PEDESTRIAN SAFETY IN ROUNDABOUTS

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Abstract

Roundabouts are becoming a more common type of intersection in Canada. A roundabout traditionally has no traffic control device such as traffic signals allocating the right-of-way between motorists and pedestrians. The pedestrian must decide when it is safe to step into the crosswalk and cross at a roundabout and the motorist must adjust their behaviour appropriately as they encounter waiting or crossing pedestrians.

This paper examines the pedestrian/vehicle collision patterns at roundabouts from several municipalities in Ontario, compared to signalized intersections with similar vehicular and pedestrian volumes. The paper develops a method to calculate pedestrian collision rates. It then identifies the pedestrian collision rates, the severity of the collisions, collision characteristics including background conditions and driver and pedestrian characteristics, implications with respect to human factors, and recommended improvements to data collection for pedestrian/vehicle collisions in roundabouts and at signalized intersections.

Introduction

Modern roundabouts started appearing on Ontario roadways as early as 2001. The City of Ottawa first introduced a single-lane roundabout in January 2001. Since then, modern roundabouts have been slowly gaining in popularity amongst road authorities across Ontario. The City of Hamilton became one of the first road authorities in Canada to build a multi-lane roundabout in 2002. The Region of Waterloo built its first roundabout in 2004 and now operates 17 roundabouts in total on its road network. All but three roundabouts in the Region of Waterloo are two-lane multi-lane roundabouts. The Cities of Ottawa and Hamilton now operate 14 and 5 roundabouts respectively. The County of Wellington built their first roundabout in an area frequented by tourists in 2009.

A modern roundabout traditionally has no traffic control device such as traffic signals allocating the right-of-way between motorists and pedestrians. The pedestrian must decide when it is safe to step into the crosswalk and cross at a roundabout and the motorist must adjust their behaviour appropriately as they encounter waiting or crossing pedestrians. The growing number of modern roundabouts in operation allows a preliminary assessment of pedestrian safety in roundabouts, through a comparison of pedestrian/vehicle collision rates and patterns at intersections with roundabouts and at signalized intersections.

Development of Average Annual Daily Pedestrian Volumes

Typically, the motor vehicle collision rate at an intersection is expressed as collisions per one million vehicles entering (vehicle collisions/MVE). The vehicle collision may be calculated for a five-year period, for example, using the Annual Average Daily Traffic (AADT) volume entering the intersection and the number of vehicle collisions at the intersection as follows:

$$\text{Vehicle collision rate} = \frac{\text{number of vehicle collisions in five years x 1,000,000}}{\text{AADT volume entering x 365 days/year x 5 years}}$$

This report is intended to address and compare pedestrian collisions rather than motor vehicle collisions at intersections and roundabouts, and therefore collision rates are expressed as pedestrian collisions per one million pedestrians entering (pedestrian collisions/MPE). To produce collision rates for pedestrians expressed in these terms, Average Annual Daily Pedestrian (AADP) volumes entering the intersection are required. For example, over a five-year period, the pedestrian collision rate for an intersection may be calculated as:

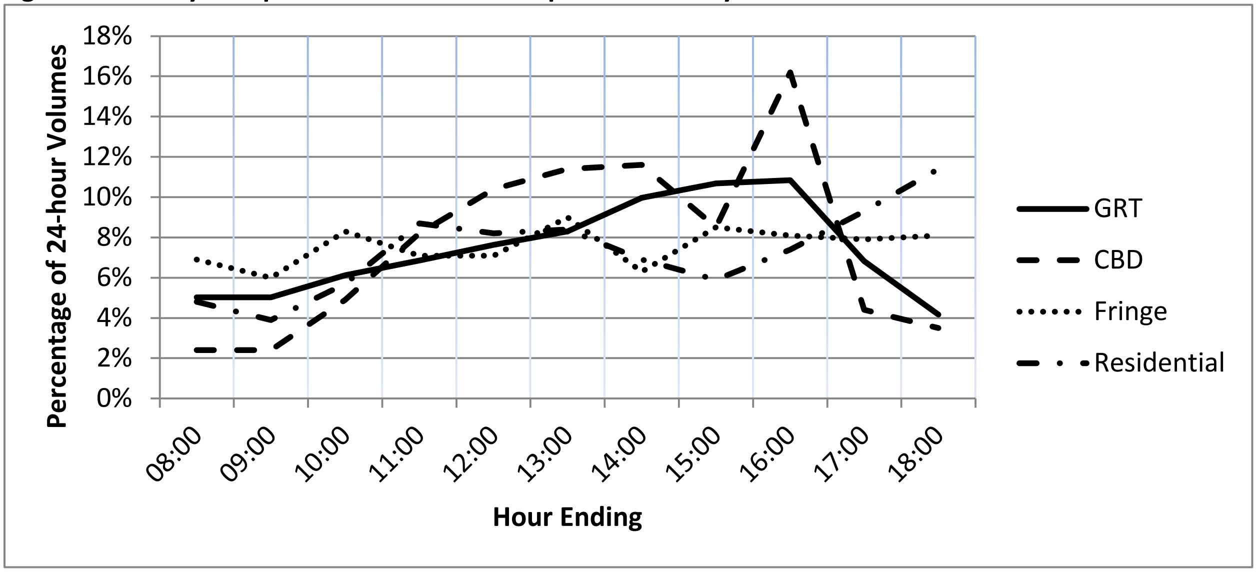
$$\text{Pedestrian collision rate} = \frac{\text{number of pedestrian collisions in five years x 1,000,000}}{\text{AADP volume entering x 365 days/year x 5 years}}$$

AADP volumes are not readily available. Road authorities typically do not obtain 24-hour pedestrian volumes and to date it has not been a typical practice to develop and analyse pedestrian collision rates. Therefore the AADP had to be established to develop pedestrian collision rates as part of this assessment.

Typically pedestrians are counted over eight hours that cover the morning, midday and afternoon peak hours. Presently there is no standard methodology to convert these eight-hour pedestrian counts into AADP volumes. To establish AADP volumes given only eight-hour pedestrian volume data, adjustment factors had to be developed using the hourly distribution of pedestrian volumes over 24 hours. With no 24-hour pedestrian counts available, the hourly distribution of roadway pedestrian volumes over 24 hours was estimated from transit ridership data. The transit ridership data included the number of passengers boarding and alighting from Grand River Transit (GRT) in the Region of Waterloo, using transit passenger data collected at 15 bus stops along Hespeler Road, in the City of Cambridge, Ontario over 22 weekdays in the month of January 2012. No GRT passenger data is available for the hours ending 1am to 5am because there is no GRT service during those hours. It is assumed that these late-night hours also have effectively no roadway pedestrian activity.

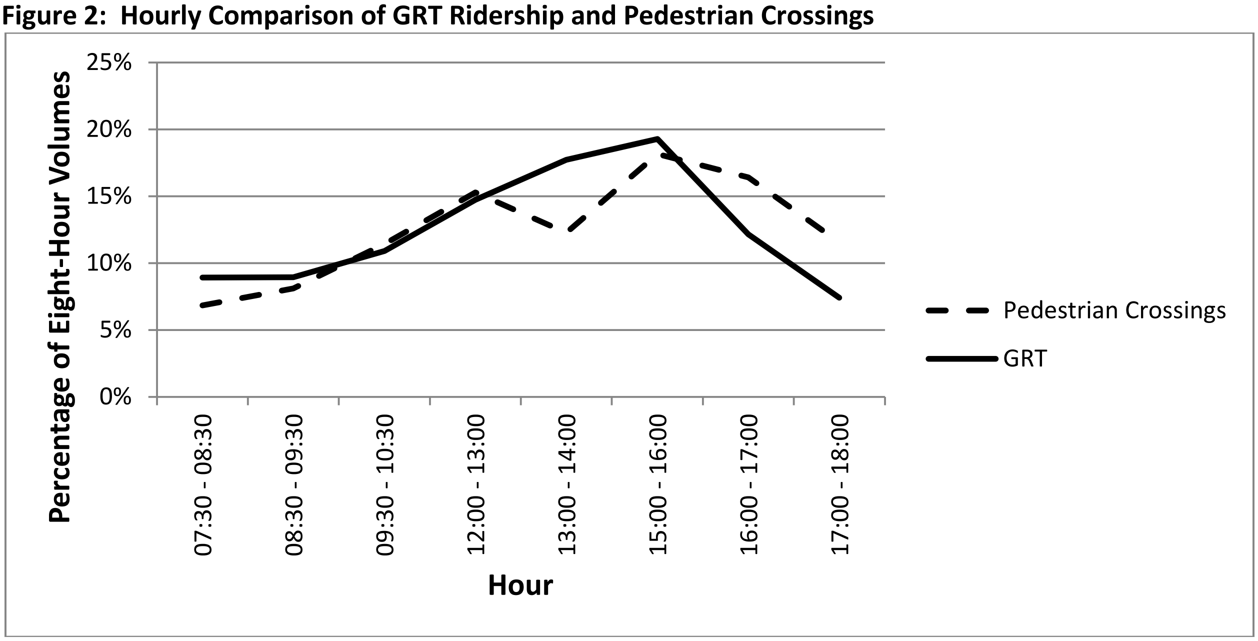
The GRT hourly ridership distribution was compared to time of day and area type adjustment factors developed and used by Zegeer et al. as part of a study assessing and comparing pedestrian collision rates at marked and unmarked uncontrolled crosswalks(1). Zegeer et al. also found that the 12-hour daily period from 7a.m. to 7p.m. represented approximately 86 percent of the 24-hour daily pedestrian volume based on 24-hour pedestrian counts completed in Seattle, Washington(2). Figure 1 compares the hourly distributions for GRT ridership and for roadway pedestrians, as developed by Zegeer et. al. for Central Business District (CBD), fringe and residential areas. The distributions are similar, indicating that the hourly distribution of GRT ridership is a reasonable estimate of the hourly distribution of roadway pedestrian activity.

Figure 1: Hourly Comparison of GRT Ridership and Roadway Pedestrian Volumes



As a follow-up analysis, the hourly distribution was compared for GRT ridership and for pedestrian crossing activity at signalized intersections. The GRT ridership data was taken from 15 bus stops on Hespeler Road over 22 days in January 2012. The pedestrian crossing activity was taken from 10 signalized intersections on Hespeler Road during a typical eight-hour count period, counted between 2010 and 2012. Figure 2 indicates that the hourly distribution is similar for the GRT ridership and the pedestrian crossing activity, confirming that the hourly distribution of GRT ridership is a reasonable estimate of the hourly distribution of roadway pedestrian activity.

Figure 2: Hourly Comparison of GRT Ridership and Pedestrian Crossings



Lastly, peak-hour/eight-hour ratios of GRT ridership and pedestrian roadway crossings were developed. Morning, midday and afternoon peak hours were considered. The ratios for the pedestrian roadway crossings were based on all eight-hour pedestrian counts undertaken in the Region of Waterloo in 2011 and 2012, at 281 signalized intersections. The ratios for GRT ridership were based on transit ridership data for typical 8 hour periods at 15 bus stops on Hespeler Road over 22 days in January 2012. Table 1 shows that the ratios are similar for GRT ridership and for pedestrian roadway crossings, again confirming that the hourly distribution of GRT ridership is a reasonable estimate of the hourly distribution of roadway pedestrian activity.

Table 1: Comparison of Peak-Hour/Eight-Hour Ratios for GRT Ridership and Pedestrian Crossings

	Morning	Midday	Afternoon
GRT Ridership	0.09	0.15	0.12
Pedestrian Roadway Crossings	0.12	0.15	0.13

Figure 3 shows the hourly distribution of GRT ridership over 24 hours, based on the sample of 15 Hespeler Road bus stops over 22 days in January 2012. Based on the above analysis, it is assumed that this is also the hourly distribution of roadway pedestrian activity. The Hespeler Road GRT ridership data was used to develop factors to convert eight-hour pedestrian count data to AADP volumes. The factors were used to first convert the eight-hour volumes to 24-hour volumes, and then adjust for the day of week and the month.

Figure 3: Hourly Distribution of GRT Ridership Over 24 Hours

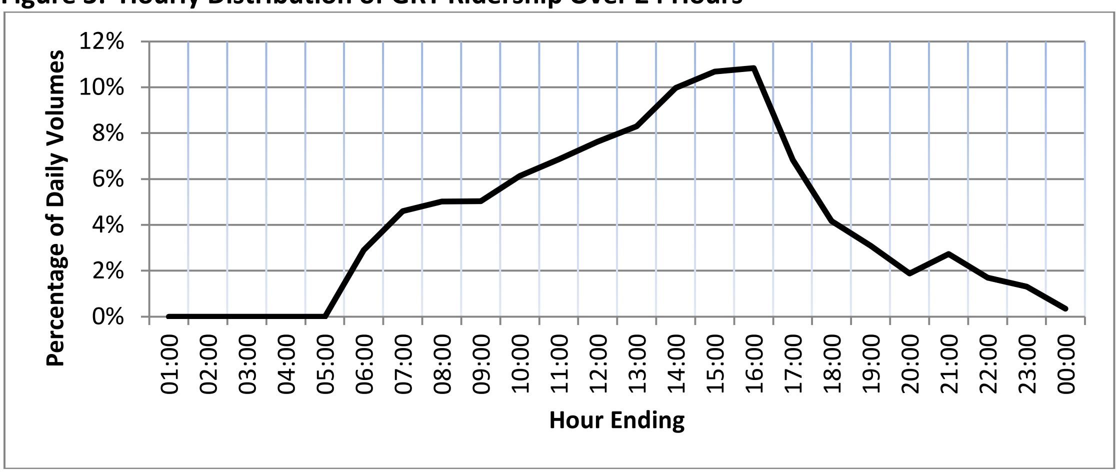


Table 2 shows the estimated hourly distribution of roadway pedestrian volumes over 24 hours. Note that the 12-hour period from 7a.m. to 7p.m. represents approximately 84% of the 24-hour daily roadway pedestrian volume, similar to the 86% found by Zegeer et al. for that same time period. Approximately 56% of 24-hour roadway pedestrian activity occurs in the hours that are generally included in eight-hour pedestrian counts; therefore the 24-hour/eight-hour factor is 1.79. A similar method was used to determine the 24-hour/four-hour factor for some four-hour pedestrian counts in the roundabout sample.

Table 2: Hourly Distribution of Pedestrian Volumes Over 24 Hours

Hour Ending	Hourly Distribution (%)	Hour Ending	Hourly Distribution (%)
01:00	0	13:00	8*
02:00	0	14:00	10*
03:00	0	15:00	11
04:00	0	16:00	11*
05:00	0	17:00	7*
06:00	3	18:00	4*
07:00	5	19:00	3
08:00	5*	20:00	2
09:00	5*	21:00	3
10:00	6*	22:00	2
11:00	7	23:00	1
12:00	8	00:00	0

* Hours generally included in eight-hour counts.

Tables 3 and 4 show the Daily and Monthly Factors to adjust the AADP for the day of week and the month. These factors are based on system-wide GRT ridership data from May 2011 to April 2012 (a sample of over 20 million passengers).

Table 3: Daily AADP Factors

Day of Count	Weekly Distribution (%)	Weekday AADP Factor
Monday – Friday	16.8	0.85
Saturday	10.0	1.43
Sunday	6.0	2.38

Table 4: Monthly AADP Factors

Month of Count	Yearly Distribution (%)	Monthly AADP Factor
January	9.5	0.88
February	8.9	0.94
March	9.9	0.84
April	8.3	1.00
May	7.7	1.08
June	7.5	1.11
July	5.7	1.46
August	5.2	1.60
September	9.3	0.90
October	9.7	0.86
November	9.9	0.84
December	8.3	1.00

Intersection Sample

In an effort to collect sufficient data on pedestrian/vehicle collisions in roundabout intersections, several Ontario road authorities were approached and requested to provide data for modern roundabouts in operation today under their jurisdiction. The data included traffic volumes, pedestrian volumes, pedestrian collision data, and roundabout opening dates. Table 5 below summarizes the road authorities who provided the roundabout data used in this paper and the number of modern roundabouts operating in their jurisdiction in 2012.

Table 5: Road Authorities That Contributed Roundabout Data

Road Authority	Number of Roundabouts
Region of Waterloo	17
City of Ottawa	14
City of Hamilton	5
County of Wellington	1
City of Mississauga	1
Region of Durham	1
Total	**39**

Nine other Ontario road authorities with a combined 9 roundabouts in operation were approached but were unable to provide count or collision data for their respective roundabouts because of resource issues, the roundabout being too new or a lack of pedestrian crossings. Most of these road authorities were however able to advise that, to the best of their knowledge, they were unaware of any pedestrian collisions occurring at their roundabouts. These anecdotal observations were noted, but did not form part of the assessment.

Comparable data on pedestrian/vehicle collisions at signalized intersections was drawn from the Region of Waterloo traffic and collision database. The data included traffic volumes, pedestrian volumes, pedestrian collision data, and the date of the signalization of the intersection. Overall, the roundabout intersections had AADP volumes ranging from 0 to approximately 1,600 pedestrians, and AADT volumes ranging from approximately 1,500 to 38,000 vehicles. Only signalized intersections that had volumes within these ranges were included, resulting in a sample of 328 signalized intersections.

To control for traffic and pedestrian volumes, the intersections were further categorized by ranges of volumes. The two ranges for AADP volumes included 0 to 100 pedestrians; and 101 to 1600 pedestrians. The three ranges for AADT volumes included 1,500 to 10,000 vehicles; 10,001 to 20,000 vehicles; and 20,001 to 38,000 vehicles. Finer ranges were not used because of the limited sample of roundabouts. Table 6 summarizes by intersection category the number of intersections, the number of pedestrian collisions, and the AADT and AADP volumes.

Table 6: Intersection Characteristics by Intersection Category

	AADT \ AADP	Roundabout Intersections 0 to 100	Roundabout Intersections 101 to 1,600	Signalized Intersections 0 to 100	Signalized Intersections 101 to 1,600
Number of Intersections	1,500 to 10,000	5	7	6	18
	10,001 to 20,000	8	8*	39	110
	20,001 to 38,000	7	4	39	116
Number of pedestrian collisions	1,500 to 10,000	0	0	0	10
	10,001 to 20,000	0	6*	10	79
	20,001 to 38,000	1	2	8	143
Average AADT entering the intersection	1,500 to 10,000	4,934	4,135	9,031	7,147
	10,001 to 20,000	16,154	14,570	15,189	15,630
	20,001 to 38,000	23,041	30,398	26,526	27,559
Average AADP entering the intersection	1,500 to 10,000	30	617	24	544
	10,001 to 20,000	29	566	40	458
	20,001 to 38,000	51	577	45	479

*Note: One of the eight intersections in this category experienced five of the six pedestrian collisions.

Pedestrian Collision Rates

Pedestrian collision rates were calculated using the number of pedestrian collisions and the AADP volumes for each intersection, for the operating life of the roundabout or traffic control signal, up to a maximum of five years. Table 7 summarizes pedestrian collision rates by intersection category. Except for one intersection category, the pedestrian collision rates are consistently less for the roundabouts than for the signalized intersections. It should be noted that in the roundabout intersection category with 101 to 1,600 AADP and 10,001 to 20,000 AADT volumes, there are eight intersections and six pedestrian collisions. However, five of these six pedestrian collisions occurred at one single roundabout. This single roundabout appears to be an anomaly that skews the collision rates for this cell.

Table 7: Pedestrian Collision Rates by Intersection Category

	AADT \ AADP	Roundabouts 0 to 100	Roundabouts 101 to 1,600	Traffic Control Signals 0 to 100	Traffic Control Signals 101 to 1,600
Pedestrian collision rate (pedestrian collisions/MPE)	1,500 to 10,000	0.00	0.00	0.00	0.57
	10,001 to 20,000	0.00	1.26	3.51	0.87
	20,001 to 38,000	1.94	1.24	2.50	1.41

Table 7 also shows a trend of "safety in numbers" for pedestrians for intersections with high traffic volumes, for both roundabouts and signalized intersections. For high traffic volume intersections, the pedestrian collision rates are lower if there are more pedestrians.

Pedestrian Collision Characteristics

Table 8 compares the pedestrian collision characteristics for roundabout and signalized intersections. Despite the small number of pedestrian collisions at roundabouts, the percentage distributions for the different characteristics are generally quite similar for roundabout and signalized intersections.

Table 8: Pedestrian Collision Characteristics

Characteristic		Number and % of Collisions	
		Roundabout Intersections	Signalized Intersections
Time of Day	• morning (5 to 11am) • afternoon (4 to 6pm) • evening (9pm) • other	4 (44%) 4 (44%) 1 (11%) 0 (0%)	60 (24%) 60 (24%) 15 (6%) 116 (46%)
Environment	• clear weather • rain • other	6 (66%) 3 (33%) 0 (0%)	185 (74%) 47 (19%) 19 (8%)
Light	• daylight • dark • dusk • other	5 (56%) 2 (22%) 1 (11%) 0 (0%)	151 (60%) 94 (37%) 5 (2%) 1 (0%)
Vehicle Type	• automobile or passenger van • municipal transit bus • other	8 (89%) 1 (11%) 0 (0%)	221 (88%) 1 (0%) 29 (12%)
Apparent Driver Action	• failed to yield the right of way • driving properly • following too close • lost control • other	5 (56%) 2 (22%) 1 (11%) 1 (11%) 0 (0%)	160 (64%) 46 (18%) 2 (1%) 1 (0%) 42 (17%)
Driver Condition	• normal condition • inattentive • medical or physical disability • other	4 (44%) 4 (44%) 1 (11%) 0 (0%)	94 (37%) 121 (48%) 1 (0%) 35 (14%)
Pedestrian Action	• crossing with the right of way • crossing without the right of way • other	6 (66%) 2 (22%) 1 (11%)	179 (71%) 37 (15%) 35 (14%)
Pedestrian Condition	• normal condition • inattentive • other	7 (78%) 2 (22%) 0 (0%)	194 (77%) 29 (12%) 28 (11%)
Pedestrian Injury	• none • minimal • minor • major • fatal	2 (22%) 3 (33%) 3 (33%) 1 (11%) 0 (0%)	26 (10%) 89 (35%) 112 (45%) 22 (9%) 2 (1%)

Implications with respect to Human Factors

The configuration and operation of roundabouts and signalized intersections may result in different human behaviours. The generally lower pedestrian collision rate at roundabouts compared to signalized intersections may be because:

- The driver has more time to judge and react to pedestrians because of the slower speeds;
- The pedestrian only has to watch for traffic in one direction at a time;
- With no traffic control signal to divert the driver's attention upward, the driver is focused on the vehicles and pedestrians around them;
- The driver is more likely to be looking in the direction of the pedestrian. When turning at a signal, the driver is often watching for conflicting traffic and not where they are going, e.g. looking left while turning right; and
- The driver and pedestrian are more likely to be alert and aware of each other because the driver and pedestrian have to decide when to go.

Conclusions and Recommendations

This preliminary analysis of pedestrian safety at roundabouts indicates that pedestrian collision rates are generally lower at roundabouts than at signalized intersections with comparable traffic and pedestrian volumes. Although the pedestrian collision rates are generally lower at roundabouts, the characteristics of the collisions that do happen are quite similar at roundabouts and signalized intersections.

For high traffic volume intersections, the pedestrian collision rates are lower if there are more pedestrians, for both roundabouts and signalized intersections.

Given the generally lower pedestrian collision rates at roundabouts, road authorities should continue to explore possible applications of roundabouts for intersections that are new or that are undergoing major improvements or that are experiencing high pedestrian collision rates.

With respect to improvements to data collection, road authorities should include roundabouts in their traffic count program. In addition, it would allow a more detailed analysis of pedestrian safety at intersections if road authorities were to regularly include pedestrian counts in their count program, at all counted intersections.

References

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2. Zegeer, C.V., Opiela, K.S., and Cynecki, M.J., (1985). *Pedestrian Signalization Alternatives* Report No. FHWA-RD-83-102, Washington, DC, Federal Highway Administration

Acknowledgements

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