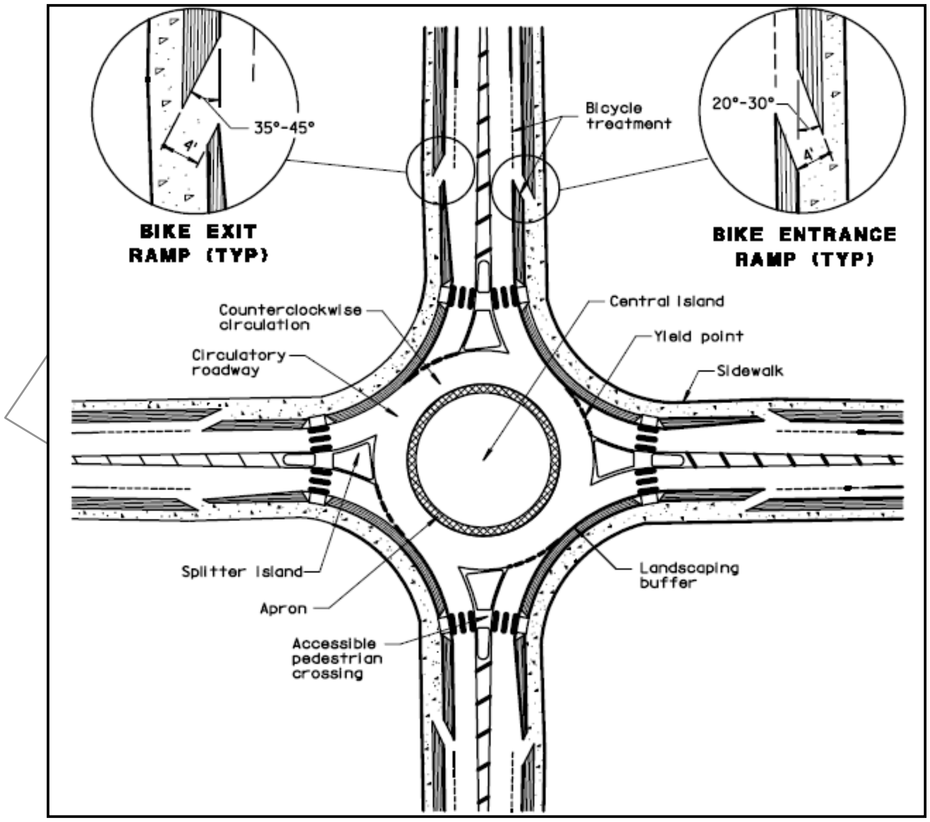


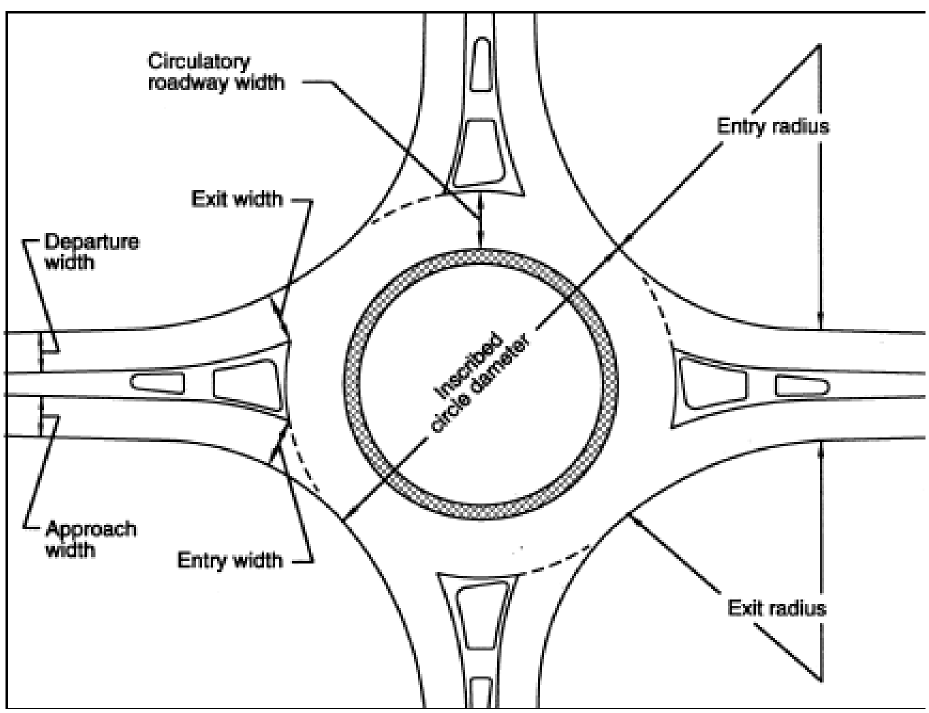
Exhibit 4: Descriptions of Modern Roundabout Features (Adapted from FHWA, 2000)

Design Feature	Description
Central Island	The *central island* is the circular island situated within the roundabout, around which traffic circulates. This central island is generally raised but can be made mountable for roundabouts with constrained circular dimensions (to accommodate larger vehicles).
Splitter Island	A *splitter island* is a raised or painted area on approach that is used to control speeds, guide traffic, separate entering and exiting traffic, and discourage wrong-way movements. Splitter islands have an effect on safety and capacity and are a critical feature for all roundabouts.
Circulatory Roadway	The *circulatory roadway* is the curved path used by vehicles to travel in a counter-clockwise fashion around the central island.
Apron	An *apron* is a mountable portion of the central island adjacent to the circulatory roadway, sometimes required on smaller roundabouts to accommodate the wheel tracking of larger vehicles.
Yield Line	A *yield line* is a pavement marking used to mark the point of entry from an approach into the circulatory roadway and is generally marked along the inscribed circle. Entering vehicles must yield to any circulating traffic coming from the left before crossing this line into the circulatory roadway.

Design Feature	Description
Accessible Pedestrian Crossings	*Accessible pedestrian crossings* should be considered at all roundabouts; however, striped crossings may be omitted at rural roundabouts where pedestrian activity is not anticipated. Where used, the crossing location is set back from the entrance line, and the splitter island is cut to provide access for all types of users.
Bicycle Treatments	*Bicycle treatments* at roundabouts provide bicyclists the option of traveling through the roundabout either as a vehicle or as a pedestrian, depending on the bicyclist's level of comfort. Bicycle entrance and egress points can provide cyclists access to multi-use paths around the roundabout perimeter to avoid interaction with vehicles within the circulatory roadway.
Landscaping buffer	*Landscaping buffers* are provided at most roundabouts to separate vehicular and pedestrian traffic and to encourage pedestrians to cross only at the designated crossing locations. Landscaping buffers can also significantly improve the aesthetics of the intersection.

The operational success of a modern roundabout is largely dependent on its geometric design elements. Using engineering judgement, a trade-off between capacity and safety arises when selecting a particular design of these elements. A roundabout built with larger dimensions will increase vehicle speeds and increase capacity, but may have an adverse effect on safety. Similarly, a smaller "mini" roundabout will promote slower speeds, but will reduce capacity. Also, consideration must be given to the design vehicle, as smaller dimensions may be problematic for larger vehicles. The process of designing a roundabout relies on finding an optimal balance between safety and capacity. Exhibit 5 highlights the more prominent geometric design elements followed by brief descriptions of each.

Exhibit 5: Primary Geometric Design Elements of a Roundabout (FHWA, 2000)



- **Inscribed Circle Diameter** - The inscribed circle diameter is the distance across the circle inscribed by the outer edge of the circulatory roadway. For single lane roundabouts, the size of the inscribed circle is largely dependent on turning requirements of the design vehicle, but it also dictates the vehicle path to ensure safe speeds through the roundabout. Typically, single-lane roundabouts have diameters in the range of 30-40m that can accommodate standard transit buses and medium to large size commercial vehicle (WB-15 and WB-20 vehicles) while maintaining circulating speeds of about 40 km/h. The size of double-lane roundabouts relies more on the provision of adequate distance between entries and exits for vehicle manoeuvres. The diameter should be a minimum of 45 m and should not exceed 60 m. Although capacities can increase with larger diameters, a diameter greater than 60 m should generally not be used as it will encourage high circulating speeds and increase the potential for collisions with greater severity.

- **Circulating Roadway Width** - The circulating roadway width is the one-way road width around the central island. For single-lane roundabouts, this width should be designed such that the turning path of the design vehicle can be accommodated. For double-lane roundabouts, the width is determined by the space required for two vehicles to comfortably negotiate the curve while travelling side-by-side. The circulatory roadway it usually not striped, even when more than one lane of traffic is expected. In cases where heavy vehicle traffic exceeds ten percent, it may be necessary to design for the passage of adjacent heavy vehicles.

- **Approach Width** - The approach width is the width of the roadway used by approaching traffic upstream of changes in width associated with the roundabout. The approach width is typically no more than half of the total width of the circulatory roadway.

- **Departure Width** – The departure width is the width of the roadway used by departing traffic downstream of changes in width associated with the roundabout. The departure width is typically less than or equal to half of the total width of the circulatory roadway.

- **Entry Width** – The entry width defines the width of entry where it meets the inscribed circle. It is measured perpendicularly from the right edge of the entry to the intersection point of the left edge line and the inscribed circle. The entry width is the largest determinant of a roundabout's capacity. The capacity of an approach is not dependent merely on the number of entering lanes, but on the total width of the entry. Entries of sufficient width to accommodate multiple traffic streams are striped to designate separate lanes. To maximize the roundabout's safety, entry widths should be kept to minimum.

- **Exit Width** - The exit width defines the width of exit where it meets the inscribed circle. It is measured perpendicularly from the right edge of the exit to the intersection point of the left edge line and the inscribed circle.

- **Entry Radius** - The entry radius is the minimum radius of curvature of the outside curb at the entry, and controls the deflection of a vehicle upon entrance to the roundabout. Therefore it is an important determinant in the approach and circulating speeds. As with other elements, a trade-off exists between safety and operational performance, so care must be taken when deciding the design.

- **Exit Radius** – The exit radius is similar to the entry radius, and its primary constraint is related to pedestrian activity. A larger exit radius may encourage higher speeds, posing danger to pedestrians. However, in a rural environment in the absence of pedestrians, a large radius is encouraged to allow vehicles the opportunity to accelerate back to their original operating speed.

3.3 Roundabout Planning Considerations

3.3.1 APPROPRIATE APPLICATIONS

The installation of a traffic modern roundabout is beneficial only if an environment is appropriate for its use. This is an important aspect of the planning process since placing a roundabout in an inappropriate location may not help its cause and may lead to adverse effects. Roundabouts should be constructed for the primary purpose of improving operations and/or safety at intersections, but they may also be considered for traffic calming or aesthetic reasons. Considerations for the various appropriate applications of roundabouts are provided in the following subsections.

3.3.2 IMPROVEMENT OF INTERSECTION SAFETY

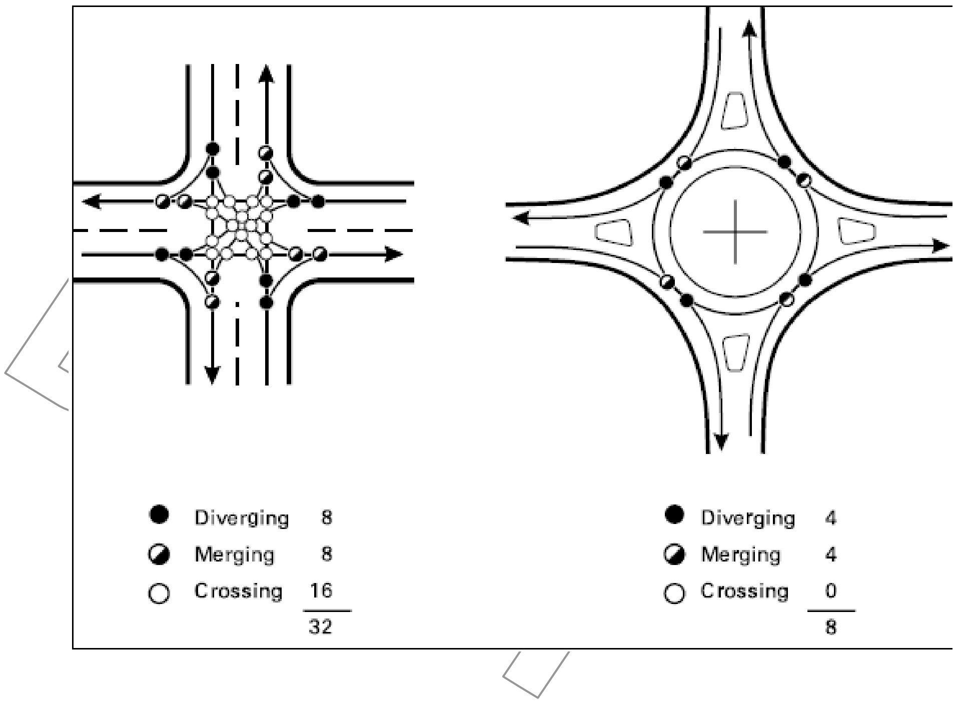
Roundabouts offer a possible solution at existing intersections that experience a high frequency of severe collisions, and planned intersection with this potential, especially locations with frequency collisions related to cross movements or left-turn or right-turn movements. Many studies have found that roundabouts have been successful in improving overall safety performance at intersections. In particular, single-lane roundabouts have been found to perform better than two-way stop-controlled (TWSC) intersections. Although the frequency of reported crashes is not always lower at roundabouts, reduced injury rates and severity are usually reported. Also, as drivers become more familiar with the operation of roundabouts, collision frequency is likely to reduce over time. The reasons for the increased safety level at roundabouts are as follows:

- Roundabouts have fewer conflict points at which the paths of opposing vehicles intersect. The potential for hazardous conflicts, such as right-angle and head-on crashes is eliminated with roundabout geometry. A 4-leg single lane roundabout has 75% fewer conflict points than a conventional 4-leg intersection (Exhibit 66). As roundabout designs become more complex (multilane roundabouts) the potential conflict points increase and the safety benefit is not as prominent. However, even with an expected lower overall crash reduction, multilane roundabouts should still result in fewer serious injuries and fatalities as compared to the alternative intersection control.

- Low absolute speeds forced by roundabout design (i.e. entry deflection and diameter of central island) allow drivers more time to react to potential conflict and, in the event of a collision, reduce the severity of the impact.

- Pedestrians need only cross one direction of traffic at a time at each approach as they traverse roundabouts, as compared with unsignalized intersections.

Exhibit 6: Number of Conflict Points for Roundabouts versus Conventional Intersections (FHWA, 2000).



3.4 Improvement of Intersection Capacity

The modern roundabout may be a preferable alternative to stop-controlled or signalized treatments for increasing the capacity of an intersection. Under conventional types of traffic control, only alternating streams of vehicles are permitted to proceed through the intersection at one time. This causes a loss of capacity when the intersection clears between phases. In contrast, the only restriction on entering a roundabout is the availability of gaps in the circulating flow. The slow speeds within the circulating roadway allow road users to safely select a gap that is relatively small. Because roundabouts do not favour one approach over another, they offer a particular advantage for improving capacity at locations where the proportions of minor street movements are high. Also, by eliminating the need for a separate pedestrian signal phase, a possible advantage in capacity can be achieved, especially where left or right turning volumes are high.

The design of any roundabout should include a detailed capacity analysis, but the following assumptions are proposed for a planning level comparison between intersection treatments:

- A roundabout will always provide a higher capacity and lower delays than all-way stop-controlled (AWSC) intersections operating with the same traffic volumes and right-of-way limitations;
- A roundabout it unlikely to offer better performance in terms of lower overall delays than TWSC intersections with minor movements that do not currently experience, nor are expected to experience, operational problems under TWSC;
- A single-lane roundabout may be assumed to operate within its capacity at any intersection that does not exceed the peak-hour volume warrant for signals; and

- A roundabout that operates within its capacity will generally produce lower delays than a signalized intersection operating with the same traffic volumes and right-of-way limitations.

3.4.1 REDUCTION OF QUEUE STORAGE REQUIREMENTS

The reduced delays and continuous flows at roundabouts allow the use of fewer lanes between intersections where long storage requirements may be required using stop-controlled or signalized intersections. Possible applications may be found at existing diamond interchanges, where high left turn volumes can cause the signalized intersection to fail. By constructing a pair of roundabouts at the ramp intersections, capacity improvements to the interchange can be accomplished without the costly requirement of widening the structure to carry additional lanes over or under the freeway.

3.4.2 ACCOMMODATION OF UNUSUAL INTERSECTION GEOMETRY

Intersections with a difficult skew angle, a significant offset, an odd number of approaches, or close spacing can be problematic when treated with conventional intersection control. Roundabouts may be a better alternative for such intersections because signal phasing is not required, and signing may be less complicated. The ability to accommodate high turning volumes makes roundabouts especially effective at "Y" or "T" junctions (i.e. intersection of Union Street E. and Margaret Street S. in the City of Waterloo).. A multi-legged roundabout design may also be useful in eliminating a pair of closely spaced intersections.

3.4.3 CONTROLLED ACCESS (RAISED MEDIAN) LOCATIONS

The introduction of roundabouts may be possible in situations where access needs to be controlled via raised medians. Roundabouts would facilitate left turns and U-turns to access properties on the opposite side of the highway. Improved access via roundabouts might reduce opposition to left turn restrictions.

3.4.4 COMMUNITY ENHANCEMENT

Roundabouts may be proposed as part of community enhancement projects rather than a solution to safety or operational problems. Such applications are used as a gateway treatment to convey a change of environment and to encourage traffic to slow down. These roundabout applications require minimal analysis as a traffic control device as traffic volumes are typically low and are not a concern; however, the planning focus should be to demonstrate that the installation of a community enhancement roundabout will not introduce traffic or safety problems that currently do not exist.

3.4.5 TRAFFIC CALMING

A roundabout may present a solution to a demonstrated need for traffic calming along the intersecting roadways. Roundabouts encourage slower and more consistent vehicles speeds, resulting in a traffic calming effect that results in a more balanced operating environment for all road users. Roundabouts of smaller geometric dimensions are most appropriate for traffic calming purposes and capacity should not be an issue as volumes should be low. Roundabouts for traffic calming purposes should generally be located on collector and local roads in residential areas.

3.5 Inappropriate Roundabout Applications

The following locations are generally noted as being unfavourable for modern roundabouts:[2]

- Locations where there is insufficient space for an acceptable outside diameter. Single-lane roundabouts generally consume more space than equivalent signalized intersections at the junction itself, but their approaches are often narrower. Multi-lane roundabouts compare more favourably in terms of space consumption. Having insufficient space for a roundabout can be overcome either through property acquisition or consideration of a mini or compact roundabout design;

- Locations where it would be difficult to provide a flat plateau for the roundabout. Most guides recommend maximum grades of 3% to 5% depending on design speed;

- Locations within a coordinated signal network, where the roundabout would disrupt the platoons; and/or

- Locations with heavy flows on the major road and low flows on the minor road, where the equal opportunity treatment of the approaches causes undue delays to the major road.

Other site-specific conditions can be potentially problematic at roundabouts, but, as with any other intersection, these conditions can be addressed with special attention to design and operational aspects. Such conditions include the following:

- High volumes of cyclists, pedestrians or heavy vehicles (including large farm vehicles);

- Presence of numerous disabled and visually impaired users;

- Along emergency services primary response routes;

- Close proximity to at-grade rail crossings;

- Intersections at the top or bottom of a grade where adequate sight distance is a concern; and/or

- Proximity of adjacent downstream signals and potential blocking due to queuing.

3.6 Roundabout Categories

Roundabouts have been categorized according to size and environment to differentiate their design and operational characteristics within different contexts. Four roundabout categories are included in these guidelines for the City of Waterloo:

- **Urban compact roundabouts** – Urban compact roundabouts are intended to be pedestrian and cyclist friendly. Perpendicular approach legs force low vehicle speeds to make a distinct right turn into and out of the circulatory roadway. Capacity should not be a critical issue for this type of roundabout. Geometric design includes raised splitter islands incorporating pedestrian storage areas and a non-mountable central island that usually includes an apron to accommodate larger vehicles.

[2] Modern Roundabout Practice in the United States, NCHRP Synthesis 264, Transportation Research Board, Washington D.C., 1998

- **Urban single-lane roundabouts** - This type of roundabout is characterized as having a single-lane entry at all legs and one circulatory lane. They are distinguished from urban compact roundabouts by their larger inscribed circle diameters (typically 33 to 40 m) and more tangential entries and exits, resulting in higher capacities. Their design allows slightly higher speeds at the entry, on the circulatory roadway, and at the exit. The roundabout design is focused on achieving consistent entering and circulating vehicle speeds. The geometric design includes raised splitter islands, a non-mountable central island, and preferably no apron.

- **Urban double-lane roundabouts** - Urban double-lane roundabouts include all roundabouts in urban areas that have at least one entry with two lanes. These roundabouts require wider circulatory roadways to accommodate more vehicles traveling side-by-side and therefore have larger inscribed circle diameters (45 - 55 m). The speeds at the entry, on the circulatory roadway, and at the exit are similar to those for the urban single-lane roundabouts. The geometric design will include raised splitter islands, a non-mountable central island, and appropriate horizontal deflection. The design of a double-lane roundabout is somewhat more complex in that adjacent vehicles must be able to comfortably traverse the roundabout without competing for the same space.

- **Mini-Roundabout -** A mini-roundabout may be considered at an intersection where the available right of way is not sufficient to install a normal roundabout with a solid central island. A mini-roundabout is a small form of modern roundabout that is fully overrunnable with a painted circle or island (or “button”) in the middle, and where all traffic should yield on entry to vehicles circulating around it. On entering the circulation, all vehicles must pass to the correct side of the central island unless they physically cannot do so, when the trailing part of the vehicle may pass over and to the "wrong" side of the central island (i.e. heavy tractor-trailer or transit bus).

  A mini-roundabout is the same as a modern roundabout but there is no solid central island, only a truck apron. The only other difference is the scale of the intersection; the inscribed circle is less than around 28 meters (90 feet). Otherwise the operational characteristics are much the same as a normal modern roundabout with a central island. This is dependent upon making the truck apron - now a stand-alone device - work properly.

  When working with normal modern roundabouts, vehicle paths are largely dictated by the central island and splitter islands. At mini-roundabouts, this is more of a precise science, with the layout designed in accordance with desired vehicle paths. Key issues are getting drivers to circulate around rather than across the central, overrunnable island which can be promoted with signage, and forcing a deflected path for the movements that cross one another's paths within the roundabout, especially left turns. In the City of Waterloo a mini-roundabout was installed at the intersection of Margaret Avenue and Union Street in 2009.

A brief summary of features and expected operations for each of these basic roundabout categories is shown in Exhibit 7.

Exhibit 7: Basic Characteristics of Roundabout Categories (Adapted from FHWA, 2000, Roundabouts, An Informational Guide)

Design Element	Urban Compact	Urban Single-Lane	Urban Double-Lane	Mini Roundabout
Recommended Max. Entry Speed	25 km/h	35 km/h	40 km/h	25 km/h
Max number of entering lanes per approach	1	1	2	1
Typical inscribed circle diameter	25 m – 30 m	30 m – 40 m	45 m – 55 m	13-25 m
Splitter island treatment	Raised, with crosswalk cut	Raised, with crosswalk cut	Raised, with crosswalk cut	Raised if possible with crosswalk cut
Typical daily service volumes on 4-leg roundabout (vpd)	15,000	20,000	Requires detailed site-specific analysis	10,000

3.7 Cyclist and Pedestrian Considerations

In most cases, planners and designers should consider the needs of pedestrians and cyclists. This requires special attention to the details of each roundabout design. General considerations for both pedestrians and cyclists are provided below.

3.7.1 PEDESTRIANS

Whenever a raised splitter island is provided, there should also be an at-grade pedestrian refuge. In this case, the pedestrian crossing facilitates two separate movements: curb-to-island and island-to-curb. The exit crossing will typically require more vigilance from the pedestrian and motorist than the entry crossing. It is recommended that all urban crosswalks be marked and be set back from the yield line by one or more vehicle lengths to shorten the crossing distance and separate vehicle-vehicle and vehicle-pedestrian conflict points. The roundabout should also be designed to discourage pedestrians from crossing to the central island (e.g. with landscape buffers on the corners). Furthermore, under all urban design categories, special attention should be given to assist pedestrians who are visually impaired, through design elements.

3.7.2 CYCLISTS

Although roundabouts have not been found to provide safety benefits to bicyclists over other forms of intersections, roundabout designs slow drivers to speeds more compatible with bicycle speeds. One of the difficulties in accommodating cyclists at roundabouts is the wide range of cycling skills and comfort levels in mixed traffic. On single-lane roundabouts, cyclists have the option of either mixing with traffic or using the roundabout like a pedestrian. Experienced cyclists are likely to choose the former option, but less experienced cyclists (including children) may be more safely accommodated as pedestrians.

In two-lane roundabout design, cyclists require particular attention due to the complexity of vehicle interactions. Bike lanes should never be used within a circulatory roadway due to these complex interactions. On double-lane roundabouts, a bicycle path separate and distinct from the path of circulatory roadway is preferable, such as a shared bicycle-pedestrian path of sufficient width to accommodate both users. Entry and exit points to such a path can be provided on the approach/exit legs of a roundabout. It may sometimes be possible to provide cyclists with an alternative route that avoids the roundabout altogether. However, the provision of bike paths or alternative cycling routes should not justify compromising the safety of cyclists through the roundabout as experienced cyclists are still likely to use it.

3.7.3 TRANSIT, EMERGENCY RESPONSE AND MAINTENANCE

In planning for and designing roundabouts in the City of Waterloo, consultation must take place with:

- Grand River Transit regarding existing and potential future transit routes and stops, and the ability of roundabout to accommodate transit vehicles
- City of Waterloo Fire Rescue regarding ability of a roundabout to accommodate fire rescue vehicles;
- City of Waterloo Public Works regarding maintenance requirements for a roundabout; and
- Waterloo Regional Police and Emergency Medical Services (Ambulance) regarding ability of a roundabout to accommodate emergency response vehicles and minimize any associated response delays.

4. SUPPORTING INFORMATION AND ANALYSES

4.1 Trends

Traffic control device warrants for various devices were developed with the purpose of providing standardization and common ground for a jurisdiction or number of jurisdictions to apply like rules and applications. In the recent past, a number of research activities and manual updates have recognized a change in approach to establishing and applying warrants for traffic control devices. These shifts in philosophy are outlined below.

Warrants Application – In the past a warrant provided quantitative threshold conditions to a transportation professional in determining the need for a particular traffic control device, essentially, and “if … then” scenario. Specifically for traffic signal control, the Ontario MUTCD warrant once served as a determinant in establishing funding from the Ministry of Transportation of Ontario for installation. Revised OTM Book 12 and recent revisions to the Canadian and US MUTCD have tended to move away from hard and fast “break points” to guidance type warranting criteria and engineering judgement. This trend recognizes that fact that a “one size fits all” approach cannot be applied to traffic control from one location to the next.

Current warranting procedures provide the transportation professional with a “tool” to evaluate the potential operational or safety benefits (and disbenefits) of traffic control devices, based on normal conditions.

Safety Versus Security and Capacity – In many cases, traffic control devices/changes such traffic signals, roundabouts, speed limit reductions, all-way stops and pedestrian signals are viewed as the “cure all” for many of the operational and safety concerns on our road networks. In many cases, the original intent of the request was to “improve safety”; however, if incorrect measures are applied, the net safety of the location may be reduced. The focus of recent research activities has centred on real safety impacts and benefits of a particular traffic control device, to counter the “it will improve safety” type request. An example of this would be the installation of an all-way stop control on a four lane major roadway with a minor residential street to improve pedestrian safety. In this case, pedestrian safety is actually decreased due to “multiple threat” of the two vehicle approaches, reduced sight lines and low motorist compliance on the major street due to low side street volume.

Road User Behaviour Considerations - Road users build expectancies about future roadway and traffic control operations and treatments, based on past experiences. The general road user has little or no knowledge of the warranting procedures outlined in engineering manuals, but what they do know is based on a relatively constant application of personal expectancies of where traffic signals, stop controls and pedestrian crossing may be encountered. When an atypical traffic control device is installed at a location, the road user may be ill-prepared to perceive and react to the situation or hazard. One of the primary purposes of warranting procedures is to provide a relatively consistent approach to traffic control within and among jurisdictions. There are many examples of municipalities and jurisdictions installing supplementary warning and information signs in an attempt to address motorist misunderstanding of a poorly designed or placed traffic control devices. Examples include:

- All-way stop control at multilane arterial roadway intersection with a minor residential street where side street traffic is infrequent and road users on the major roadway exhibit poor compliance. Other poor applications include the placement of all-way stop control at private driveways to municipal roadways or on a ninety degree corner in a residential area;

- A mid-block pedestrian crossing provided at a location where motorists become accustomed to few interrupts by pedestrians (low crossing pedestrian volume), and are surprised when the crossing is used;

- Closely spaced traffic signal controls that cause motorists to become confused by viewing contradicting signal displays from downstream signals; and

- Unreasonably low posted speed on a major roadway cause significant speed differentials between compliant road users and those proceeding at a comfortable speed.

4.2 Other Warrants

Based on our review, a number of additional traffic control warrant-type procedures were identified; however, were not documented in detail as they can be referenced as stand-alone guidelines, including:

- School crossings/school crossing guard;

- Traffic calming devices; and

- Audible Pedestrian Signals (APS).

5. POLICY OPTIONS

Based on a review of the existing City of Waterloo warrants and practices, and those being applied in other jurisdictions, three policy options were identified for the City dealing with traffic controls:

- Provide additional warrants for traffic control devices not currently covered by the City's warranting procedures;

- Modify existing City warrants to adhere to provincial/federal standards and/or recent research findings; or

- Maintain existing City warrants.

Each of these options is outlined below.

5.1 Additional Warrant Applications

The City's and the Region's existing traffic control device warrants encompass the major traffic control devices, which typically have formal warranting procedures. Based on a review of other jurisdictional practices, a review of new warrants for consideration by the City of Waterloo is provided below:

- **Audible pedestrian signals (APS)** – Jurisdictions across Canada and the US have established policies for installing APS, ranging from general guidelines to highly structured rating systems with minimum point systems. Other municipalities rely on a less "value or numbers based" approach to prioritize their APS installations through a committee selection process with representatives for the visually impaired community. From current research efforts in the area of APS, it appears that the latter process of guidelines paired with a committee-recommended priority listing is the preferred method. As such, it is not recommended that an APS device "warrant" be established.

- **Marked pedestrian crossings** – A number of jurisdictions permit the use of marked pedestrian crossing locations at uncontrolled locations, with the inclusion of pedestrian crossing signs. Currently, owing mainly to liability issues, the City does not permit these uncontrolled applications except as designated school crossings. Recent research (Zegeer at al) indicates there may be situations, such as on low volume two-lane roads or in low speed situations such as downtown areas, where marked crossings at uncontrolled locations may be permitted. However, in these cases no net benefit in safety was identified, so it is recommended that the City maintain their position of no marked crossings at uncontrolled locations.

In summary, it is not recommended that the City pursue the development of formal warrants beyond those that they currently have in place.

5.2 Maintain and Support Existing Warrants

The City's existing warrants appear to represent fair and consistent guidelines for traffic control device application. The City should monitor any developments in the area of traffic control warrants, to determine the need to update their policies based on any future research.

It is recognized that warrants are established to apply to "typical" or "normal" roadway, intersection or road user operating conditions. There may be instances the warrants are not met and where engineering judgement must prevail due to special circumstances or site-specific conditions. These may include, but not be limited to, situations where:

- Atypical physical or operational road or pedestrian network characteristics exist;

- Positive guidance or human factors considerations prevail over the standard warranting procedures from a road user safety perspective; and
- Road users in the area have special needs, i.e., older pedestrians, cyclists or motorists, young pedestrians or cyclists or pedestrians will visual or hearing impairments.

6. POLICY RECOMMENDATIONS FOR CITY OF WATERLOO TRANSPORTATION MASTER PLAN

It is recommended that the City maintain their existing traffic control device warrants, and introduce the new warrants for the use of roundabouts presented in this paper. By maintaining and expanding the City's existing traffic control device warrants, the following benefits may be realized:

- Provide a relatively consistent application of traffic control;
- Establish priority funding of traffic control devices in a fair and logical approach;
- Reduce cases where traffic control is excessive or inappropriate, which causes additional person-delay and emissions;
- Reduce the potential for road user apathy and non-compliance, which may lead to an increase in collision potential;
- Facilitates the ability to effectively regulate and enforce traffic regulations and by-laws; and
- Provide the development community with a benchmark for establishing appropriate traffic control devices related to their development proposal impact.

In terms of implementing these recommendations, it is recommended that City staff, in association with the Region of Waterloo as required, continue to provide advice and documentation to Council on the appropriateness of proposed traffic control devices and that the impacts of varying from approved warrants be clearly documented.

In addition, the City should pursue opportunities to educate the public with regards to proper traffic control applications and the reasons behind the warrants that they have established. The City's existing web site, in association with the Region's web site, can both include valuable resource information relating to transportation matters such as a Speed Watch Program, Red Light Cameras, roundabout use, truck routes, the bicycle network, etc. The City's web site and public correspondence (i.e., public information centres, responses to resident inquiries) are also good opportunities to provide the general information to inform residents of the rationale behind their warranting procedures.