IDENTIFYING AND ADDRESSING ROUNDABOUT ACCESSIBILITY ISSUES CONFRONTING PERSONS WITH VISION LOSS IN CANADA: A PILOT STUDY

by

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ABSTRACT

Municipalities and Transportation Agencies in Canada are building more roundabout intersections to promote efficient and safe movement of traffic for their low carbon footprint, low lifetime maintenance cost, and better safety performance thereby reducing collision frequency and severity, among other benefits. The main disadvantage is that Persons with Vision Loss (PWVL) feel unsafe when crossing the street on roundabouts.

One of the objectives of this research project is to identify the concerns and challenges experienced by PWVL on roundabouts in Canada through a workshop and opinion surveys involving participants scattered across the country. Another objective is to conduct a field study assessing if the installation of sound strips on the road could help PWVL when deciding to cross the streets on the roundabout in Thunder Bay. To achieve these objectives the research team collaborated with the City of Thunder Bay, the staff, and clients of the Canadian National Institute for the Blind (CNIB) to plan and facilitate various events. It should be mentioned that 3D models of roundabout were used in training and to illustrate points relevant to roundabout accessibility when discussing with PWVL and other stakeholders.

Seven volunteers from CNIB were present each time that field study was done on the four approaches used at the roundabout both at the initial stage when nothing was placed on the road, and later after the strips were installed. Data analysis was subsequently done for vehicle speed, delay felt by PWVL, as well as the percentage of vehicles that yielded to pedestrians with the results showing that 57 percent of the people who took the survey indicated they would need any available accessibility aid to navigate the roundabout.

Also, the majority of the vehicles monitored had a final speed that exceeded the initial speed on the approach to the crosswalk, with a few of the vehicles exceeding the maximum allowed 40 KPH speed on the roundabout. Similarly, 57.33 percent of vehicles yielded to pedestrians before the treatment was installed and 40.60 percent of vehicles yielded to pedestrians after the treatment was installed on the roundabout. Meanwhile, the average delay felt by each pedestrian on the crosswalk reduced from 41.39 seconds before the sound strip was installed to 38.34 seconds after the installation. Notably, the feedback received was positive on the 3D models used. However, 2 of 54 vehicles that yielded to pedestrians on the crosswalk did stop without reaching the first row of strips.

Finally, results from this pilot study are expected to provide insight into the concerns of PWVL regarding roundabouts, forming the basis for further investigation into ways of making roundabouts more accessible for PWVL, which is an ongoing concern not only for this population group but also Transportation professionals and stakeholders in Canada.

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LIST OF ACRONYMS

ABS	Acrylonitrile Butadiene Styrene
AI	Artificial Intelligence
APS	Accessible Pedestrian Signal
AV	Autonomous Vehicle
CNIB	Canadian National Institute for the Blind
CORE	Course on Research Ethics
EV	Electric Vehicle
FHWA	Federal Highway Administration
ITE	Institute of Transportation Engineers
LU	Lakehead University
MUTCD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
PRT	Perception Reaction Time
PVC	Poly Vinyl Chloride
PWVL	Person(s) or People With Vision Loss
REB	Research and Ethics Board
RRFB	Rectangular Rapid Flashing Beacon

TAC	Transportation Association of Canada
TWSI	Tactile Walking Surface Indicator

CHAPTER 1. INTRODUCTION

This chapter contains background information on the topic of this research project, the scope of the work and the objective of the research as well as an outline of the organization of the report.

1.1 Background

Municipalities and Transportation Agencies in Canada are building more roundabout intersections due to the geometry that compels low travel speed for vehicles, and thus enhancing traffic calming, efficiency and safety. Also, roundabouts help limit environmental pollution by minimizing wait time and delay in traffic that is otherwise experienced at conventional intersections, and therefore reducing carbon footprint of the intersection. Also, with no signals installed, the roundabout has low lifetime costs as an advantage. However, despite its growing popularity in North America, roundabouts pose a set of unique challenges to pedestrians with vision loss who must rely on hearing and sound cues to find gaps in traffic for safe navigation. Furthermore, having electric and autonomous vehicles, silent operators that are growing in number, on the roundabout makes the situation even riskier for this group of pedestrians.

Hence, the need for this study to investigate how roundabouts accessibility impacts Persons with Vision Loss (PWVL) and the issues or challenges that this particular group of the population has at these locations. Moreover, the study will search how jurisdictions in Canada and elsewhere in the world equip roundabouts with extra accessibility features, beyond the minimum requirement, in an effort to enhance safety for vulnerable pedestrians - especially PWVL. Subsequently, a pilot study will be conducted to test the effectiveness of an accessibility feature at roundabouts.

1.2 Scope of Work

The scope of work for this research project is to plan and host a national workshop, conduct an opinion survey and perform a pilot study considering a simple mechanical solution to the perceived problem, and collecting data on a site in Thunder Bay with the participation of local volunteers with vision loss.

1.3 Research Objectives and Significance

The main objectives of this research are to determine the concerns and challenges faced by PWVL when navigating the roundabout, and to test the effectiveness of a mechanical treatment in helping PWVL when deciding to safely cross the streets on the roundabout. To achieve these objectives, a comprehensive literature review will be completed on what has been done in Canada, as well as other countries around the globe, about roundabout accessibility for PWVL. Moreover, a field study at a roundabout in Thunder Bay will be performed to complete the objectives.

Minor objectives, or steps taken to accomplish the main objectives of this research are as follows:

- To obtain authorization from Lakehead University's Research and Ethics Board in order to conduct research involving human volunteers
- To contact and plan with the Canadian National Institute for the Blind (CNIB), national workshop and opinion survey in order to reach PWVL all across Canada and contact volunteers for the field study

- To schedule and conduct the national workshop in collaboration with CNIB
- To prepare and conduct the online survey with CNIB
- To prepare and test the mechanical treatment at Lakehead University campus
- To evaluate and prepare the data collection process at the roundabout in Thunder Bay
- To use a 3D model of a roundabout in conversations about accessibility with stakeholders and participants
- To collaborate with CNIB in planning, as well as meeting volunteers on site for data collection
- To install the mechanical treatment in collaboration with the City of Thunder Bay, a construction company and people from LU
- To collect data at the site with volunteers before and after the treatment has been installed
- To analyze the data collected and determining the concerns of PWVL and the effectiveness of the mechanical treatment
- To do safety analysis of the intersection using collision reports obtained from Thunder Bay Police Department spanning the period of time preceding the building the roundabout until the period of time after the roundabout has been built.

Achieving these objectives will provide a boost to the level of knowledge needed by PWVL to navigate this type of intersection. Results of this research project can ultimately help PWVL make informed decisions when crossing the street at the roundabout regardless of driver's behavior and other factors that are beyond the pedestrian's control.

In other words, the significance of this research is to investigate roundabout accessibility and safety for PWVL using Thunder Bay as the case study of the situation in Canada.

This is a pilot study without funding and, as such, there is a limited ability to collect data. Nevertheless, the research work is considered to be extremely valuable, forming a basis for future research on an important topic that can be extended to the concerns of older populations on the roundabout and other transportation facilities.

1.4 Organization of the Thesis

This thesis report consists of five chapters. The first chapter presents the introduction of the research topic as well as the objectives of the research. The second chapter includes a comprehensive literature review related to roundabouts and accessibility at these locations. In chapter three, sections 3.1 to 3.4.3 describe the methodology used for identifying concerns and issues related to roundabouts accessibility and PWVL. Although there is possibility for different concerns and issues to consider, as well as numerous ways of tackling them under various conditions. Sections 3.4.4 to 3.6.1 cover the simple mechanical solution used in this research to test its effectiveness in relation to the issues and problems identified at the roundabout. Chapter 4 shows the results obtained from analyzing the data collected via survey and field study including recorded video material related to identifying and addressing concerns from PWVL on roundabouts. Finally, discussions of results and inferences drawn from this research project are included in Chapter 5. The last chapter also presents a brief insight into possible future research that might be built upon findings from this pilot study.

CHAPTER 2. LITERATURE REVIEW

This chapter presents a comprehensive review of literature on basic information pertaining to roundabouts, accessibility considerations given to roundabouts in different countries, as well as relevant considerations given by PWVL to this type of intersection in the transportation network.

2.1 Background

Persons with vision loss may need help when identifying crosswalk locations, refuge islands, curbs, and ramps within the transportation network. The person will likely misjudge oncoming vehicle's speed and distance or misread the driver's intentions or not see or detect the vehicle at all. There is no on-the-spot training available at every (new) location where PWVL need to cross. So, even when led by a guide dog, the decision is for the human to make, something that can be problematic if adequate information is not available or is misleading.

Tactile Walking Surface Indicators (TWSI) and other features embedded in the ground and structures, or audible signals from control signs along the way, can be particularly helpful in guiding PWVL as long as the locations follow a common and logical pattern as found at regular intersections.

The types of location that are different, for which specific considerations are necessary for PWVL, are traffic – circles, rotaries generally as well as roundabouts. Although, traffic – circles and rotaries have been in North America for a long time, modern roundabouts are relatively new in this part of the globe [1] where about 50,000 are estimated to exist currently.

A roundabout may replace the intersection of single or multilane roadways [1]. The roundabout as a circular intersection, allows for traffic to flow in an anti-clockwise pattern with a travel speed below 50km/h [1]. Furthermore, the roundabout is differentiated from other traffic circles used in traffic calming, by its design for speed reduction, while at the same time requiring drivers to yield on approach to others within the circulatory roadway.

When considering safety at intersections, the collision of vehicles can be very severe at conventional intersections especially when the vehicles collide perpendicularly, whereas the roundabout eliminates such collision pattern thus reducing the severity of crashes. Moreover, pedestrian-vehicle conflict points are up to 16 in a conventional intersection as compared to 8 on a roundabout, which is a big boost to road safety [2][3]. As with any other part of the transportation network, road traffic injury must be prevented as much as possible at intersections [4]. Additionally, keeping traffic at a relatively low speed on roundabouts is an advantage for pedestrians as long as drivers yield to pedestrian traffic.

Proponents of roundabouts often claim that vehicle-pedestrian collisions at roundabouts is not rampart, but a probable reason for such observation may be that pedestrians (PWVL) try altogether to avoid using the roundabout [1]. These pedestrians must face other risks in the alternative routes taken.

However, roundabouts are not without disadvantages [5]. One important disadvantage to consider is the difficulty that pedestrians, especially PWVL, experience when crossing the street. This is very relevant since the World Health Organization (WHO) estimated in 2021 that about 2.2 billion people are visually impaired globally [6].

Persons with vision loss rely on ambient sound and acoustic properties to determine and estimate in which direction traffic flows at any given time. This process of detection of traffic is relatively easy at conventional intersections since streets are connected at, or nearly at, a 90-degree angle. Whereas, such determination of traffic using sound cue is more difficult at roundabouts with its circular nature [1]. The noisy environment on the roundabout when vehicles go around the central island makes it hard and potentially misleading for PWVL to determine the direction of travel or how close vehicles are to the PWVL.

Furthermore, the pedestrian must start crossing the street appropriately in order to complete the process without conflict or collision [1]. For a regular pedestrian, the start of the process when crossing the road will require that the pedestrian looks in both directions of traffic and then make a decision, but the PWVL need to be convinced of traffic pattern based on sound, and be reassured when the overall noise in the area has subsided. This process is prone to error especially during rush hours when the background noise does not subside quickly [1].

Regarding safety at roundabouts, studies have shown that a combination of offset-approach design and signalized crosswalks can help reduce delays for vehicular traffic while providing pedestrians with the gap needed to cross a roundabout [7][8]. Also, from studies, it was learnt that the farther the crosswalk can be kept away from the circulatory roadway, the better protected the PWVL are [1]. That keeps the sound originating from the circulatory roadway far from interfering on the crosswalk, while allowing PWVL a longer section of the road where vehicles could be detected soon enough as the vehicles approach the crosswalk.

If rumble or sound strips are installed on the street before the crosswalk, the sound produced as a vehicle passes will alert PWVL of an approaching or passing vehicle [8]. Also, these rumble strips and the sound produced will keep drivers at alert as they approach the roundabout [9]. Note that, in order to avoid the nuisance sound originating from rumble strips, the strips are not allowed, by regulation, too close to residential areas.

It seems that accessibility will be tremendously improved for PWVL if vehicles are forced to yield on crosswalks by installing signals there. The signal should always show the green light to drivers, and when needed, in the process, give the pedestrian some green time to cross the street while the driver receives the red light. This is commonplace on conventional intersections. However, highway administrators in the USA do not encourage signalizing roundabouts [10]. Similarly, it appears that signalizing roundabouts is not a common occurrence in Canada either.

2.2 Roundabout Types

The types of roundabouts described briefly in the following subsections include Mini-Roundabout, Single–Lane Roundabout, Multi-Lane Roundabout, and Turbo Roundabout.

2.2.1 Mini-Roundabout

This type of roundabout, shown in Figure 1 below, has a maximum of one entering lane. It is used in low-speed urban environments where space is not sufficient for single-lane roundabouts. About 15 thousand vehicles per day are expected on this type of roundabout, where the central island is typically between 14 to 27 meters and mountable by large vehicles [11].

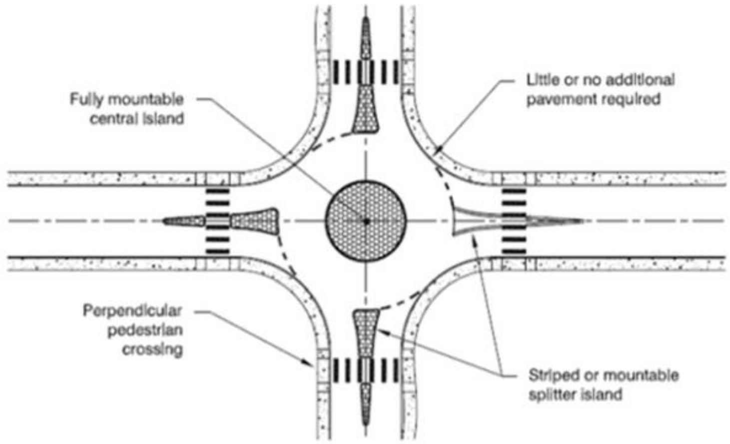


Figure 1: A Mini-Roundabout [11]

2.2.2 Single-Lane Roundabout

This type of roundabout has single-lane entrances and circulatory lanes as shown in Figure 2 below. The central island is typically about 28 to 60 meters wide and can be a mountable truck apron for large vehicles to maneuver. It has raised splitter islands and crosswalks [11].

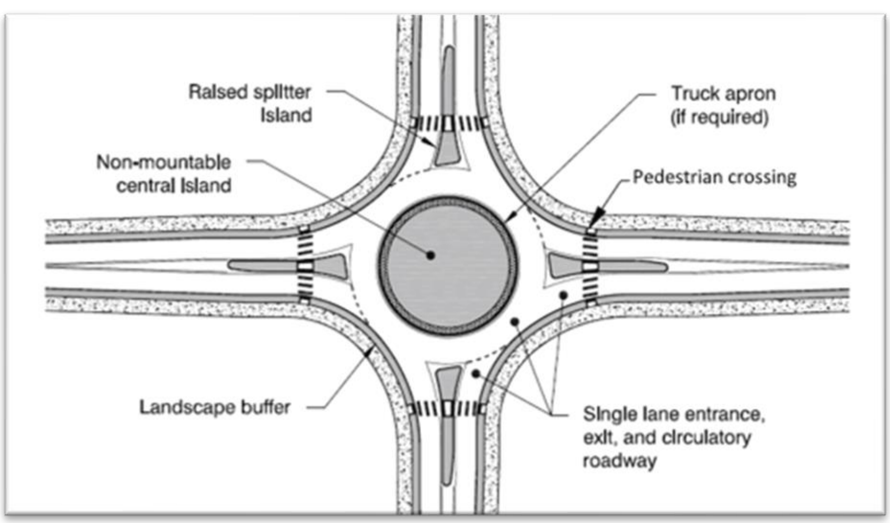


Figure 2: A Single-Lane Roundabout [11]

2.2.3 Multi-Lane Roundabout

As shown in Figure 3 below, a multi-lane roundabout has two or more lanes which may vary on one or more approaches. It contains non-traversable central islands, mountable truck apron, raised splitter islands, and crosswalks [11].

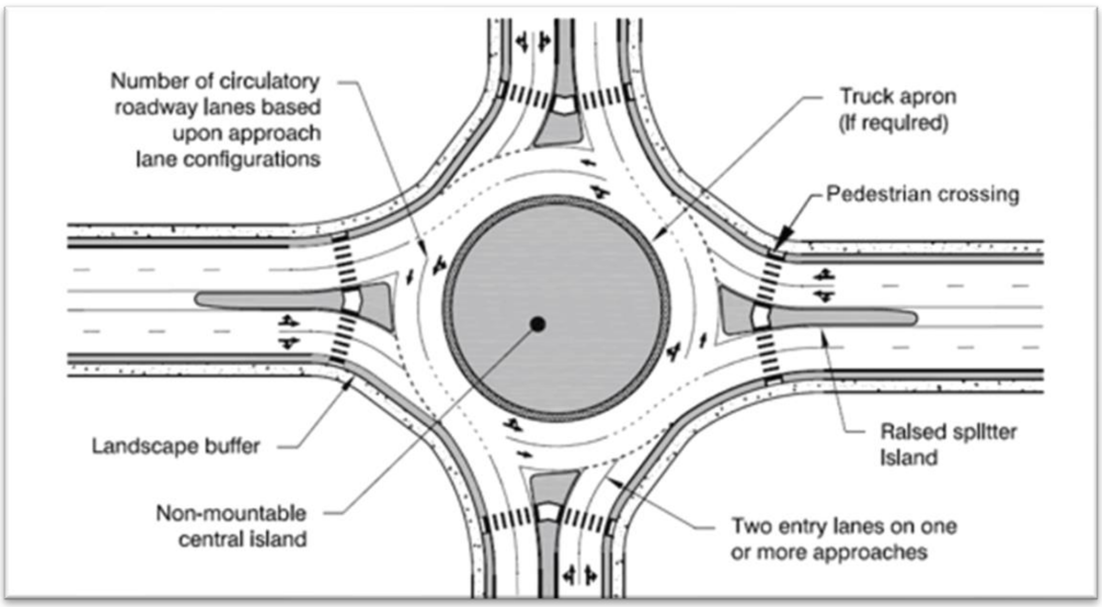


Figure 3: A Multi-Lane Roundabout [11]

2.2.4 Turbo Roundabout

This type, shown in Figure 4 below, is rare in Canada. Turbo roundabout was first designed in the Netherlands in 1996. It seems as if the multilane roundabout that is native to North America. Turbo roundabout allows vehicles to enter the system perpendicularly, and by design, keeps vehicle speed very low. Also, for enhanced safety of the roundabout, the curbs are designed to prevent lane changing within the roundabout [11].

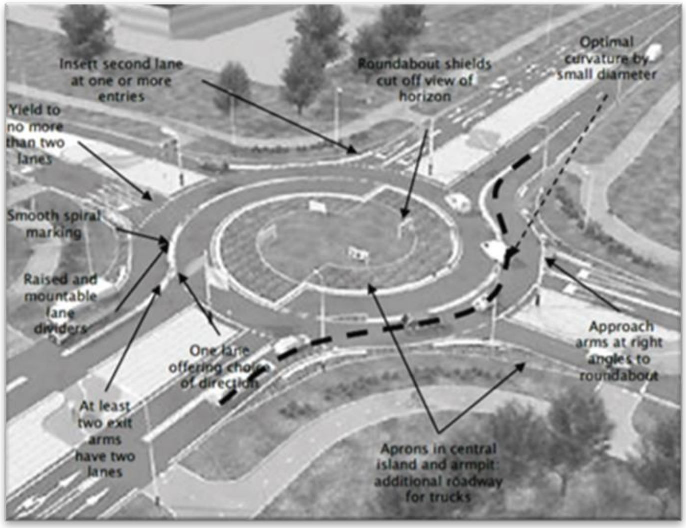


Figure 4: A Turbo Roundabout [11]

2.3 Roundabout Geometry

Some of the geometric design elements of the roundabout are for the entrances, circulatory roadway, splitter island, crosswalk, and central island. The focus here is on those elements that might impact vehicles and speed, such as the width of entry, exit lane width, entry angle and the circulatory roadway. Also, some attention is paid to the elements related to pedestrian crossing, such as the splitter island and the crosswalk [11]. Generally speaking, the larger the radius of a roundabout, the greater the speed of vehicles there, and the riskier it is for pedestrians crossing there [12].

The entry width (e), shown in Figure 5 below is the width of the road at the point of entry. It is also known as the total width of the lane which the driver can use effectively. On a single-lane approach, entry width should not exceed 6 meters, and 12 meters on a dual-lane approach [11]. Moreover, the width of the approach lane just prior to the entry lane flare is known as the approach half width (v) [11]. The exit width, however, is similar to the entry width and should be designed to keep exiting vehicles away from opposing traffic at the end of the splitter island [11].

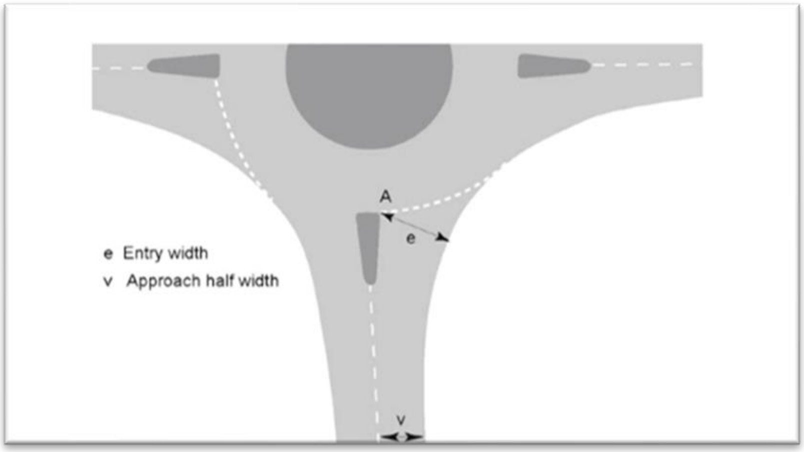


Figure 5: Entry Side [11]

Regarding the entry angle, the entry lane (Curve EF) illustrated in Figure 6 below, has a line BF projected onto another line on the circulatory roadway lane (Curve AD), subtending an angle ϕ (Phi) at C.

The entry angle Phi alludes to the conflict angle between the vehicle that is approaching the circulating traffic of vehicles within the roundabout. Optimally, angle Phi should be between 20 and 60 degrees. When approaching at a large entry angle with high speed, rear-end collision is quite likely to occur [11].

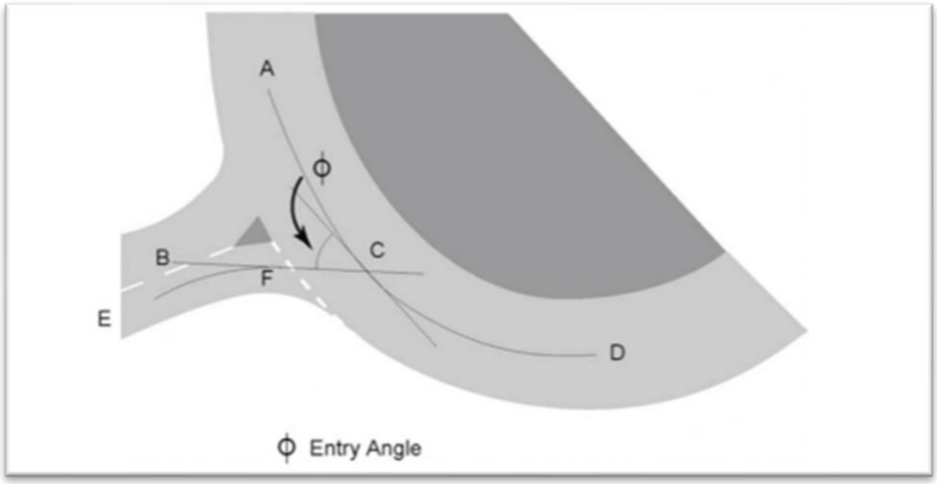


Figure 6: Showing Vehicle Entry Angle Phi (ϕ) [11]

The circulatory roadway in the roundabout should be about 4.2 to 7.2 meters in width depending on intersection size and design vehicle needs for a single lane roadway. For a two or three lane roadway where vehicles with larger swept areas travel, the width of the circulatory roadway should be no greater than 15 meters. If the roadway is wider, there is a risk of drivers misusing the road, vehicles going clockwise in the wrong direction, inside the circulatory roadway [11].

Splitter islands are used on all approaches on the roundabout to separate vehicles that are entering the roundabout from those departing. They are curbed, raised above the pavement surface and kept 2.4 meters wide for pedestrians to take refuge. Splitter islands are, however, painted on local roads, and not actually built. For a collector road, the splitter island is made 8 to 10 meters long, and 12 meters minimum length for the arterial road. Finally, for improved pedestrian safety, the splitter Island should be designed and built to extend upstream for a distance that is equal one-half of the required driver's stopping sight distance [11].

The pedestrian crosswalk should have 2.4 meters minimum width for splitter island, so that pedestrians with stroller or bicycle could easily seek refuge. The crosswalk should be at least 6 meters upstream of the yield bar. The crosswalk must be appropriately marked with paint, properly drained of pooling water, regularly cleared of snow in the winter and, if raised, must have a detectable warning surface to delineate the edge of the street. As shown in Figure 7 below, crosswalk alignments could be either perpendicular crosswalk alignment or flat crosswalk alignment [11].

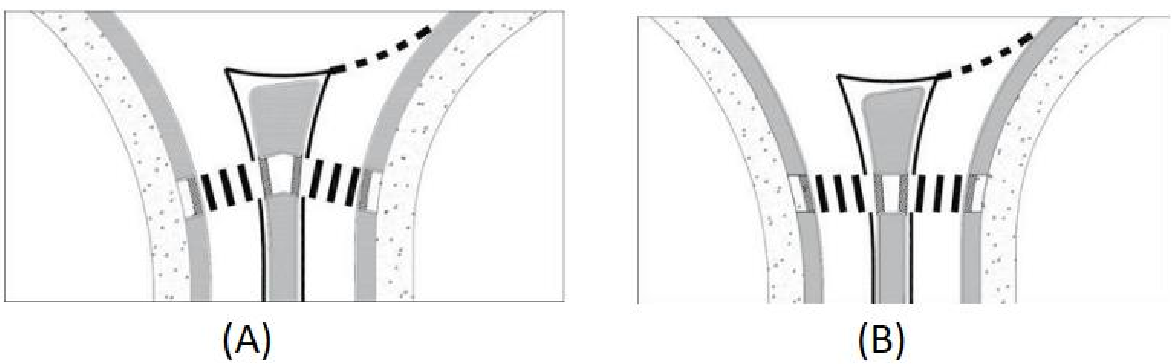


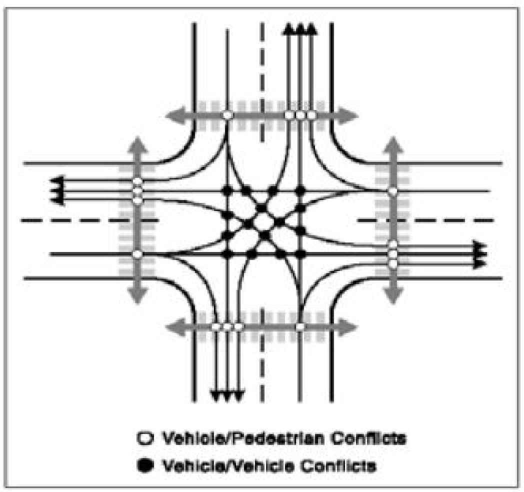
Figure 7: Type (A) is perpendicular crosswalk alignment. Type (B) is flat crosswalk alignment [11]

2.4 More on Advantages and Disadvantages of Roundabout

Roundabouts have several advantages that give them an edge over conventional intersections. Some of the advantages and disadvantages are discussed in this section.

2.4.1 Advantages of the Roundabout

Roundabouts enhance safety in the transportation network by the reduction of approach and circulatory speed of traffic, coupled with the reduction in deflection angle for vehicles at the entrances of the roundabouts. The maximum allowable speed could be 40 KPH in an urban setting. Furthermore, conflict points between vehicles and pedestrians are fewer in a roundabout compared to conventional intersections which is a direct result of eliminating right and left turns [2] The total pedestrian-vehicle conflicts are reduced from 16 (that is 4 conflict points per leg multiplied by 4 legs) to 8 (that is 2 conflict points per leg multiplied by 4 legs) as shown in Figure 8 below. Moreover, roundabouts are potentially good platforms for beautifying the surrounding area, as long as safety is not jeopardized. The central island could be painted colorfully and decorated to look aesthetically pleasing.



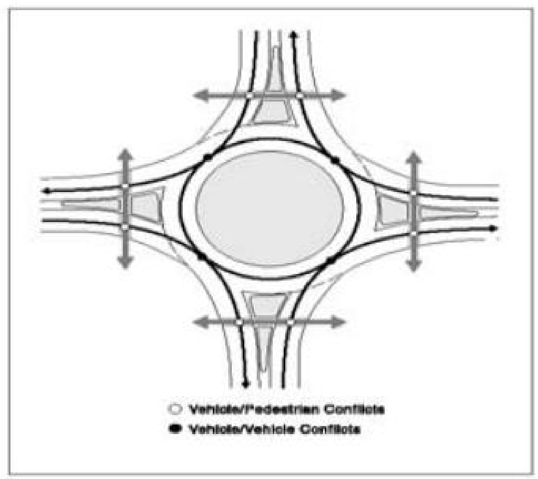


Figure 8: Vehicle - Pedestrian conflict points at a Signalized Conventional Intersection compared to a Single-Lane Roundabout [2].

Another benefit of roundabouts includes better traffic management and minimizing delays. Additionally, vehicles can maneuver and make U-turns on roundabouts, thus saving drivers some time. Also, roundabouts are more affordable on life cycle costs when compared to signalized conventional intersections. Furthermore, emission levels and carbon footprint are lower for traffic on roundabout. Finally, roundabouts are helpful and preferred in earthquake-prone regions since they will still perform even with power outages which often result in the aftermath of an earthquake disaster.

2.4.2 Disadvantages of the Roundabout

Roundabouts require higher initial monetary investment, as well as greater length of time to build. There is also a need for public education on how to use this type of facility, which comes at some financial cost.

The pedestrian must generally walk long distances and desist from using the central island as a shortcut for crossing the roundabout [13]. Furthermore, PWVL feel unsafe using the roundabout since the normal sound cues needed to aid navigation are not there, and the direction of vehicles are not exactly detectable or are sometimes found confusing. The sound produced by vehicles that are traveling in the circulatory roadway transmits to the crosswalk where it masks and interferes with the sound of vehicle that is approaching the particular crosswalk where the PWVL stand.

2.5 Pedestrian Safety and Accessibility Needs

Regarding pedestrian safety, roundabouts have some things inherent that are favorable for pedestrians. These include the likelihood that traffic slows as they approach the roundabout, the existence of the probability that drivers would yield to pedestrians, and that pedestrians only have to cross the roads in two steps, having the splitter island positioned midway through the journey. However, vulnerable road users such as PWVL have difficulty finding safe gaps for crossing the street, because they cannot clearly identify the direction of movement of vehicles and their location due to the continuous movement of traffic on the roundabout.

The challenge to PWVL worsens with the increase in the number of lanes to cross on the roundabout because of obstruction caused by the vehicle near the pedestrian, to the driver in the lane that is farther from the pedestrian, as the pedestrian stands on the edge of the road.

The following subsections will present different safety and accessibility considerations related to roundabout elements and how they impact PWVL.

2.5.1 Pedestrian Speed and Collision Risk

Pedestrians with disabilities are particularly slow when walking. Figure 9 below shows varying walking speeds of persons with different forms of disability. PWVL with cane walk at approximately 0.8 m/s (or 2.62 ft/s) [14]. Vehicles, however, travel much faster, posing a risk to pedestrians who share the same space. Figure 10 below shows the relationship between vehicle speed and the fatality risk to the pedestrian in the event of a collision. For a vehicle traveling at 40 KPH in the roundabout, the pedestrian runs a fatality risk of about 3.5% [15].

	Average Walking Speed	
Impairment/Assistive Device	ft/s	m/s
Cane/Crutch	2.62	0.80
Walker	2.07	0.63
Wheelchair	3.55	1.08
Immobilized Knee	3.5	1.07
Below-Knee Amputee	2.46	0.75
Above-Knee Amputee	1.97	0.60
Hip Arthritis	2.44 - 3.66	0.74 - 1.12
Rheumatoid Arthritis (Knee)	2.46	0.75

Figure 9: Walking Speeds for Physically Impaired Pedestrians [14]

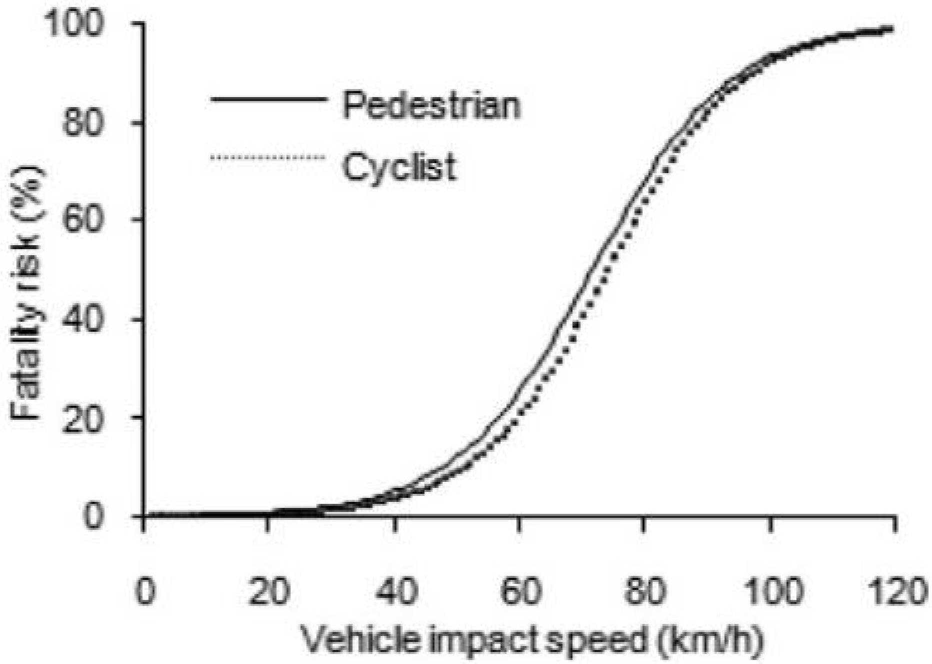


Figure 10: Relationships between Vehicle Speed and Fatality Risk for Pedestrians in a Collision [15]

Note that the risk of collision increases rapidly once the vehicle speed reaches about 45 KPH. Therefore, vehicle speeds at roundabouts should be kept at the recommended 40 KPH in order to keep fatality risk low for pedestrians.

2.5.2 Accessibility needs of PWVL

Persons with vision loss might experience hardship at unfamiliar locations, especially at roundabouts due to its geometric design and layout. When crossing the street, PWVL would first have to find the crosswalk, then orientate in the direction to go when crossing, and finally find a gap in traffic in order to cross. All these steps are necessary despite the irregularity and lack of distinctiveness of sound patterns heard on the roundabout.

Some of the guidelines proposed and mentioned in the Canadian National Institute for the Blind (CNIB) Clearing our Path Document, for enhancing accessibility of roundabouts are, to avoid placing on the roundabout anything that will increase background noise, such as water fountains, which can mask vehicle’s sound. The list includes disallowing placement of a tall object on the central island that may obstruct drivers view within the roundabout. The document suggests the application of consistency with equipment installed for visual and tactile cues. It is necessary to paint and mark pavement clearly and ensure that tactile used are detectable where pedestrians are meant to enter or cross the road. Also, concrete barriers for fencing should be provided to deter pedestrians from using the central island in crossing the roundabout. A “Yield to Pedestrians” sign, that is based on the Manual on Uniform Traffic Control Devices (MUTCD) requirements should be installed appropriately. Also, having an Accessible Pedestrian Signals (APS) installed on roads with one or two lanes is considered necessary. Furthermore, providing overpasses or underpasses on roads with three or more lanes is ideal. Lastly, it is expected that standard red-yellow-green traffic light, when used, be set to default on green for drivers to see [16].

2.5.3 Accessibility Treatments

Transportation Association of Canada (TAC) Design Standards, as guideline for roundabout development, indicate several treatments for addressing accessibility issues faced by PWVL. Some of them include providing detectable edge treatment of curbs, ensuring color contrasts of curbs, installation of railings and fences positioned where crossing is not expected, where such a fence does not impede road maintenance work [12]. Moreover, electronic gadgets such as audible beacons could give PWVL the cue needed to stay on a straight course when crossing [17]. The beacon broadcast its position and the observer walks straight towards the beacon's position. Similarly, a "Talking Sign" system, comprising of a transmitter that is positioned on signages, and a handheld receiver carried by the PWVL assists with accessibility when crossing the street. The transmitter broadcast up to 160 feet or 48.7 meter distance away to reach the receiver which in turn acts as the loudspeaker for the PWVL to know where to go [18]. One standard non-electrical treatment for giving accessibility cues to PWVL is the Tactile Walking Surface Indicator (TWSI) built into the pavement as a nonvisual cue for orientation and wayfinding [19]. These TWSI devices help PWVL, who walk on them and feel them under their feet, to transition from the sidewalk to the road pavement. The PWVL must have undergone special training to understand what the cues are saying when felt under the soles of the feet.

Another treatment that could be used for roundabout accessibility is to install the rumble strips, provided it is not a nuisance to people living nearby. The strips could give audible warning to PWVL when a vehicle goes over the strip while approaching the crosswalk.

Also, models of streets and intersections layouts can be 3D-printed, and given to PWVL to have them familiarized with the location, by touching and feeling the model [20]. 3D printed models have been tested and found to help PWVL better, compared to tactile graphics (maps) with mobility and wayfinding [21].

Finally, concerted effort must be made to protect the interests of people with other forms of disability while seeking improvement in accessibility for PWVL. Other treatments to be considered include raising pedestrian crossings, installing Rectangular Rapid Flashing Beacons (RRFBs) with Accessible Pedestrian Signals (APS), recommended by CNIB.

2.5.4 Signalization for a Crosswalk

Another measure that could be helpful for PWVL is signalization of crosswalks. Providing signals for a crosswalk is desirable, especially on a road with high vehicle volume and many PWVL using the intersections. Moreover, signalization would also be beneficial where there is moderate pedestrian activity on a multilane roundabout, which is more difficult to cross compared to roads with fewer number of lanes. Such a signal could be one of two types that TAC allows for installation in Canada.

The first type is a flashing amber beacon that is roundly shaped, highlighting markings and signs where pedestrians need to cross. These signals have audible notifications telling PWVL that drivers may not stop, therefore suggesting that these beacons are only to persuade drivers to yield and are not to compel drivers to stop. An example can be found on a roundabout in Thunder Bay with Rectangular Rapid Flashing Beacons (RRFBs) and Accessible Pedestrian Signals (APS),

The second type of signal is a red-amber-green vehicle signal which continuously shows vehicle traffic a green light but upon activation by pedestrians, it goes through a cycle that awards green time for pedestrians to walk across which means red light for vehicles at that moment.

2.5.5 Importance of Rectangular Rapid Flashing Beacons (RRFBs) and Accessible Pedestrian Signal (APS)

This sub-section goes a little more in depth than the previous on Rectangular Rapid Flashing Beacon (RRFB). The RRFBs are amber lights that activate when the button to control is pushed on the pole at the beginning of the crosswalk, triggering the Accessible Pedestrian Signal (APS). Figure 11 below shows an example of these devices. The APS responds by saying a couple of times, “Amber light is flashing; vehicles may not stop immediately.” Once the RRFB is activated and begins to flash, it should last between 20 and 30 seconds. When the APS systems that are installed on opposite approaches of the same leg on the roundabout are activated at the same time by different people intending to cross the same road in opposite direction, the system is designed to operate without interference of sound generated when the APS is activated on opposite sides of the same road. In addition to meeting accessibility standards, specifications and requirements set by the MUTCD or the authorities in the jurisdiction where the roundabout is located, there is also need to follow instructions contained in TAC’s Pedestrian Crossing Control Guide (2018) for devices [22]. Finally, to complement everything discussed so far on accessibility, and as part of their advocacy work, the Canadian National Institute for the Blind (CNIB) expects agencies to become acquainted with requirements stated in the Clearing our Path Document, consider and implement such for roundabout accessibility [23][16].

Figure 11: Accessible Pedestrian Signal [12]

2.5.6 Signage on Roundabout

Roundabouts are required to have signs by each crosswalk indicating that pedestrians are using these locations to cross. By law, a standard pedestrian crosswalk sign with Manual of Uniform Traffic Control Devices (MUTCD) identification number RA-4 guarantees the right of way for the pedestrian. The sign must indicate that the pedestrian is walking just as symbolized relative to the middle of the road. The sign in Figure 12 below has numbers RA-4R for the right-hand side. Conversely, RA-4L must be used as the left-hand version. As illustrated in Figure 13 below, signs must be placed along the roadsides, indicating where the crosswalk is positioned. If the road is two-way, back-to-back symbols are used on both sides. As shown in Figure 14 below, a Pedestrian Crosswalk Ahead sign, code number WC-2, should be installed if and when visibility is limited [24].

Figure 12: Standard Pedestrian Crosswalk Sign [24]

Figure 13: The Roundabout in Thunder Bay with the "Pedestrian Crosswalk" sign

Figure 14: The Roundabout in Thunder Bay with the "Pedestrian Crosswalk Ahead" (WC-2) sign

2.6 Sound Strips Research on Roundabouts

In a Technical Liaison Committee Report produced by the Institute of Transportation Canada (ITE) Canada, formerly known as the Canadian Institute of Transportation Engineers (CITE), it is suggested to install sound strips at the approaches of a roundabout for the benefit of PWVL [25]. However, it appears no study has ever been done on the topic in Canada. Two studies with the consideration of rumble strips as treatment for roundabout accessibility need for PWVL in the United States were presented in the National Cooperative Highway Research Program (NCHRP) 674 Report and the Federal Highway Administration (FHWA) 2006 Report.

The NCHRP 674 report considered a Channelized Turn Lane with an allowed speed range of 20 – 30 MPH (or 32.2 – 48.3 KPH). Drivers there did not pay much attention to pedestrians as the drivers always tended to focus more on traffic where they would be merging. Drivers' yield behavior was as low as 15 to 18 percent, prompting the researchers to think that accessibility on CTL might be worse than it is thought to be on the roundabout across the USA. The researchers hoped there would be a national accessibility guideline for CTLs [26]

According to the researchers, the difficulty arising from crossing the road on the CTL is due to high ambient noise levels from nearby traffic upstream the crosswalk, making it unlikely that the PWVL would have recognized when vehicles got off the through traffic and went on the CTL. The solution was to plaster sound strips to the surface of the pavement with the intention of increasing audible information given by turning vehicles versus through vehicles, as cue for PWVL to use in street crossing. Also, pedestrian-activated flashing-yellow beacon were installed to boost drivers yielding behavior [26].

The result showed that the use of sound-strip as treatment reduced the intervention of the orientation and mobility trainer, who was assisting the PWVL on site, from 5.6 to 1.4 percent. Furthermore, the sound-strip treatment decreased overall pedestrian crossing delay from an average of 23.4 seconds to 12.2 seconds per lane. The researchers believed that the reduction in delay was due mainly because PWVL were able to utilize yield and gap opportunities in crossing sooner with the help of the installed sound strip [26].

The researchers concluded that the sound-strip treatment only partially improved the accessibility need of PWVL on CTL. They suggested that signals be installed when traffic volume and speed are high on CTLs, to eliminate the risk of vehicle-pedestrian collision. The researchers wished to see the sound strip and beacon tested further for their low cost and the control they offer. Although they didn’t try the experiment on a low-speed, low-volume road, the researchers believe the effectiveness of the sound strip would have weakened as vehicle speed reduced. Finally, the researchers hoped that the sound strip treatment used on CTL would be replicated on single – lane roundabouts [26].

On its part, the FHWA 2006 Report focused on double-lane roundabout accessibility for PWVL. The studies done in the report were to evaluate the effectiveness of the sound strip treatment on a two – lane roundabout.

The first one of the two studies was done on a closed course under controlled conditions, where there was no treatment, and later applying the sound strip treatment. Testing under these two conditions showed that the sound strip increased the chance of PWVL detecting vehicles when assessing the situation. Also, the delay time experienced by the PWVL was reduced by more than one second with the instalment of the sound strip.

For the second study, when comparing the controlled condition, without treatment, to the condition with treated pavement, it was found that many of the drivers yielded before reaching the sound strip, leading to the conclusion by the researchers that the treatment with sound strip was ineffective. However, the researchers suggested that the experiment be tried on a single lane roundabout crossing [27].

2.7 Safety of Roundabouts in Other Countries

To avoid a situation where vehicles have to stop frequently for each person or group of pedestrians who stand at the unsignalized crosswalk in the United Kingdom (UK), the crosswalk becomes signalized once a warrant threshold of pedestrian traffic is reached. Signalizing a crosswalk implies installing a traffic light that goes from green to amber to red light, in the process of stopping vehicle traffic so that pedestrians can cross the road. The threshold necessitating signals is found by taking the pedestrians' volumes per hour, multiplied by the square of number of passing vehicles per hour, over an average of peak four hours of traffic count. If this product is greater than 100 million, then a signalized crossing is required for the crosswalk. As a result of high pedestrian volume, there are many signalized crosswalks on roundabouts in the UK, thus ensuring that green time is fairly split between vehicles and pedestrians [28]. Installing signals on the crosswalk should be beneficial to PWVL, as they are guaranteed a gap in traffic when vehicles stop at the red light. It should be noted, however, that the signals were installed in the UK to improve vehicle operations rather than for pedestrian access [29].

Regarding vulnerable road users in general, the Northern Ireland, Scottish and Welsh Offices at the Department of Transport made mention of guard rail for protecting those pedestrians with any form of disability [30]. Such protective barricade is to keep pedestrians from straying into the path of vehicle traffic and vice versa, which could be of immense benefit to PWVL in particular.

Furthermore, spinning cones are used in the UK to help PWVL. When crossing the road, the device is activated by pushing the button on the pole. In response, the spinning cone vibrates when it is safe for the pedestrian to cross [31]. The mechanism of how the spinning cone works or other details about the cones were not mentioned in the literature, but one could imagine that this device is likely to help PWVL who might also be deaf. By touching with the hand, a vibrating cone on a pole at the crosswalk could be the alternative for informing those who otherwise couldn’t have heard the sound from the Accessible Pedestrian Signal (APS) when trying to cross the street.

In France, roundabouts are signalized where adequate pedestrian refuge is provided between both directions of vehicle travel lanes. The crosswalks are positioned about 15 meters away from circulatory roadways. Such crosswalks are also offset from each other to keep pedestrians from going through the splitter island and entering straight into the road ahead when vehicles have not been stopped by the signal. Lastly, with guard rails in place, pedestrians are forced to make use of the crosswalks [29]. It is reasonable to believe that these accessibility measures implemented in France would have benefited the PWVL when crossing the street.

Signalized roundabouts are allowed in the Netherlands when enough room is provided for vehicle storage on the circulatory roadway [29]. Nothing else in the literature reviewed about the Netherlands was mentioned of roundabout accessibility for PWVL. It can be assumed, however, that a signalized roundabout most likely would allow some green time for the pedestrian, while simultaneously showing the red light to vehicles, therefore safeguarding PWVL when they cross the street.

In Spain, it was mentioned that the risk posed by silent Electric Vehicles (EVs) and Autonomous Vehicles (AVs) to PWVL was a concern [32]. Without acoustic signals, PWVL would run a high risk of being involved in conflict with any vehicle that is silent. To solve the problem, the European Union demanded that automobile manufacturers ensure effectively as of July 1, 2019, that EVs generate some form of acoustics when the speed is below a threshold where the engine and tires are not producing audible sound. For all electric vehicles, the Acoustic Vehicle Alert Systems (AVAS) must operate at a minimum of 56 decibels and maximum of 75 decibels when vehicles travel up to 20 KPH. Automakers also are being creative with solutions. In response to the new law, the Japanese company Nissan made a non-deafening loud whistle for forward motion and beeping sound for motion on reverse [33][34]. Although, it is unknown how effective this new measure is for now, it is likely to be of great help to PWVL when at the roundabout with passing EVs or AVs.

A thesis written in Sweden highlights the importance of having proper lighting installed at roundabouts to help pedestrians, especially when PWVL are passing. About 95% of PWVL in Sweden, according to an estimate in the paper, still have partial sight, and they experience some difficulty in the dark or in very bright light. So, putting appropriate lighting in place would be really helpful. Another issue discovered in the Swedish research is the problem experienced by PWVL who complained about cyclists being difficult to detect on roundabouts because their bicycles are small and silent. Also, cyclists make the pedestrian area difficult for PWVL because cyclists don’t yield to those walking, and their behavior suggests there is no rule of engagement when dealing with cyclists, who always do whatever they prefer [35] There is need to do extensive work on how PWVL and cyclists will be interacting since active transportation, the mode where people are walking and cycling, is gaining more traction these days.

A paper published in 2019 regarding Roundabouts in Japan showed that there are fewer roundabouts when compared to Europe and North America. Also, schools in Japan are starting to create awareness about the need for more roundabouts compared to signalized conventional intersections which becomes paralyzed in the aftermath of earthquakes and resultant power outages [36]. Furthermore the Society of Civil Engineers and the Institute of Electrical Engineers in Japan are advocating for more roundabouts for disaster mitigation purposes since roundabouts will allow traffic to continue flowing even when there is power outage [37][38]. Something negative about roundabouts in

Japan is that, many motorists surveyed there are of the opinion that sharing the roundabouts with cyclists worsened traffic conditions [36].

Finally, to boost accessibility on a roundabout in Lida, a city in Japan's Nagano prefecture, braille blocks were installed in the walkway for wayfinding and for safety precautions [39]. This certainly must have been a positive impact on the condition of PWVL who might have traversed the street there.

In New Zealand, an opinion survey showed that pedestrians felt safer with Cyclist Roundabout, also known as C-roundabout, which was specially designed and developed as an initiative by Land Transport New Zealand to make roundabouts cyclist-friendly. It was reported that the 85th percentile vehicle speed was successfully reduced to 30km/h at the entry and exit points of the C roundabout, which they claimed is suitable for the safety of all vulnerable road users – including pedestrians and cyclists. Furthermore, 61 percent of pedestrians surveyed thought the C-roundabout was safe, 35 percent of pedestrians hoped to see more C-roundabouts [40][41]. However, there was no mention of PWVL in particular being asked how they felt on the C-roundabout, therefore not much can be said about the safety of the PWVL in a space dominated by cyclists.

In Australia, marking pavement and providing well-illuminated signs on the crosswalk at the roundabouts boosted drivers' understanding of who has the right of way, resulting in compliance with traffic rules and pedestrian safety [42]. Also, maintaining consistency with the sound, that is the single tone, produced by the Accessible Pedestrian Signal (APS) in Australia and Europe is excellent and prone to less confusion for PWVL when compared to the situation in USA and Canada, where there is no consistency in the cuckoo and chirp sounds that are meant to signify different directions. The cuckoo sound is used to indicate North-South direction, and the chirp sound for East-West direction when on the crosswalk. This inconsistency in North America has led to a system that researchers have documented as being ambiguous and confusing [43]. It is likely that PWVL would do better when crossing at intersections using a single tone APS.

2.8 Research Gap in using Sound Strips to boost Roundabout Accessibility for PWVL

The work presented by the FHWA 2006 report on the use of sound strips to address the accessibility needs of PWVL on roundabouts focused specifically on the USA. So, nothing is known about how the process might perform if and when tried in Canada. Thus, becoming a gap in the research, highlighted by the fact that the CNIB has shown great interest in knowing what the situation is across Canada, and commissioning the research team to do this study.

Also, that the FHWA 2006 study was done on a double-lane roundabout left a gap in knowledge about the potential for sound strip treatment on single lane roundabouts. The authors of the FHWA report recognized the need and did recommend for future work to explore such options.

Using sound strips that were made of Poly Vinyl Chloride (PVC) material in the USA study implied there is possibility of exploring, in Canada, other types of materials. Other variability would include, and not limited to, testing what happens in winter season. These are some of the gaps that can be covered in future research works, which could possibly build on some of the findings of this pilot study.

CHAPTER 3. RESEARCH METHODOLOGY

The approach and methodology used in carrying out this research are enumerated in this chapter. The different steps taken are included in the following paragraphs.

3.1 National Events

The national workshop, held in collaboration with the CNIB, took place on September 8, 2022. The opinion survey, targeted at a national group of participants, followed immediately.

3.1.1 National Workshop on Roundabout Safety and Accessibility

The research team met with staff from CNIB to discuss the possibility of conducting a national workshop regarding safety and accessibility of roundabouts with their clients. An agreement was reached and CNIB promoted the event for about three weeks nationwide. During these three weeks, the potential questions to discuss during the event were prepared and shared with staff from CNIB. Present at the workshop were 18 participants from the Atlantic coast to the Pacific coast of Canada, 4 CNIB staff who facilitated the event and a team of 2 researchers.

Judging by the names and voices of attendees, it appeared that participants were a fair mix of both male and female. However, nothing is known about their age group, or what percentage of total CNIB membership they represented. Appendix Figure A1 shows the agenda and workshop discussion questions used.

3.1.1.1 Importance of the Workshop and the Discussion Questions

Several of the questions prepared for the event were general about accessibility, others were specific related to roundabouts, while others focused on conventional intersections. These questions were intended to keep the discussion focused, having PWVL share their stories and talk about their experiences when dealing with roundabouts.

3.1.1.2 Preparation of Discussion Questions

The agenda and questions for the national workshop were prepared with the aim of engaging participants on the subject of roundabout accessibility for PWVL, their issues and concerns, as well as their experiences with this type of location. During the planning phase, the questions compiled were sent to CNIB staff for input and feedback before they were finalized for the national workshop.

Some of the discussion questions considered are listed below:

- Is there a roundabout within a kilometer radius or distance of your home?
- Do you have to cross a roundabout often?
- Are there positive things you feel about roundabouts?
- Are there negative things you perceive in roundabouts?
- Do you deliberately avoid roundabouts?
- What is the ideal roundabout you are hoping for?
- When you have a complaint about a road, intersection, roundabouts, *et cetera*
- How do you register that complaint (with the owner of the infrastructure such as the city or provincial government)?
- Do you find the method easy?

- Is the response effective and satisfactory?
- Would you prefer to have a more effective method?
- What are the positive things you see in regular intersections?
- Are there negative things you perceive in regular intersections?

3.1.2 Roundabout Accessibility Survey

A survey was conducted immediately after the national workshop finished. It was meant as follow up with PWVL who attended the workshop, as well as asking for input from those who did not participate in the workshop. No details about sex, age, and other personal information were asked the participants. So, it is hard to say how representative the few respondents were. Appendix Figure A2 shows the sample opinion survey questions shared with participants through the Microsoft Forms. It was imagined that one way to influence participation was to make the questions short and simple. Also, using email or other electronic means of sharing the questions was expected to boost participation.

3.1.2.1 Importance of Survey Questions

One of the objectives of this research project is to identify the issues and concerns that PWVL have regarding roundabouts. In that sense, it is important to understand the process PWVL follow when crossing intersections. For this purpose, it seems logical to ask how PWVL perform tasks such as identifying the crosswalk, aligning with it, finding a gap in traffic, beginning crossing, and staying on course without losing orientation. Therefore, the survey was designed with several questions related to these tasks. Other questions were about how this demography of people registers complaints with the agencies that are responsible for addressing the issues and difficulties faced by PWVL while using roundabouts or conventional intersections. The questions included in the survey might have covered only some of pertinent information about roundabout accessibility challenges for PWVL and for that reason, the last part of the survey provided the opportunity for participants to add anything else they wanted the research team to know in reference to the research topic.

3.1.2.2 Preparation of the Survey Questions

The purpose of the questions in the survey was to help the average person understand what PWVL grapple with at roundabouts. As it was done with the questions for the workshop, the list of questions for the survey was sent to CNIB who commissioned this research work for input and feedback before they were finalized.

Some of the survey questions, as well as their relevance to the research specifically, are as follows:

- Are you able to locate the crosswalk? The relevance of this question is, inability to locate the crosswalk will constitute a fundamental accessibility issue for PWVL being investigated by this research
- Are you able to stay oriented and complete the crossing without veering or becoming disoriented? The ability to stay on course without becoming disoriented when moving from one point to another in an effort to cross the street is important. Thus, becoming a fair and valid accessibility question to ask PWVL Knowing the situation with each respondent will help inform the report for this research
- Do you use any accessibility aids to stay aware of traffic situations at a crosswalk? The PWVL relied on sound cue and possibly accessibility aids for navigation. An

answer to this question would have helped the research team make a more robust report on what the accessibility issues were for PWVL in Canada.

- Do you need any accessibility aids to find a gap in the traffic to complete a street crossing? Since the research work was about providing accessibility aid to PWVL, an answer to this question would have given a sense of what the need was for the research effort

3.1.2.3 Introduction and conduction of the Survey

By the time the workshop was taking place, the roundabout accessibility opinion survey questions were already prepared and kept online using Microsoft Forms. Information regarding the survey questions, what they were about, and the means of sharing were briefly mentioned at the event, so potential participants would know what was expected of them.

Event facilitators at the workshop promised to forward the link for the survey to attendees and other CNIB clients who were not present as soon as the workshop was over. Participation was open to all clients at CNIB. To attract as many participants as possible, the survey was made available for about a month, with reminder sent through the CNIB staff to their clients across the country. Although there was no limit imposed for participation, only 7 people responded to the opinion survey, and so the result should not be taken to represent the entire population of PWVL in Canada.

3.2 Site Selection and Description

The research team needed a roundabout that is accessible for their work. That is, having tactile on the curb, Rectangular Rapid Flashing Beacon (RRFB) with Accessible

Pedestrian Signal (APS) in place to help boost accessibility, making street crossing as easy as it possibly could for PWVL, and thus becoming some of the criteria for choosing a site.

The site selected is the only one in Thunder Bay meeting the set criteria. The roundabout situated at the intersection of Edward Street and Redwood Avenue in Thunder Bay, was built between June and September of 2021. The facility is shown in Figure 15 and Figure 16 below. Positioned in the Northwest is Oasis Family Dental Clinic, in the Northeast is Janzen's Pharmacy, in the Southwest is a Shopping Mall's Parking Lot, and in the Southeast is a cleaning company (Supreme Cleaners).

The roundabout has four legs, two on Edward Street (2-lane road) and the other two on Redwood Avenue (1-lane road). The crosswalks on Edward Street, the busier one of the two streets, has RRFBs with APS that responds when triggered, saying, "Amber light is now flashing; vehicles may not stop immediately." The posted speed for both roads intersecting on the roundabout is 60 KPH, which reduces to 40 KPH on the roundabout.

Figure 15: Intersection at Edward Street and Redwood Avenue on June 3, 2021- North is the top–left corner of the photo [44]

Figure 16: Intersection at Edward Street and Redwood Avenue on September 9, 2021 - North is the top–left corner of the photo [45]

3.2.1 Approaches Selected for Traffic Flow and Pedestrian Observations

The research effort will focus on specific on-site approaches, shown in Figure 17 below, since this is a pilot study. Approach 1 is Edward Street North going Southbound into the roundabout, Approach 2 is Redwood Avenue West going Westbound exiting the intersection, Approach 3 is Redwood Avenue West going Eastbound towards the roundabout, and Approach 4 is Edward South Street going Southbound leaving the roundabout.

Figure 17: Focused on Approaches 1 to 4 - North is the top–left corner of the photo [45]

3.3 Permission and Testing at Lakehead University

This subsection presents the steps involved in the process of obtaining permission from Lakehead University in order to conduct the research project with human subjects, as well as testing the equipment and rehearsing data collection plans on LU campus.

3.3.1 Permission from Lakehead University

Obtaining permission from Lakehead University's Research and Ethics Board (REB) is mandatory before any research involving human volunteers can be conducted. Also, it was required to obtain the consent of officers at Lakehead University Security Service and the University's Department in charge of Risk Management and Access to Information in order to do any testing on the university's grounds.

3.3.1.1 Lakehead University Research and Ethics Board

A request to conduct research considering human subjects was submitted to the LU REB. Part of the process included taking a Government of Canada Course in Research Ethics, CORE 2022. The certificate received for participation in the course, shown in Appendix Figure A3, was submitted with the request to the LU REB. Finally, a consent letter for the volunteers, with a sample shown in Appendix Figure A4, was also required for this process. Granting the permission took several weeks that included a few clarifications related to the research process between the Research Team and the REB office.

3.3.1.2 Department of Risk Management and Access to Information

In order to test the equipment to be used for the sound strips in Parking Lot 5, an application requesting permission was submitted to the Department of Risk Management and Access to Information. The Director assessed this application to ensure that the testing procedure and materials posed no risk of harm to lives or properties on campus. This permission was granted after a few days.

3.3.2 Material Preparation for Sound Strips

The Technologists in the Department of Civil Engineering at LU assisted in preparing the sound strips used for this research. The sound strips consisted of a 6-inch long, 1, and ½ inch diameter pipe split longitudinally into three equal parts and pieces of dowel. For the pipe, two different materials were considered and tested. The two materials were Poly Vinyl Chloride (PVC) and Acrylonitrile Butadiene Styrene (ABS). When compared to each other, the expectation is for PVC to show more resistance to heat and the ABS to absorb shock better. At the end, pipes made from both materials were used. The pieces of dowel were appropriately cut into the required lengths by splitting each piece in half along the diameter so that it could fit in each length of strip. Figure 18 below shows the fabricated sound strip materials on display in the parking lot at the LU campus before being installed.

In order to secure and seal the strip and dowel treatment to the pavement's surface, the "Eterna Bond" tape shown in Appendix Figure A5 was used. The choice of tape was based on the advice of local construction material dealers and what is available on the market. The most suitable tape is the type that bonds well, requiring the pavement and material surfaces to be kept dry from moisture and clean of debris.

Figure 18: Fabricated strips and dowel on display at LU campus

3.3.3 Testing the material and procedure in LU Parking Lot 5

Weather permitting, steps were taken to have the strips installed on campus. First, the location of the strips was selected on the entrance driveway such that it was not too close to the nearby Oliver Road entrance or to the parking area in Lot 5. Then, the pavement surface was swept clean removing debris and moisture. Once the area was ready, the strips made of the PVC - ABS materials with the dowel beneath were plastered to the pavement near the entrance of LU Parking Lot 5 as shown in Figure 19 and Figure 20 below. For this process, the dowel was first laid down then the PVC or ABS strip went on top, and the Eterna Bond tape of 4 inches wide in size was applied. For safety reasons, an orange and black striped tape was stuck to the top of the strips to forewarn drivers of what is on the road surface.

As rehearsal for data collection on the roundabout, two rows of sound strips placed in the university was an opportunity for assessing the “click-clack” sound generated by vehicles that were moving through the driveway into the parking lot at the maximum allowed speed - 25 KPH, or less. The space between adjacent rows of strips was measured to sufficiently accommodate a vehicle from axle to axle in between the two rows of strips.

The test was performed not only to prepare for the installation of the sounds strips and check that it will work without any problems, but to determine if the sound produced by the strips is clear and how far away it could be transmitted from source. For this purpose, the test was monitored by listening to the sound generated when vehicles drove over the rows of strips and hearing the sound intensity to gauge how it decays as the observer stood progressively and incrementally away from the source of the sound, on the way to the Faculty of Engineering Centennial Building situated nearby.

Figure 19: Entrance driveway to Parking Lot 5 and the Centennial Building from Oliver Road. (Photo Credit: Google Maps)

Figure 20: Strips installed at the entrance driveway of Parking Lot 5

Furthermore, the scene of passing vehicles was recorded on the camera, shown in Figure 21 below, as they moved from the first row of the strips to the second row. The video segment recorded could be reviewed later to find the speeds of the vehicles, since the distance between the two rows of strips was predetermined and the amount of time each vehicle took to traverse between the two adjacent rows of strips could be estimated.

Figure 21: Nikon D3500 Camera mounted to monitor the zone for traffic

During the test at Lakehead University, the performance of certain electronic equipment, shown in Appendix Figure A6, intended for use at the field study was evaluated. The speed radar gun, one of the equipment, was meant for checking individual vehicles' speeds, ranging from 10 to 200 KPH. One limitation with the speed radar gun is when monitoring speeds for several vehicles platooning at different speeds through the zone. Obtaining the speed so quickly for each vehicle in the platoon even when their speeds were slightly different was not possible with the radar gun.

Another equipment tested was the sound level meter which works when recording the sound level for events occurring every 30 seconds. Unfortunately, this is not useful when watching events where vehicles randomly drive past the rows of strips in less than 30 seconds intervals. The lack of funding available for the project, mentioned earlier, imposed tremendous limits on the operational budget considered for acquiring sophisticated equipment to be used.

It could be said that, testing out the procedure in the parking lot on the LU campus helped determine an optimal way of installing the strips, or collecting data, a process to be repeated at the roundabout. The endeavor at LU also helped with quantifying the materials needed, as well as estimate the workforce and time required to install the sound strips at the roundabout.

Strips used on the roundabout are Identical in size and shape to the ones used on LU campus, but different because each strip is disposable. The tape is sticky and becomes inseparable from the strip after peeling it off the pavement surface at LU Parking Lot 5, and thus useless afterwards. Also, the intense heat and vehicle weight tarnishes the integrity and strength of the strips once used, so they were not re-usable on the roundabout where heavier vehicle traffic was expected.

The importance of the process followed on LU campus is that it gives the sense of what to expect at the roundabout. Furthermore, the test at LU campus provided valuable information on how to install the materials, the number of people to do the installation, the amount of time needed, material’s performance, ways of collecting the data and how to handle the situation when traffic starts flowing. Success at testing in parking Lot 5 on LU campus became a form of morale and confidence booster for the work ahead on the roundabout. The City of Thunder Bay allowed a limited amount of time for the field study, and it, unlike the time spent in Parking Lot 5, wasn't meant for trial and error.

3.4 Roundabout Preparation and Field Data Collection

This subsection presents the steps taken to prepare the site for data collection as well as other activities that were planned for that purpose.

3.4.1 Roundabout Set-Up

The City of Thunder Bay provided enormous support for this research, including granting permission for field study and data collection at the roundabout. However, for safety concerns and to avert hinderance to traffic flow, the City of Thunder Bay was particularly strict with the length of time that the research team could stay for at the location collecting data. Nothing belonging to the research team was expected on the site beyond the permitted time. Also, the City of Thunder Bay collaborated with the group of people on site during the installation and removal of the sound strips.

To prepare the site, the research team visited the roundabout several times to familiarize with the area, and to determine the best locations for sound strips and cameras ahead of data collection. Measurements were taken of different parts of the roundabout to determine the quantities of materials needed for making and installing the sound strips. The locations for the rows of sound strips were basically constrained and determined by the design configuration of the roundabout. As an example, the space between the rows of strips on the exiting approach of the minor road was so short due to the location of the crosswalk at the roundabout. Similarly, the location of the strips on the incoming approaches was constrained by entrances and exits to businesses and stores in the vicinity of the roundabout.

Other logistical details gathered from the site includes the estimation of the length of each row of strips, which was based on dimensioning and measurements taken of the site. Regarding the cameras, several positions were considered for each selected approach and the most suitable ones were determined. Figure 22 below shows the final positions for the camera and the location of the sound strips by approach.

Figure 22: Showing where the camera and strips were positioned. North is the top-left corner of the photo [45]

Numbers 1, 2, 3, and 4 shown in Figure 22 are the four approaches being monitored on the roundabout (as indicated previously). The camera is represented by the rectangular box with an arrowhead pointing towards the crosswalk on each approach. The red-colored rectangular box with an arrowhead depicts the camera that is pointing towards the major road, and the blue - colored rectangular box with an arrowhead depicts the camera pointing towards the minor road. The solid blue and red lines with arrowheads are in the first quadrant, while the broken blue and red lines with arrowheads are in the second quadrant of the roundabout. Two rows of strips, represented by yellow lines, are to be placed on the pavement on each approach. Also, the solid yellow lines on the road pavement indicate where inbound vehicles enter the roundabout. While the broken yellow lines on the road pavement show exit points for outbound vehicles.

Figure 23 below shows the schematic and rough dimensioning completed for the roundabout. The green color indicates the number of vehicle lanes on each approach. The blue color shows where the rows of strips are placed. For easy traffic tracking on the roundabout, Flag 1, Flag 2, and Flag 3 respectively, were introduced and used on the roundabout.

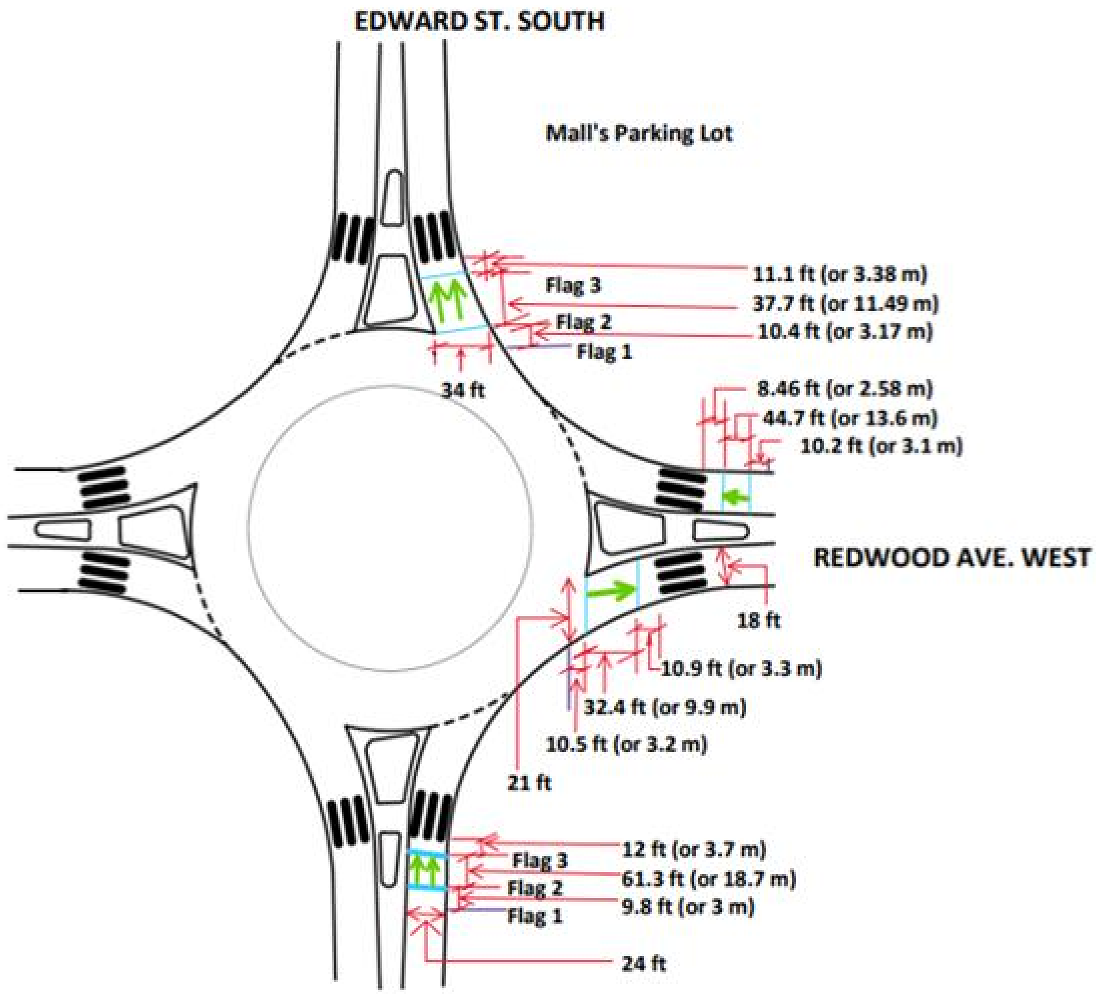


Figure 23: Dimensioning part of the roundabout to use for field study [27]

Figure 24 below shows the partitioning of the roundabout into four segments corresponding to the respective approaches. Approach 1 is themed in green, bounding the edges of the rectangular tags on the approach. The reddish-brown color applies to Approach 2, yellow to Approach 3, and blue to Approach 4. Also, the letter A represents the distance of the closer row of strips from the crosswalk of interest, B is the distance of the farther row of strips, C is the length of the row of strips positioned closer to the crosswalk of interest, and D is the length of the row of strips positioned farther from the crosswalk.

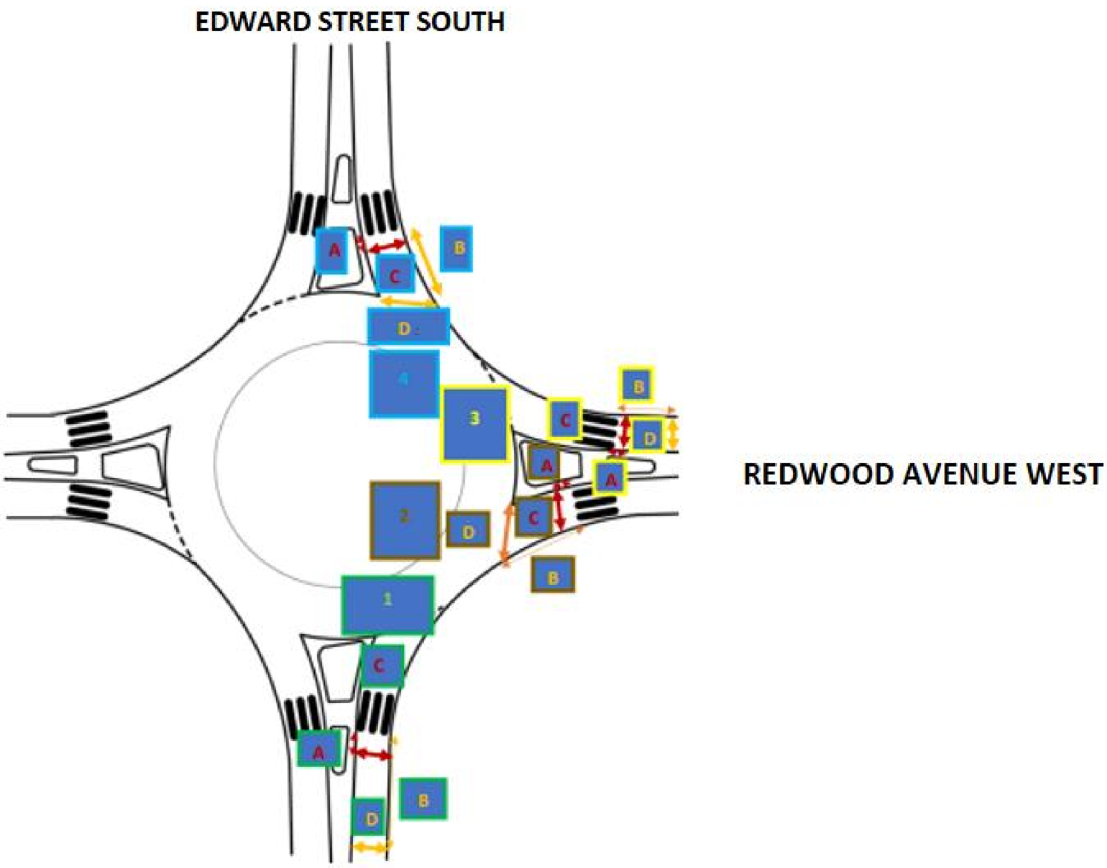


Figure 24: Showing more details about the dimensioning of the roundabout [27]

Appendix Figure A7 shows a matrix containing the estimated length of strips and rolls of tapes, judging by the experience gathered at LU Parking Lot 5, required for pavement treatment, based on details given in Figure 23 and Figure 24.

3.4.2 Initial Monitoring

On Wednesday, August 31, 2022, the roundabout was monitored with random pedestrians. At this time, there were no volunteers and no treatment in place. The exercise lasted about 15 minutes on each of the four approaches selected.

3.4.2.1 Random Pedestrians

At this stage, watching vehicles and random pedestrians' interaction on the roundabout helped prepare for the time when volunteers would be coming on site. It was observed that pedestrians crossing at the crosswalk on Approaches 1 and 4 along Edward Street, the major road, had the option of pushing the button on the pole in order to activate the RRFBs with the APS responding by saying that, "Amber light is flashing, vehicles may not stop immediately." Then, the pedestrians find a gap in traffic and finally cross the street. The button to activate the RRFB and the APS are located on poles situated at the beginning of the crosswalk and on the splitter island respectively, implying that the crossing is done in two stages. On the other hand, the Approaches 2 and 3 along Redwood Avenue do not have RRFBs or APS, so the pedestrian directly seeks to find a gap to cross once they reach the beginning of the crosswalk.

3.4.2.2 Testing Equipment for Performance On-site

At this stage, the equipment was tested on site ahead of the time that data would be collected with volunteers.

The camera was set up in each approach as described above (see Figure 22). The camera was adjusted for precision, set at the appropriate angle, and checked for optimal performance. The segments recorded on video were later checked to ensure that the expected data was collected and documented properly. Similarly, the decibel meter and the speed radar gun were checked with random sampling. Just as noticed on the LU Parking Lot 5 trial, the speed radar gun and the decibel meter were confirmed again on the roundabout to be unsuitable for this research's operational need.

3.4.2.3 Data Collected on the Camera

Since the speed radar gun was not adequate for this data collection, vehicle speeds are to be estimated from the data collected with the camera onsite. The video footage recorded is later reviewed to determine the amount of time the vehicle traveled from one point to another indicated by red flags at the approaches. With the distance between two adjacent flags pre-determined and measured, the speed could be estimated using the ratio of distance to time. In the same way, the acceleration of a vehicle could be determined as the rate of change of velocities (speed), with time, as the vehicle travels within the segment being monitored on the roundabout.

Furthermore, the video footage will be reviewed for other pedestrian-related data since the delay felt by PWVL can be quantified. However, PWVL would be providing more details, communicated verbally to the research team, to give any other feedback on traffic gap perception, or talking about how safe the PWVL felt at the crosswalk on the roundabout.

3.4.2.4 The importance of Speed and Acceleration measurements

Although this research is focused more on pedestrians than it is on drivers, the research team thought that an understanding of vehicle and traffic dynamics on the roundabout would be useful in finding solution to accessibility issues that may arise from driver's behavior. Hence, determining speed and its rate of change, or acceleration, as vehicles travel towards the crosswalk when doing the field study would be an important aspect of this research.

3.4.3 Monitoring PWVL on Untreated Pavement

Stakeholders converged on-site on Thursday, October 13, 2022, for data collection when the treatment had yet to be applied to the roundabout.

3.4.3.1 Introducing the Volunteers

The volunteers who participated in the onsite data collection exercise are clients of CNIB. Information such as age, gender and familiarity of use of roundabouts were not requested from participants. For this pilot study, the main consideration was to allow any CNIB client to provide their insights about roundabouts. For future research work, information about participants will be included in the survey. Some of the participants still have residual vision, and a couple others must aid their mobility by using a cane or guide dog.

For data collection, these volunteers were divided into two groups to optimize the process at all four approaches selected from the roundabout. In addition, three staff members from CNIB including a mobility specialist volunteered their time to collaborate during data collection exercise.

3.4.3.2 The logistics involved

There were challenges faced in mobilizing the two groups of volunteers for field study and data collection on the roundabout. Finding a time that works best for volunteers and CNIB staff, as well as arrangements for transportation of volunteers to the site by CNIB staff were some of the biggest worries. To be efficient on time with the field study, the two groups were scheduled for 90 minutes each back-to-back. The first group started at about 11 am, and, as planned, the second group showed up at 12:15 pm to start at 12:30 pm. The CNIB staff members including a mobility specialist were present with both groups from 11:00 am until 2:00 pm.

The research team arrived at the site about 90 minutes before the first group of volunteers were scheduled to show up, allowing for adequate time to set up the main camera, the backup camera, their accessories and any other equipment needed on site.

For this process, the volunteers are briefed shortly before starting the data collection session. Then, each volunteer takes their turn at each approach along with a research team member and the mobility orientation specialist from CNIB. Once they have pushed the button for the APS on Approaches 1 and 4, or aligned to cross on Approaches 2 and 3, the volunteers would be indicating when they feel there is a gap to cross the street. For safety precaution, the volunteer with the CNIB staff would have to step back from the crosswalk, while the member of research team steps forward to cross the road. Volunteers will not be crossing any of the approaches during the data collection exercise.

Data collection started and proceeded with everyone taking their turn and continuing until all the volunteers for respective groups have completed the task on Approach 1. Then, the entire group of volunteers migrated to the next approach until all four approaches were evaluated. Events at the site were recorded on video to be processed and analyzed later for data on speed, acceleration, delay, vehicle yield, and any other value that the research team was interested in.

Appendix Figure A8 shows the plan and sequence of events described above, with everyone starting on the first approach before migrating to the next. The figure also shows the amount of time allocated to each volunteer in their role on-site.

It was requested also that the volunteers share information about how they felt on each one of the approaches, or provide any comments about challenges they faced while going through the exercise of determining a gap in traffic or making ready to cross the streets at the roundabout.

3.4.4 Safety Measure – Sound Strips

The safety measure related to accessibility evaluated in this research project was the placement of sound strips before the crosswalks at each one of the approaches of interest at the roundabout. In order to conduct the field study, the City of Thunder Bay was contacted as the agency in charge of the roundabout, and therefore, according to the Ministry of Transportation Ontario (MTO)'s Ontario Traffic Manual (OTM) Book 7 (2014), having authority over traffic control and other protocols when installing the strips [46]. The following paragraphs will present the steps taken in the process of installing the sound strips.

3.4.4.1 The logistics involved

As mentioned earlier in this report, the quantity of materials needed for the sound strips to be installed at all four approaches considered at the roundabout was estimated based on the outcome of LU parking lot testing that was done earlier, and the measurements taken at the roundabout. The necessary materials were prepared in the lab with the help of the technologist for the Department of Civil Engineering at LU. Appendix Figure A9 shows the raw dowel and ABS pipe materials used for the sound strips. Furthermore, the sliced strips and dowel are shown in Appendix Figure A10. As discussed previously, ABS was chosen, because it is denser and better material at absorbing shocks as compared to PVC. These properties are important for the heavy traffic conditions that are expected at the site when data is being collected.

One important consideration for the installation of the sound strips at the site was the unpredictability of the weather conditions for the season when data was scheduled to be collected. The situation was made more complicated by the difficulty in finding a day that works best for all stakeholders, and therefore necessitating constant monitoring of the weather.

Unlike what was already learnt about the adhesive tape in LU Parking Lot 5 during the summer months, using the tape under frosty early morning weather in the Fall also required monitoring. Testing would be needed, a few days before the expected data collection date, to see how the tape sticks with the strip and pavement in the early morning hours. Appendix Figure A11 shows the morning weather monitored just days before the data collection took place on site. Similarly, Appendix Figure A12 illustrates the test carried out with a piece of strip that was installed on the pavement on Sunday, October 23, 2022. Due to the uncertainty of the field study for the reasons indicated above, cancelation of plan for the next episode of data collection was an option considered by the research team and stakeholders to the very end.

3.4.4.2 Installation of Strips

The installation of the strips was done early in the morning of Thursday, October 27, 2022, in weather condition considered to be good enough for this type of work. Regarding traffic control, the City of Thunder Bay's two-person crew closed the roads for about 2 hours, starting at 5 am. For the process of installing the strips at each one of the four approaches selected on the roundabout, a crew of four people from Pioneer Construction and a team of four people from Lakehead University were there. The location of the rows of strips in each one of the approaches, already measured, was marked and indicated by red flags as mentioned earlier in the report. In total, there were two rows of strips per approach. On Approaches 1 and 4, the length of each row of strips was to cover two lanes of traffic, and for Approaches 2 and 3 the length was for one lane.

Before laying down the strips, the road was swept clean of dirt at the location for each row of strips. Also, a blowtorch was used to remove moisture from the pavement surface. Moreover, the strips were wiped dry before applying the adhesive tape to plaster the strips and dowel to the surface of the road.

Furthermore, the orange and black striped tape was placed on each row of strips for motorists' safety and precaution. Appendix Figure A13, Figure A14, and Figure A15 show some of the scenes on site as installation work progressed. An example of the rows of strips on site after installation is shown in Figure 25 below with fully installed rows of strips on Approach 2 along Redwood Avenue West going Westbound. The picture indicates Flag 1 as the first of three flags, located the farthest from the crosswalk. Flag 2, coinciding with the position of the first row of strips as if going downstream with traffic. Lastly, the position of Flag 3, coinciding with the position of the second row of strips as if going downstream with traffic, is nearest to the crosswalk. The flags put in place make the tracking of moving vehicles in the area less challenging for the naked human eyes.

Figure 25: Fully Installed Strips on Approach 2 at Redwood Avenue West going Westbound

3.4.4.3 How the Treatment Works

The treatment with sound strips is meant to warn the pedestrian of vehicles approaching the crosswalk and is not expected to change the driver's behavior. As shown in Figure 25 above, the rows of strips with the curb and the splitter island form a rectangular space to be monitored. Thus, any vehicle going through this space would have to drive over the rows of strips, and when they do, the sound produced could be heard by the person nearby at the crosswalk. This sound gives the PWVL an audible cue about vehicles driving through the area before the crosswalk they are waiting on to cross the street.

The main purpose of these sound strips is to help PWVL in their decision to cross the street as indicated above. When PWVL hear the sound as the vehicle passes the first row of strips to enter this monitored zone, they receive the signal that a vehicle is approaching. This works well even for electric vehicles that are otherwise silent. If the vehicle passes over the second row of strips and the PWVL hears the sound originating at the second row of strips, it is interpreted that the vehicle is close to the crosswalk and not yielding. On the other hand, if there is no sound at the second row of strips after a couple of seconds it will be interpreted as that the vehicle did not drive over the second row, and that the vehicle has yielded to the pedestrian. Such realization of vehicular yield providing a gap in traffic helps the PWVL decide to safely cross the street.

3.4.4.4 Positioning the Rows of strips and Flags

Positioning the sound strips appropriately helps provide sufficient Perception Reaction Time (PRT) for the PWVL. For this purpose, it may be best that the first row of the strip be pushed upstream against oncoming traffic as much as possible away from the second row depending on the posted speed of the approach. However, for this location there are constraints on how much space is available for keeping the rows of strips apart from each other.

When considering Approach 1, vehicles coming from the driveway of the strip mall with Circle K convenience store on Edward Street North just before the roundabout could have interfered with the monitoring process if they turn right into Approach 1 where monitoring was happening. As a result, the first row of strips was positioned in a way that no vehicle could have passed through without going over the first row of strips. In other words, the area being monitored was defined by the location of this driveway instead of setting a more adequate distance commensurate with the speed of vehicles approaching the roundabout from this end.

Regarding Approach 2, vehicles leaving the roundabout have an extremely short distance to travel before reaching the crosswalk. This area is constrained and determined by the design and construction of the roundabout, thus limiting the space available to be monitored. As a result of this tightness of the space, it is possible to see vehicles yield to pedestrians some distance before they reach the first row of strips on that approach.

Approach 3 allows for larger space to be monitored because the driveway to the Shopping Mall's parking lot is far away upstream of Redwood Avenue West going Eastbound. However, vehicles turning left from the Dental Clinic's parking lot nearby and upstream of Approach 3 must be fenced out of the monitored space.

Finally, the situation with Approach 4, on a double-lane road, is similar to the situation on Approach 2 on a single-lane road since both approaches are exit points from the roundabout. Vehicles at this approach could easily stop short of reaching the first row of strips as explained above. However, the number of vehicles coming out of the roundabout into Approach 4 is much higher than the number on Approach 2, something that could make the crosswalk on Approach 4 seem overwhelmed with passing vehicles if and when drivers don't yield to pedestrians. Also, motorists could become tempted and easily exploit the configuration of Approach 4, by speeding up as they exit the roundabout.

Table 1 below shows the distances between the red flags positioned on the respective approaches, relative to the rows of strips and the crosswalks. The red flags, shown in Figure 25 above, were placed as markers along the side of the road, in the area being monitored at each approach, to help track vehicles as they travel downstream on the roundabout towards the crosswalks. Flag 1 is the farthest upstream of the crosswalk. Further downstream is Flag 2 at some distance not so far away from the crosswalk, and Flag 3 being the closest to the crosswalk.

Table 1: Showing Distances between Flags, Rows of Strips, and Crosswalk on Approaches

	Distance from Flag 1 to Flag 2 (Strip Row 1) in meters	Distance from Flag 2 to Flag 3 (Strip Row 2) in meters	Distance from Flag 3 (Strip Row 2) to Crosswalk in meters
Approach 1	3.00	18.70	3.70
Approach 2	3.20	9.90	3.30
Approach 3	3.10	13.60	2.58
Approach 4	3.17	11.49	3.38

3.4.4.5 The use of Flags for Speed Measurement

The respective speeds of different vehicles traversing the corridor under observation could be determined relative to the flags. Thus, the Initial speed or Speed 1 was considered between the first two flags, and the final speed or Speed 2 was estimated between the last two flags. Furthermore, knowing Speed 1 and Speed 2 does allow for determining how the vehicle accelerates or decelerates as it approaches the crosswalk.

3.4.5 Monitoring PWVL on Treated Pavement

Now is time to evaluate the treatment and determine if the sound strips installed for accessibility purposes would have made a difference to PWVL when deciding to cross the streets. As discussed above, PWVL rely on the ambient sound at an intersection especially at a roundabout when determining the direction in which vehicles travel and the existence of gaps in traffic.

3.4.5.1 The logistics involved

The process followed here is the same as it was when monitoring without the treatment. This phase of data collection took place on October 27, 2022, under favorable weather condition, with the same groups of volunteers present as there were at the previous data collection session.

For this event, each volunteer was briefed again in regards to the process and protocol to follow. It was emphasized that the PWVL should indicate if they could hear the sound coming from the strips in row 1 and row 2. They should also indicate if they felt it was safe to cross.

3.4.5.2 Sequence of Events

This phase of data collection occurred in several steps. Volunteers were divided into two groups and proceed in the same manner as described earlier in subsection with each doing exact same thing as the other. Again, as done previously, volunteers should not have to cross the road on any of the approaches during the data collection exercise.

This process is the same as what was done previously, where each volunteer takes their turn at each approach along with a research team member and the mobility orientation specialist from CNIB. Once they have pushed the button for the APS on Approaches 1 and 4, or aligned to cross on Approaches 2 and 3, the volunteers would be indicating when they perceive vehicles cross the rows of sound strips. As usual, and for safety precaution, the volunteer with the CNIB staff would have to step back from the crosswalk, while the member of research team steps forward to cross the road. This process will have everyone begin on the first approach and repeated for each volunteer in each group before migrating to the next approach on the roundabout.

Appendix Figure A8 shows the amount of time allocated to each volunteer in their role on-site, the plan and sequence of events previously described in this document.

Again, PWVL were asked to verbally share information on anything they noticed during the process, and particularly about their feeling on the crosswalk while trying to cross the street now with the sound strips in place compared to when there were none.

3.4.6 Removal of Strips

Later in the afternoon, after the data collection session finished and all volunteers left, it was time to remove the strips from the road. The pavement treatment was only allowed onsite while the data collection exercise was conducted. To facilitate the removal exercise, as shown in Figure 26 below, the City of Thunder Bay had one of its traffic control vehicles drive-through blocking off the road to protect people who were doing the removal and cleaning up the road. This process took about 30 minutes, with a team of 3 people from the university quickly peeling off the strips and pieces of dowel from the pavement. The surrounding area was also cleaned, and all waste materials were packed properly and disposed of appropriately.

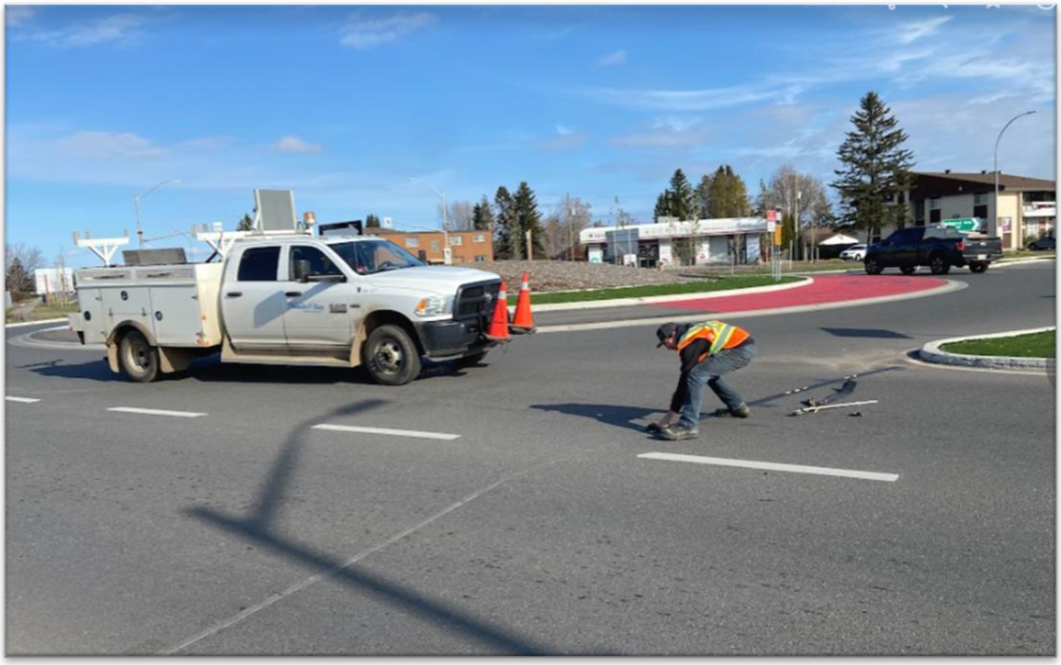


Figure 26: Strips being removed from the road

3.4.7 Impact of Weather, Season, and other Variables

Under Summer and Fall weather conditions, the strips with the tape used would have lasted a couple of weeks positioned on a road with low traffic volume. On the other hand, its performance in Winter weather remains unknown. For sure, snow removal activities on roads during winter time would have made the strips unsuitable in the current above-ground configuration. Furthermore, the fact, as indicated by one of the volunteers during the research, that PWVL perceive sounds differently under different weather conditions, makes the impact of weather a significant factor. The individual who made this claim did not elaborate, but it is worth investigating further at another time in the future. Basic science teaches that the speed at which sound travels varies, depending on air temperature, so that could be responsible for why the PWVL might have perceived sound differently during winter compared to non-winter months. The observer who monitors vehicles visually might not be so impacted by the lag in sound speed, due to varying temperatures. Finally, it is unlikely that day or night time variation would have impacted the performance of the strips.

3.5 3D Model of a Roundabout

A 3D model of some random roundabout was used in illustrating to PWVL how the roundabout is configured. Figure 27 below shows this 3-Dimensional roundabout model printed in blue. This model consists of three different topographical levels. The lowest topographical level on the model indicates the surface where vehicles pass on the roundabout; the next level up is where pedestrians walk, while the highest level is neither for pedestrian nor vehicle traffic.

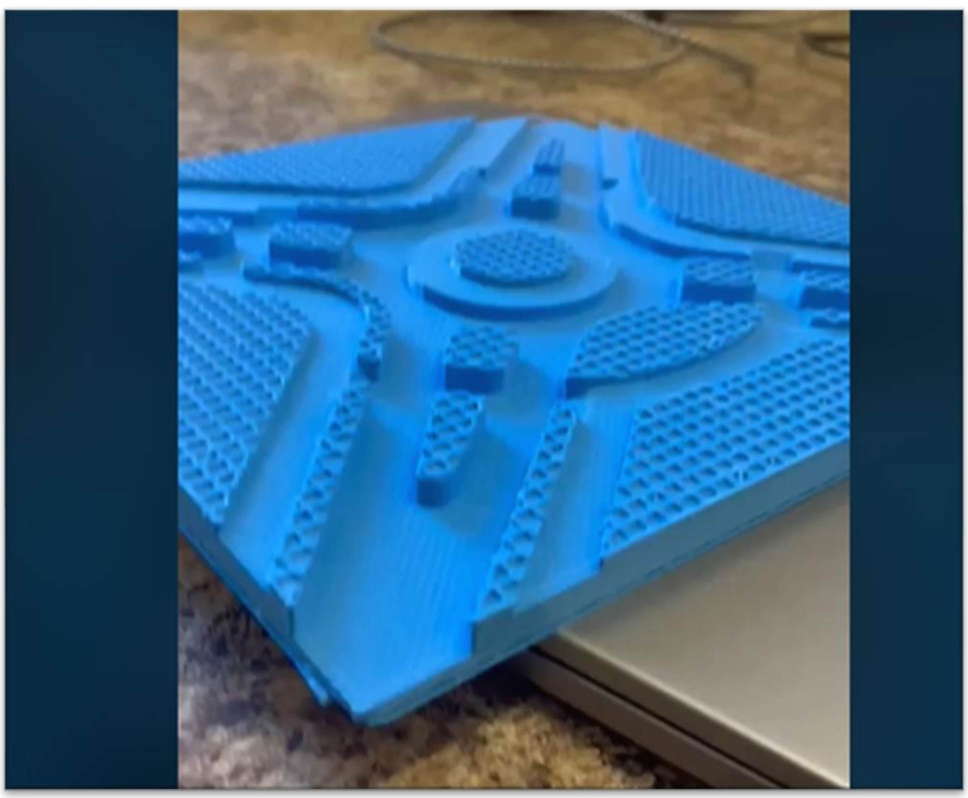


Figure 27: Showing the three layers of the 3-Dimensional model

3.5.1 How the 3D Model was introduced in this project

One of the CNIB staff who is involved in the research area related to PWVL suggested the use of the 3D model of a roundabout that he had on hand. For that purpose, this staff member sent the file containing the designed 3D model for the research team to print. The model was printed with the help of Makerspace at Lakehead University's main library. It was decided to print first a smaller version of the 3D model in blue to test the printer's ability, and later a couple models of 7- and-1/2 -inch by 7- and- 1/2-inch size was printed in both blue and orange colors.

3.5.2 Its use at CNIB

With the 3D model, some information related to the roundabout were conveyed to the volunteers, who felt the model by touch and thus making some sense of the roundabout. Also, printing in brighter colors makes it more useful for PWVL who could see better bright colors than regular colors. Figure 28 below shows the orange 3D model used in this research project.

Figure 28: Showing a model in orange color

3.5.3 Its use at TAC Convention

The model was taken to the Transportation Association of Canada (TAC) 2022 National convention at Edmonton. It was shown for illustration purposes when a discussion about Roundabout Safety and Accessibility took place. It was well received by the community involved in roundabout and geometric design for roads.

3.6 Evaluating Police Collision Reports

Upon request, Thunder Bay Police Department provided redacted copies of 32 vehicle collision reports to the research team. 22 of the reports were to be analyzed for the intersection for the period between June 2, 2018, to June 21, 2021, before the roundabout was developed, as well as 10 reports for the period December 1, 2021, to November 19, 2022, after the roundabout was built.

3.6.1 Evaluation and Analysis

The intention of this analysis is to determine how the intersection has impacted the pedestrian historically, especially since it was converted into a roundabout. Information such as collision number, date and time of collision, speed of each vehicle involved in collision, the road surface condition, weather condition, lighting condition, type of collision and severity of injuries arising from the collision, were extracted from the reports.

The information gathered from the reports were aggregated and shown on collision diagrams. Furthermore, classification was made to show how daytime compares to nighttime with respect to the number and severity of injuries or damage that occurred, which could range from just property damage only, to minor injury, serious injury or fatality.

CHAPTER 4. DATA ANALYSIS AND RESULTS

This chapter presents the analysis and results of the national workshop, the opinion survey shared with PWVL through CNIB, and the field data collected with and without sound strips at the roundabout.

4.1 National Workshop

The information gathered at the national workshop was summarize in a report. The 13–point conclusion of this workshop include the following:

(1) PWVL wanted municipalities, agencies and other stakeholders who build roundabouts to know that PWVL feel unsafe when trying to cross the street on roundabouts.

(2) Agencies must continuously educate drivers, the general public, and PWVL on how to navigate or cross the street on roundabouts.

(3) Agencies need to regularly check curbs at roundabouts and maintain or repair damaged parts.

(4) Agencies need to provide Tactile Walking Surface Indicator (TWSI), and well-maintained curb cuts, among other features possible, for safe crossing at crosswalks on roundabouts and other circular traffic calming structures, including those in a residential area. PWVL can better orientate themselves with such accessibility features in place.

(5) Agencies must provide reliable means of transmitting audible cues to PWVL to stay aware of traffic movement in a roundabout where discernment of traffic movement patterns is very difficult.

(6) Agencies need to locate pedestrian crosswalks far away from where drivers tend to feel unrestricted from speeding and accelerating. Currently, the configuration of many Canadian roundabouts has the crosswalks positioned just a short distance from exit points of the circulatory roadway in the roundabout, with the outbound vehicles starting to speed up as they exit the roundabout.

(7) Agencies should provide vibrating cones or any other devices and measures that might help improve accessibility beyond the APS on crosswalks. Although vibration cones don't guarantee that drivers would stop for a pedestrian, cone vibration is better than the audio or sound effect that become drowned out in the noisy background.

(8) Agencies should provide raised crosswalks at roundabouts.

(9) The process of making complaints about roundabout accessibility, and other matters regarding transportation accessibility, to some agencies needs to be revised or optimized using Artificial Intelligence (AI), and upgrading into a system that is more beneficial for PWVL, and the general public when they file complaints. According to the workshop participants, with the current system, complaints are treated fairly quickly by the city authorities and agencies in charge, if the complainant is well known. It appears to be a slow and frustrating system for the average person, which often ends in a disappointing official response.

(10) If the law permits, agencies should have cameras installed on major intersections to monitor incidents for pedestrian safety. Such video recording could help resolve any issues serving as evidence when complaints are made by vulnerable road users.

(11) Agencies should ensure that APS is located in a consistent position to make it easy for PWVL. The APS should be at a reasonable height, standardized for all locations, where the sound can be most helpful in guiding PWVL. Consistency in tone is equally

important. If a countdown with timing is displayed visually for pedestrians who can see, the same information should be made available audibly for PWVL at the maximum length of time possible.

(12) Agencies should deter the aggressive behavior of drivers who obstruct the pedestrian path at the crosswalk while such drivers themselves wait for a gap in traffic. Perhaps the installation of cameras would be helpful in addressing this problem.

(13) Agencies should consider deterring or punishing drivers who whip through the pedestrian crossing at unsignalized intersections.

Based on the information provided above, it appears that there are major concerns from PWVL and CNIB staff regarding roundabouts and how to communicate with transportation agencies that are responsible for this type of locations of the transportation network. Beyond what is indicated above, more details can be seen in Appendix Figure A16 for the report that was compiled on the workshop.

4.2 Survey and Comments

The following subsections will summarize the comments received from the survey performed after the national workshop.

4.2.1 Nationwide Opinion Survey

There was a total of seven responses received for the survey. For future surveys, consideration should be given to the lack of internet access and inability to read on the computer, as some of the factors that can pose significant limitations to participants and their involvement. Regardless the low participation at this survey due to those aforementioned limitations, the response to the survey provided valuable insight for the project. The feedback from the seven respondents, summarized in Figure 29 below, indicates that most PWVL would need an accessibility aid for finding gaps in traffic at roundabouts, therefore justifying the need for such safety measure as the sound strips to improve accessibility.

Question about Roundabout	Number of people answering Y/N	Remarks
Are you able to locate the crosswalk?	5 of 7 said "YES"	Uses Tactile, Audible Signal, Curb Cut
Are you able to stay oriented and complete the crossing without veering or becoming disoriented?	5 of 7 said "YES"	Difficulty due to circular motion of traffic
Do you use any accessibility aids to stay aware of traffic situations at a crosswalk?	3 of 7 said "YES"	Using a cane or guide dog is hard due to the complexity of roundabouts. Hearing is the best way
Do you need any accessibility aids to find a gap in the traffic to complete a street crossing?	4 of 7 said "YES"	Not sure if such aid(s) exist(s)

Figure 29: Summary of the National Opinion Poll Conducted

4.2.2 PWVL's Comments during Data Collection – before versus after Installing Treatment

PWVL shared their thoughts and perceptions of the process when crossing the streets at the roundabout while data was being collected for the research. Before and after the installation of the sound strips, volunteers who stood on the crosswalk, indicated when they felt that vehicles had stopped, or when they found a gap in traffic and were ready to cross the street.

Table 2 below contains the summary of those comments which confirmed that the strips installed indeed helped PWVL detect gaps in traffic. Details of those comments by volunteers are presented in Appendix Figure A17.

These comments are very important because they provide insightful information from the volunteers right at the moment that the use of roundabouts is performed. Many of the comments were very relevant and need to be considered for future research in order to account for so many factors that are crucial and important to PWVL.

Table 2: Comments made by volunteers before and after the sound strip treatment was installed

Approach	Before Treatment	After Treatment
1	A. Difficult to determine the direction of vehicle movement B. Difficult to know if vehicles are yielding C. Difficult to determine if vehicles are yielding on the farther lane D. Insufficient amount of time on the APS to cross	A. Able to hear the sound from the farthest and closest strips to know if vehicles stopped B. Need some time to start crossing to ensure vehicles are not moving C. Still unsure if vehicles stop with certainty
2	A. Unable to determine when vehicles are exiting the roundabout	A. Unable to tell if vehicles stop, when vehicles

	B. Only feel safe if there is no vehicle on the roundabout C. Unable to determine if it is a 2-stage crossing and where the Splitter Island is	don't cross the farthest strip
3	A. Had problem determining when vehicles are exiting the roundabout, implying interference sound coming from Approaches 2 and 4	A. No problem
4	A. Unable to determine if vehicles are exiting the roundabout in the direction of the crosswalk where the volunteer is waiting	A. Farthest strip is helpful, but still difficult to differentiate between the lanes when vehicles yield B. It felt as if an insufficient amount of time was given to the APS for gap detection and crossing

4.3 Data Analysis and Results.

The following subsections present the analysis and results of the data collected at the roundabout on three different occasions. First with random pedestrians, next with PWVL on an untreated pavement, and finally with PWVL on treated pavement.

4.3.1 Results when monitoring random Pedestrians on Untreated Pavement

On August 31, 2022, monitoring to see the interaction between vehicles and pedestrians was successfully done. This knowledge gives the research team an idea of what might happen later at the roundabout, and helps them plan better for different scenarios they may face on site. As example, upon noticing that some vehicles were speeding as they left the circulatory roadway on the roundabout, it became more pronounced that plans must be made ahead of time to ensure the safety of people who come on site during data collection sessions especially the volunteers.

4.3.2 Results when monitoring with PWVL on Untreated Pavement

As indicated above, data was collected with volunteers participating without the sound strip treatment on October 13, 2022. Video recordings of the event on site was done according to the methodology explained earlier in Chapter 3. These recordings were processed and data were analyzed. Results are presented below.

4.3.2.1 Actual Sequence of Events

Volunteers were divided into two groups and data was collected at different times for each group as described previously. Each group went progressively through each one of the four approaches considered at the roundabout and all data was recorded for each volunteer from each group. The details of the sequence of events with Groups 1 and 2 of PWVL are shown in Appendix Table B1 and Table B2

4.3.2.2 Speed

Speeds 1 and 2 for individual vehicles were calculated with the use of Flags 1, 2 and 3 planted on each one of the approaches. Details about the location of each one of these flags as well as the distances between them were presented and described earlier in chapter 3.

The graphs in Figure - Ia, Figure – Ib, Figure – Ic, and Figure -Id show both speeds of vehicles on each of the four approaches with the first group of volunteers. Also, the corresponding Table - Ia, Table - Ib, Table – Ic and Table – Id for each approach respectively show the average speed, as well as the two-tailed statistical significance of these speeds. Similarly, with the second group of volunteers on site, Figure – Ie, Figure – If, Figure – Ig, and Figure -Ih with their corresponding Table – Ie, Table – If, Table – Ig, and Table – Ih. The number of vehicles observed by group per approach varied from 8 to 41.

Even when the statistical significance, measured by the term referred to as the p-value in statistics, is less than 0.05, the threshold where a hypothesis is challenged statistically, the significance in this project was expected because the size of data samples available is not sufficiently large as indicated previously due to several reasons, and thus should not lead to any conclusions about patterns noticed in the data.

For this pilot study, the “t-Test: Paired Two Sample for Means” was used to determine the statistical significance of repeated measures. However, measures of estimating the effect size were not used in the analysis of data for this pilot study. Such measures of estimating the effect size will be considered in the future if the sample size is not sufficiently large, to have a sense of the effect of the changes being implemented

On site, it felt as if drivers were speeding more on the major road, especially when exiting the roundabout. In the figures below, for multiple vehicles monitored, the blue line and dot indicate the initial speed or Speed 1 for each vehicle approaching the crosswalk, while the corresponding orange line and dot represent the final speed or Speed 2 of the same vehicle. It appears for the most part, that the average value for Speed 2 surpasses the average for Speed 1. Furthermore, a few of the vehicles on the graph can be seen to have exceeded the roundabout’s allowable speed limit of 40 KPH.

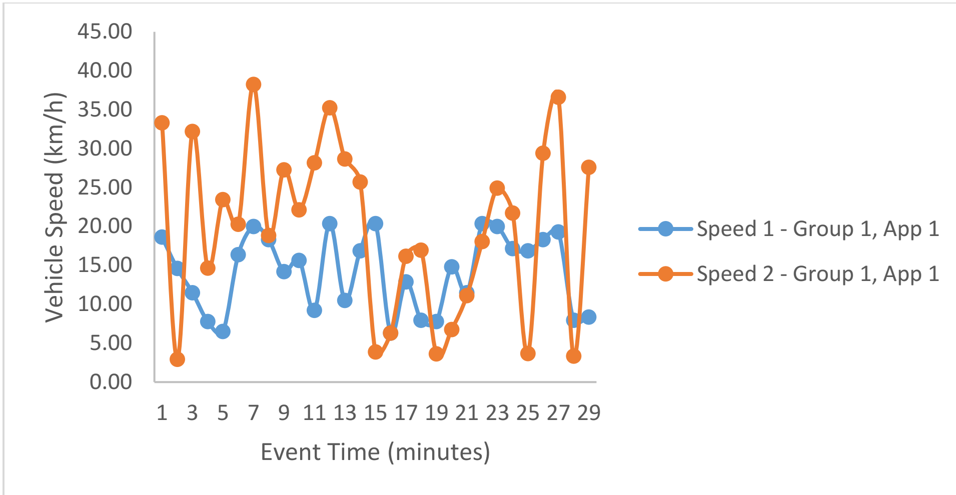


Figure – I a: Vehicle Speed versus Time of Event's Occurrence without Treatment - Group 1 Approach 1. Each of the multiple vehicles monitored, passing through the scene has a pair of speeds named Speed 1 and Speed 2

Table - I a: Some Speed Statistics - Volunteer Group 1 on Approach 1 Before Treatment

Before Treatment **Group 1, Approach 1**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	14.15	20.04
Standard Deviation (KPH)	4.87	11.10
Statistical Significance	0.006	Two Tail

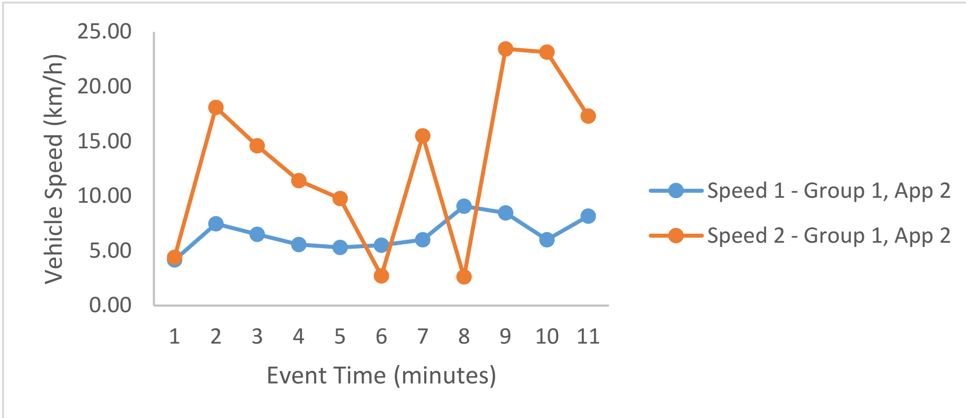


Figure – I b: Vehicle Speed versus Time of Event's Occurrence without Treatment - Group 1 Approach 2

Table - I b: Some Speed Statistics - Volunteer Group 1 on Approach 2 Before Treatment

Before Treatment **Group 1, Approach 2**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	6.57	13.00
Standard Deviation (KPH)	1.53	7.52
Statistical Significance	0.014	Two Tail

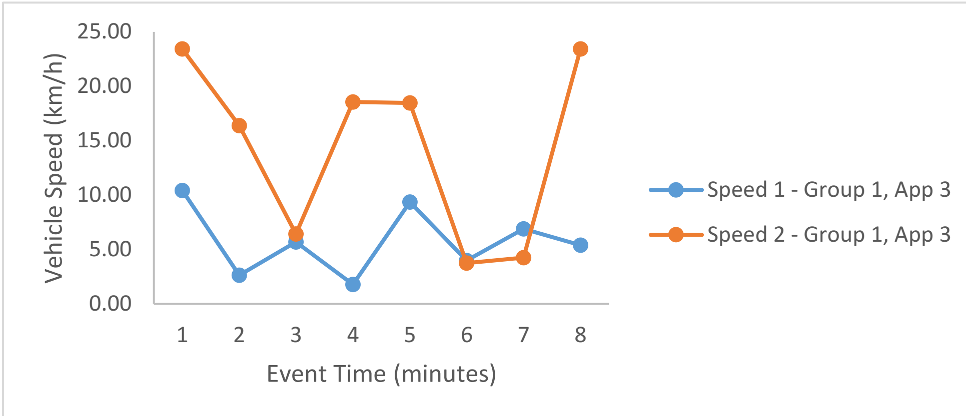


Figure – I c: Vehicle Speed versus Time of Event's Occurrence without Treatment - Group 1 Approach 3

Table - I c: Some Speed Statistics - Volunteer Group 1 on Approach 3 Before Treatment

Before Treatment **Group 1, Approach 3**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	5.78	14.34
Standard Deviation (KPH)	3.04	8.28
Statistical Significance	0.021	Two Tail

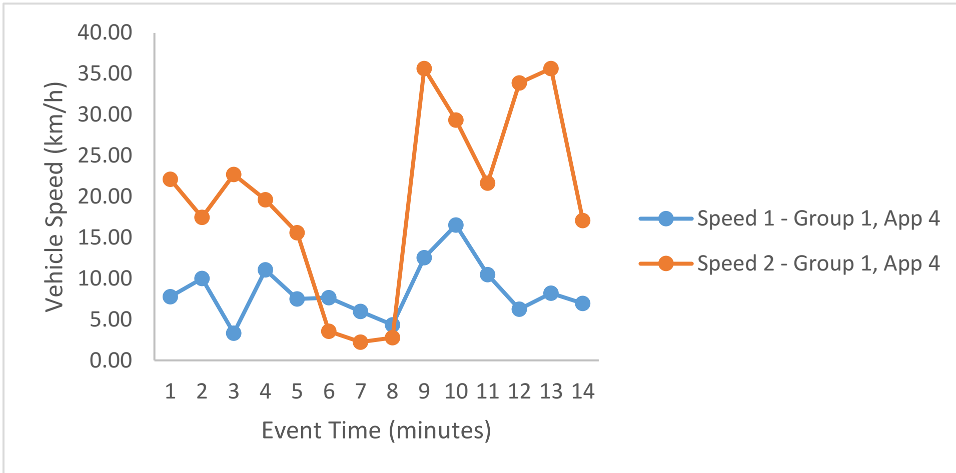


Figure – I d: Vehicle Speed versus Time of Event's Occurrence without Treatment - Group 1 Approach 4

Table - I d: Some Speed Statistics - Volunteer Group 1 on Approach 4 Before Treatment

Before Treatment **Group 1, Approach 4**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	8.47	19.96
Standard Deviation (KPH)	3.44	11.44
Statistical Significance	0.001	Two Tail

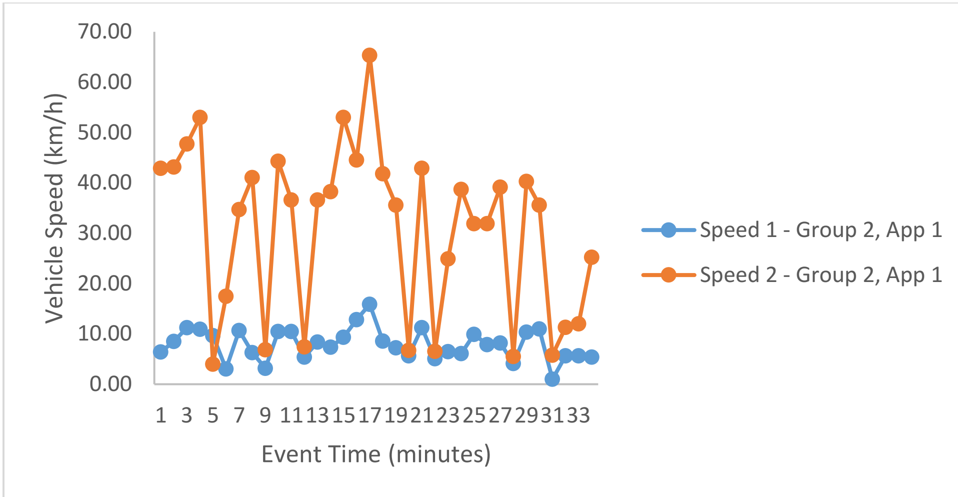


Figure - I e: Vehicle Speed versus Time of Event's Occurrence without Treatment - Group 2 Approach 1

Table - I e: Some Speed Statistics - Volunteer Group 2 on Approach 1 Before Treatment

Before Treatment **Group 2, Approach 1**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	7.93	30.97
Standard Deviation (KPH)	3.12	16.67
Statistical Significance	P < 0.001	Two Tail

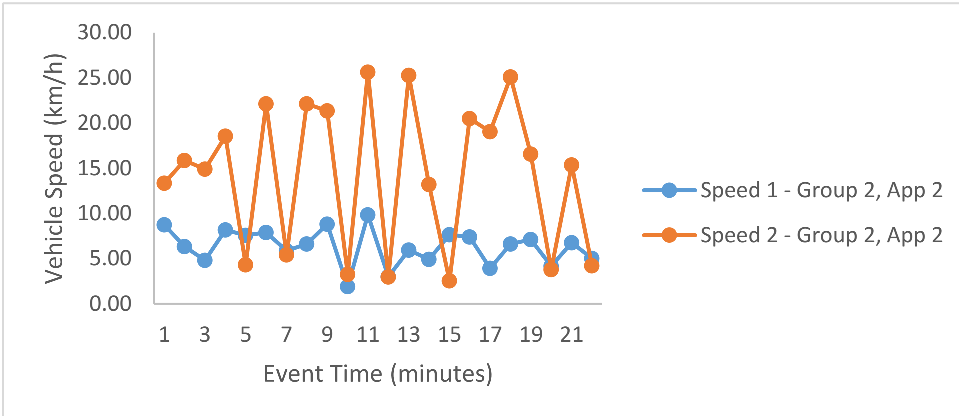


Figure - I f: Vehicle Speed versus Time of Event's Occurrence without Treatment - Group 2 Approach 2

Table - I f: Some Speed Statistics - Volunteer Group 2 on Approach 2 Before Treatment

Before Treatment **Group 2, Approach 2**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	6.32	14.34
Standard Deviation (KPH)	1.99	8.19
Statistical Significance	$P < 0.001$	Two Tail

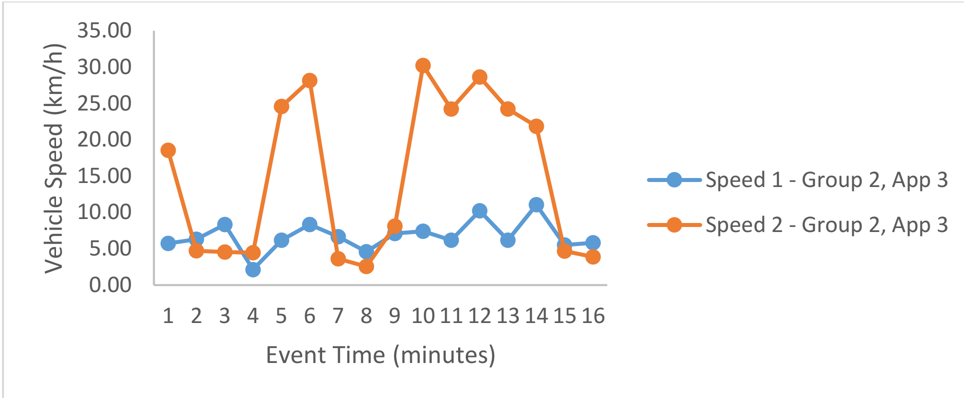


Figure - I g: Vehicle Speed versus Time of Event's Occurrence without Treatment - Group 2 Approach 3

Table - I g: Some Speed Statistics - Volunteer Group 2 on Approach 3 Before Treatment

Before Treatment **Group 2, Approach 3**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	6.74	14.82
Standard Deviation (KPH)	2.11	10.95
Statistical Significance	0.006	Two Tail

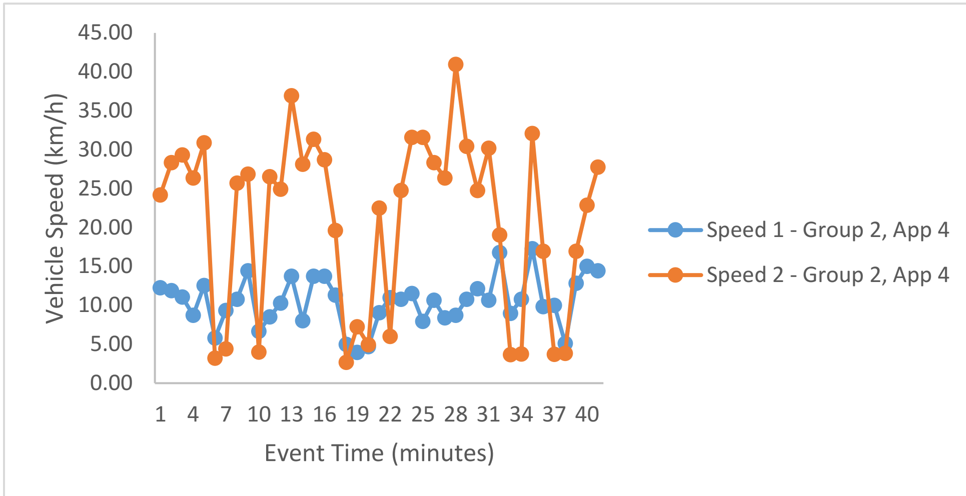


Figure - I h: Vehicle Speed versus Time of Event's Occurrence without Treatment - Group 2 Approach 4

Table - I h: Some Speed Statistics - Volunteer Group 2 on Approach 4 Before Treatment

Before Treatment **Group 2, Approach 4**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	10.47	21.03
Standard Deviation (KPH)	3.14	11.21
Statistical Significance	P < 0.001	Two Tail

4.3.2.3 Acceleration

It is simplistic to assume that vehicles are not accelerating towards the crosswalk on the roundabout when pedestrians wait for drivers to slow down and yield. Unfortunately, that was not the case and several drivers kept moving and totally ignored the pedestrian who hoped in vain to find a gap in traffic. The acceleration profile determined for the vehicles per approach on the roundabout before the treatment was applied is graphically shown in Figure – IIa, Figure – IIb, Figure – IIc and Figure – IId with the first group of volunteers on site. Similarly, Figure – IIe, Figure – IIf, Figure – IIg and Figure – IIh show the situation while the second group of volunteers was there.

The acceleration for vehicles approaching the crosswalk is denoted by the positive y-axis on the graph, which is plotted against the deceleration on the negative y-axis. Furthermore, for each approach, information about average acceleration and standard deviation for all the vehicles are provided on Table – IIa, Table – IIb, Table – IIc, and Table – IId for the first group of volunteers, as well as Table – IIe, Table – IIf, Table – IIg, and Table – IIh for the second group of volunteers. Observations for acceleration also ranged from 8 to 41 vehicles for these approaches.

It appears from the graphs that the acceleration features and tilts more prominently on the positive y-axis than it does on the negative, implying that most vehicles that were monitored indeed accelerated more than they decelerated as they approached the crosswalk.

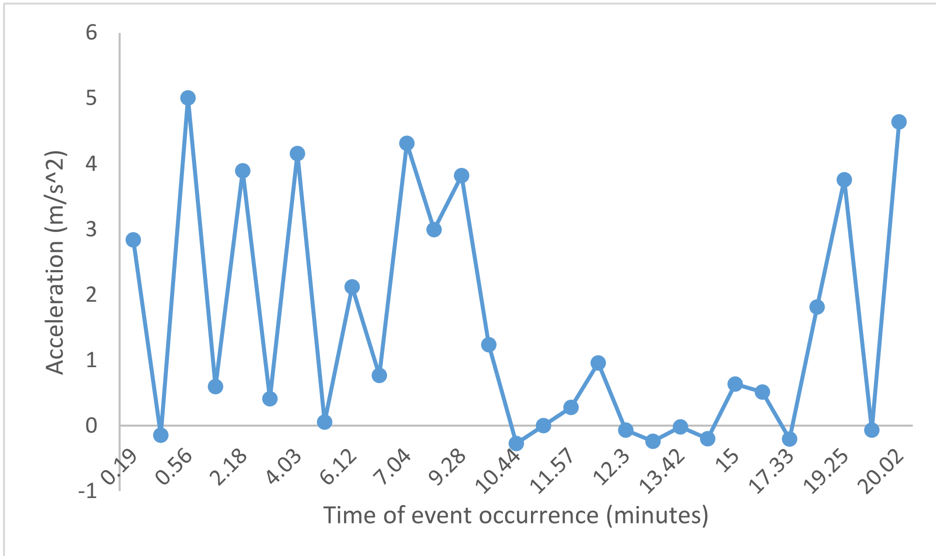


Figure - II a: Vehicle Acceleration versus Time of Event's Occurrence without Treatment - Group 1 Approach 1

Table - II a: Some Acceleration Statistics - Volunteer Group 1 on Approach 1 Before Treatment

Before Treatment **Group 1, Approach 1**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	1.50
Standard Deviation (m/s^2)	1.79

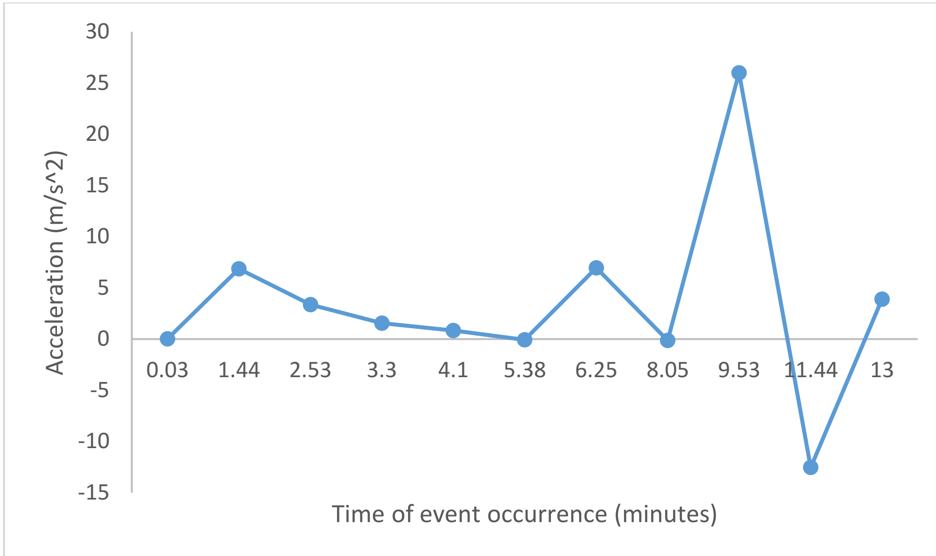


Figure - II b: Vehicle Acceleration versus Time of Event's Occurrence without Treatment - Group 1 Approach 2

Table - II b: Some Acceleration Statistics - Volunteer Group 1 on Approach 2 Before Treatment

Before Treatment **Group 1, Approach 2**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	3.34
Standard Deviation (m/s^2)	9.14

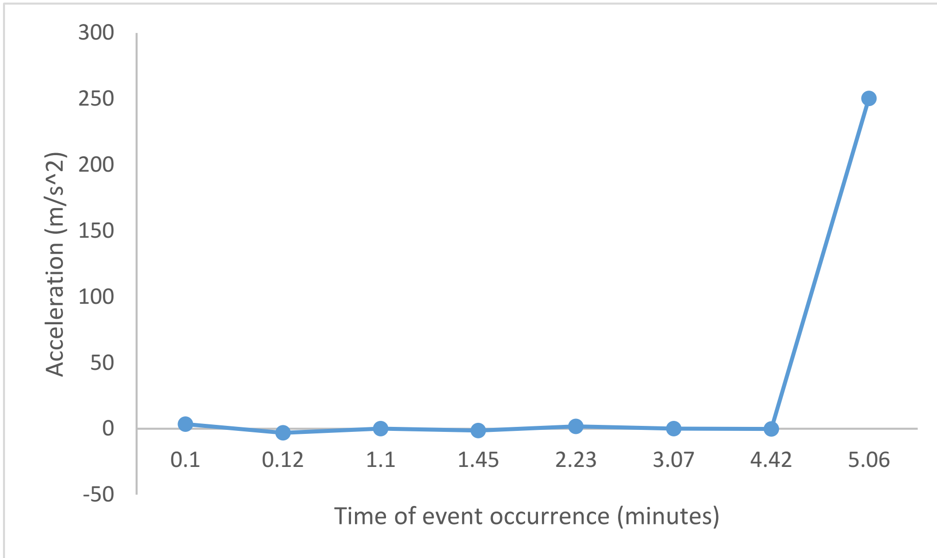


Figure - II c: Vehicle Acceleration versus Time of Event's Occurrence without Treatment - Group 1 Approach 3

Table - II c: Some Acceleration Statistics - Volunteer Group 1 on Approach 3 Before Treatment

Before Treatment **Group 1, Approach 3**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	31.41
Standard Deviation (m/s^2)	88.54

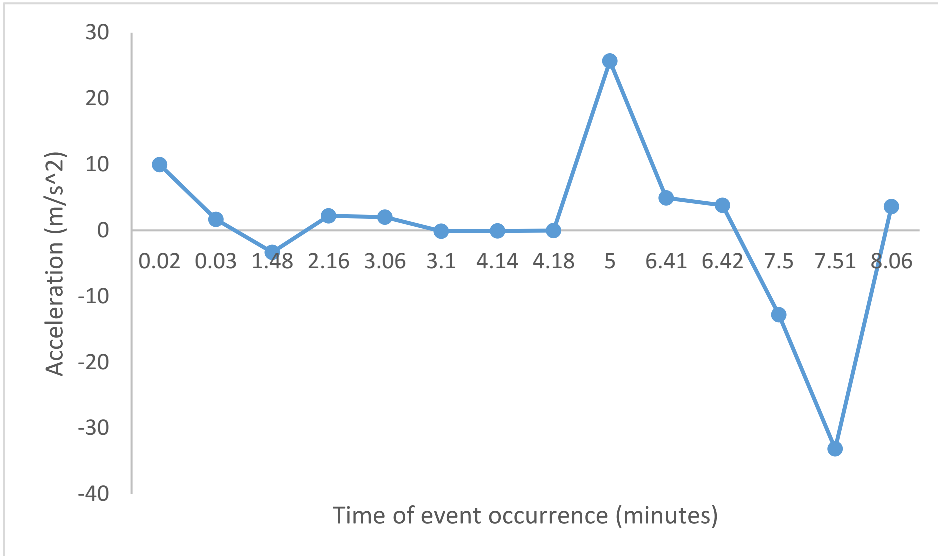


Figure - II d: Vehicle Acceleration versus Time of Event's Occurrence without Treatment - Group 1 Approach 4

Table - II d: Some Acceleration Statistics - Volunteer Group 1 on Approach 4 Before Treatment

Before Treatment **Group 1, Approach 4**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	0.31
Standard Deviation (m/s^2)	12.69

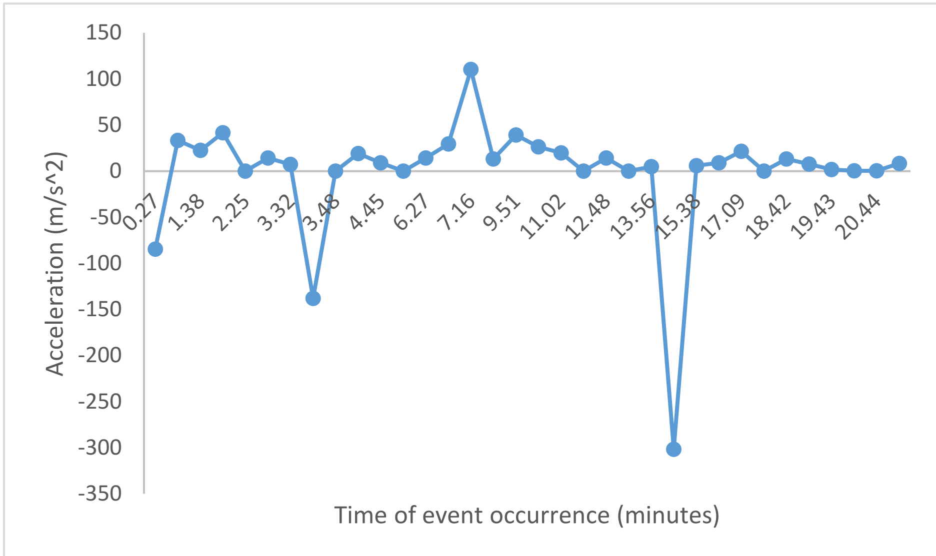


Figure - II e: Vehicle Acceleration versus Time of Event's Occurrence without Treatment - Group 2 Approach 1

Table - II e: Some Acceleration Statistics - Volunteer Group 2 on Approach 1 Before Treatment

Before Treatment **Group 2, Approach 1**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	-1.07
Standard Deviation (m/s^2)	64.75

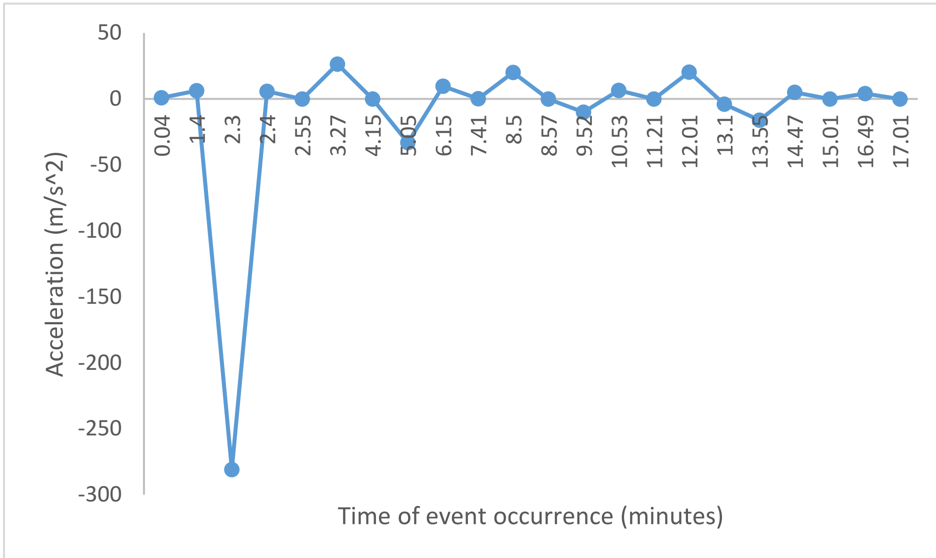


Figure - II f: Vehicle Acceleration versus Time of Event's Occurrence without Treatment - Group 2 Approach 2

Table - II f: Some Acceleration Statistics - Group 2 on Approach 2 Before Treatment

Before Treatment **Group 2, Approach 2**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	-10.92
Standard Deviation (m/s^2)	61.53

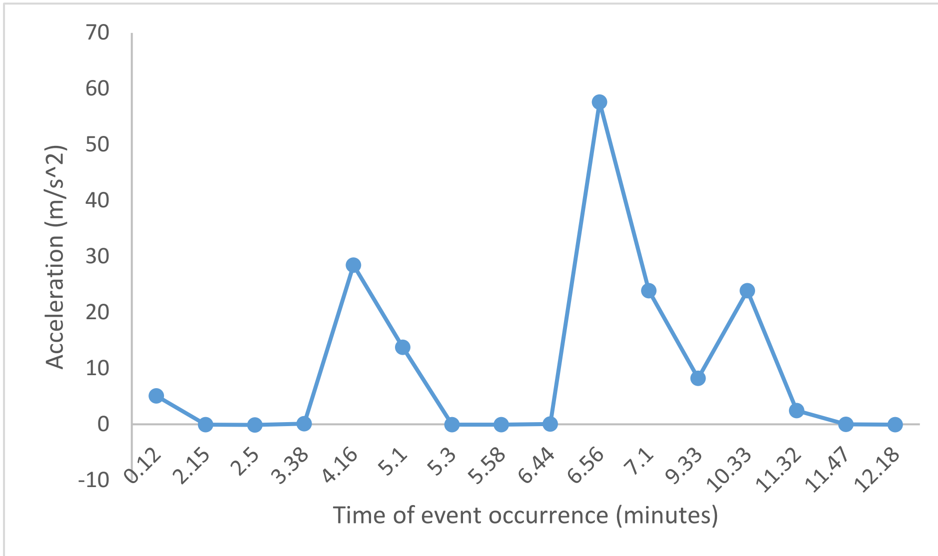


Figure - II g: Vehicle Acceleration versus Time of Event's Occurrence without Treatment - Group 2 Approach 3

Table - II g: Some Acceleration Statistics - Volunteer Group 2 on Approach 3 Before Treatment

Before Treatment **Group 2, Approach 3**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	10.20
Standard Deviation (m/s^2)	16.12

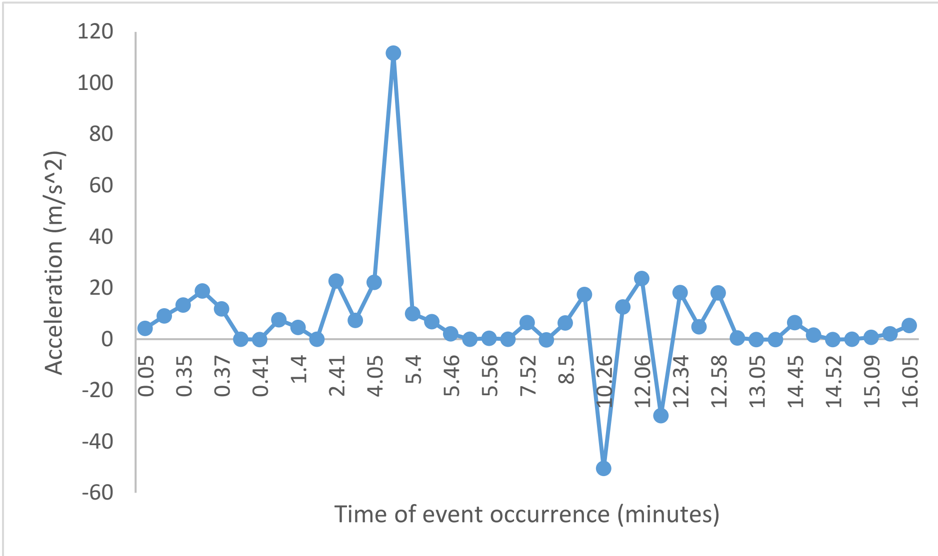


Figure - II h: Vehicle Acceleration versus Time of Event's Occurrence without Treatment - Group 2 Approach 4

Table - II h: Some Acceleration Statistics - Volunteer Group 2 on Approach 4 Before Treatment

Before Treatment **Group 2, Approach 4**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	7.21
Standard Deviation (m/s^2)	21.05

4.3.2.4 Delays

The roundabout has RRFBs with APS on Approaches 1 and 4 as indicated previously. With no treatment done to the pavement, the amount of time each pedestrian spent activating the RRFBs with the APS, waiting for gaps in traffic, and the delay felt on the crosswalk were determined with the data collected. Then this information on the respective group to which the PWVL belong, the approaches where they were on the roundabout, the number of attempts the pedestrian made at crossing, the delay they felt in seconds on the RRFBs - APS, or the delay whilst waiting for vehicles to yield, the total delay the pedestrian experienced, as well as the average delay felt per pedestrian were estimated and are presented in Figure 30. Figure 31 shows the delays plotted on a histogram, while the average delay felt by the pedestrian on each attempt at crossing the road is summarized further in Figure 32.

Please note that even though there is no RRFB with APS on Approaches 2 and 3, it appears that the PWVL took some time to align and prepare to cross the road on those approaches. Thus, for convenience and ease of data presentation, the amount of time taken for the PWVL to align on the road has been interpreted and categorized as if spent on pushing the APS button.

Group	Approach	Number of attempts by PWVL	Delay on APS (sec)	Delay waiting for Yield (sec)	Total Delay (sec)	Average Delay (sec/ped)
1	1	6	58.32	62.36	120.68	20.11
	2	4	25.77	483.34	509.11	127.28
	3	3	19.17	110.54	129.71	43.24
	4	2	20.99	26.13	47.12	23.56
2	1	7	44.03	84.57	128.60	18.37
	2	6	45.07	329.46	374.53	62.42
	3	6	50.16	120.95	171.11	28.52
	4	7	54.86	161.16	216.02	30.86
Sum (sec)		41	318.37 (= 5.30 min)	1378.51 (= 22.98 min)	1696.88 (= 28.28 min)	
Average Delay felt (sec/ped)			7.77	33.62	41.39	

Figure 30: Number of attempts made by groups of pedestrians on different approaches and the delay felt before treatment was applied

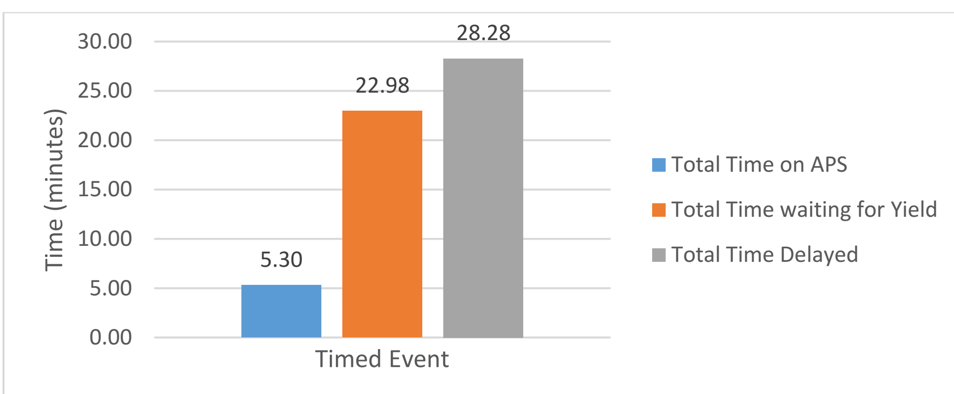


Figure 31: Time spent on APS, waiting for a gap, and total delay before treatment

Average time spent on the APS, waiting for vehicle yield or delayed altogether for each of the 41 attempts made by pedestrians to cross the road on the roundabout before treatment.				
	Time spent on APS	Time spent waiting for vehicle yield	Time delayed altogether	
Average =	7.77	33.62	41.39	seconds/pedestrian-attempt
	0.13	0.56	0.69	minutes/pedestrian-attempt

Figure 32: Average time spent by each pedestrian at each attempt on the APS, waiting for yield and delayed altogether before treatment was applied

4.3.2.5 Vehicles Yield versus No-Yield

Another important factor determined from the data collected was the percentage of vehicles that yielded versus those that did not yield to PWVL while standing at the crosswalk waiting to find a gap in traffic in order to cross the street. This “Yield or No - Yield” factor is important in order to provide some insight to driver’s behaviour at roundabouts.

Table – IIIa, Table – IIIb, Table – IIIc and Table – IIId below show the percentage of vehicles that yielded versus those that did not yield to the first group of volunteers at the crosswalk on Approaches 1, 2, 3, and 4 respectively before installing the treatment on the pavement. Similarly, Table – IIIe, Table – IIIf, Table – IIIg and Table – IIIh contain information that are related to the second group of pedestrians.

Generally, the observation was that several drivers behaved poorly as vehicles were not yielding hundred percent of the time on all approaches to pedestrians who needed to cross the road. Since the sample size of the data set collected during this research is small, any conclusion drawn on the driver's behavior will be premature and unsupported.

Table - III a: Showing vehicles' percent yield before treatment – Group 1 on Approach 1

Vehicles Percent Yield – Before Treatment Group 1 on Approach 1			
The number of vehicles that yielded	**The number of vehicles that did not yield**	**Percent Yield**	
7	2	**77.78**	**%**

Table - III b: Showing vehicles' percent yield before treatment – Group 1 on Approach 2

Vehicles Percent Yield – Before Treatment Group 1 on Approach 2		
The number of vehicles that yielded	**The number of vehicles that did not yield**	**Percent Yield**

1	**0**	**100.00**	**%**

Table - III c: Showing vehicles' percent yield before treatment – Group 1 on Approach 3

Vehicles Percent Yield – Before Treatment Group 1 on Approach 3			
The number of vehicles that yielded	**The number of vehicles that did not yield**	**Percent Yield**	
1	**0**	**100.00**	**%**

Table - III d: Showing vehicles' percent yield before treatment – Group 1 on Approach 4

Vehicles Percent Yield – Before Treatment Group 1 on Approach 4			
The number of vehicles that yielded	**The number of vehicles that did not yield**	**Percent Yield**	
3	**1**	**75.00**	**%**

Table - III e: Showing vehicles' percent yield before treatment – Group 2 on Approach 1

Vehicles Percent Yield – Before Treatment Group 2 on Approach 1			
The number of vehicles that yielded	The number of vehicles that did not yield	Percent Yield	
8	4	66.67	%

Table - III f: Showing vehicles' percent yield before treatment – Group 2 on Approach 2

Vehicles Percent Yield – Before Treatment Group 2 on Approach 2			
The number of vehicles that yielded	The number of vehicles that did not yield	Percent Yield	
6	6	50.00	%

Table - III g: Showing vehicles' percent yield before treatment – Group 2 on Approach 3

Vehicles Percent Yield – Before Treatment Group 2 on Approach 3			
The number of vehicles that yielded	The number of vehicles that did not yield	Percent Yield	
6	1	85.71	%

Table - III h: Showing vehicles' percent yield before treatment – Group 2 on Approach 4

Vehicles Percent Yield – Before Treatment Group 2 on Approach 4			
The number of vehicles that yielded	The number of vehicles that did not yield	Percent Yield	
11	18	37.93	%

The total number of vehicles that yielded is 43, with 32 vehicles not yielding on the roundabout, and hence a 57.33 percent yield before the treatment was applied. This is considered a poor result making the PWVL feel neglected.

4.3.3 Results when monitoring PWVL on Treated Pavement

Some of the graphs and tabulations made of the data collected on October 27, 2022, are shown in this section. The research team imagined that the treatment applied to the pavement should not have influenced the driver's behavior and vehicle dynamics on the approaches being monitored. The treatment is intended to assist PWVL in making a sense of traffic on the roundabout and to determine when vehicles have yielded before the crosswalks.

4.3.3.1 Actual Sequence of Events

The sequence of events with volunteer Groups 1 and 2 on the roundabout is shown in Appendix Table B3 and Table B4.

4.3.3.2 Speed

With the treatment installed, Speeds 1 and 2 for the vehicles was estimated as previously done when the treatment wasn't there. Speeds of vehicles on each of the four approaches with the first group of volunteers are indicated in Figure – IIIa, Figure – IIIb, Figure – IIIc and Figure – IIId. Also, for each of the approaches, information about the average speed of the vehicles, the standard deviation from the average speed, as well as the two - tailed statistical significance of these speeds are shown on Table – IVa, Table – IVb, Table – IVc and Table – IVd respectively.

For the second group of volunteers Figure – IIIe, Figure – IIIf, Figure – IIIg, Figure – IIIh and Figure – IIIi, with their corresponding Table – IVe, Table – IVf, Table – IVg, Table – IVh and Table – IVi. Please note that the second group of volunteers did repeat events on Approach 1, because one of the volunteers showed up on site later. The number of vehicles sampled ranged from 7 to 36. Statistical significance of experimental results could have impacted what hypothesis is challenged or kept, but in this pilot study the limited amount of data collected due to the restrictions explained earlier will have an effect on this.

As shown previously, the blue line and dot indicate the initial speed or Speed 1 for each vehicle that approached the crosswalk, while the corresponding orange line and dot represent the final speed or Speed 2 of the same vehicle. It appears in this case that the average value for Speed 2 surpasses the average for Speed 1, and on a handful occasions drivers exceeded allowable speed of 40 KPH on the roundabout. Also, it felt to PWVL and other observers who stood on the crosswalk that drivers were speeding especially on their departure from the roundabout on the major road, even with the sound strips installed.

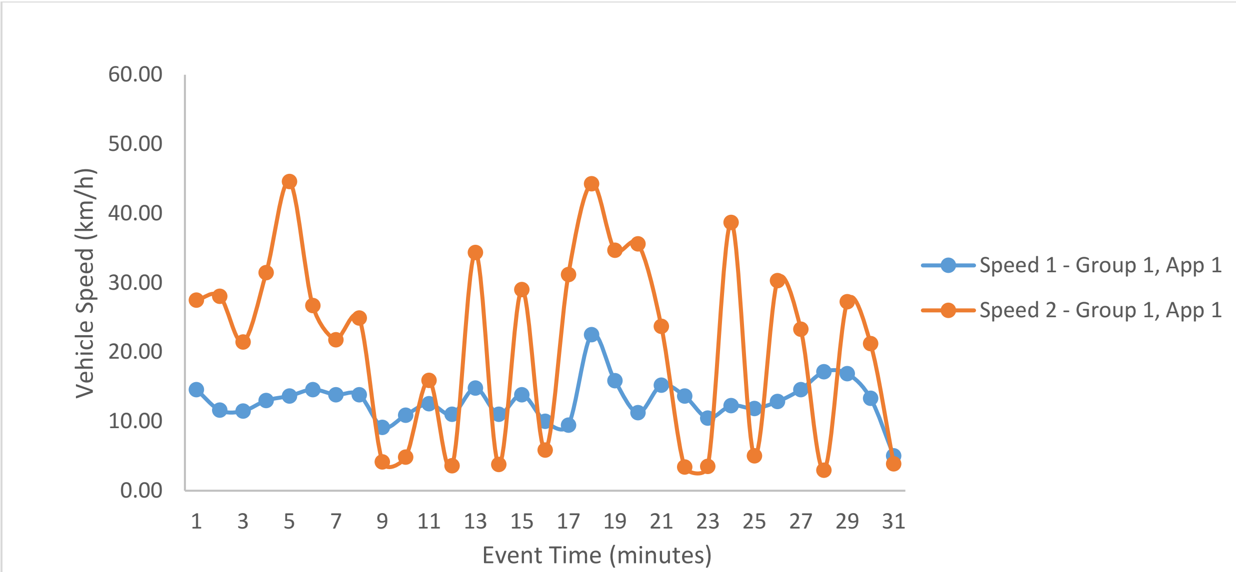


Figure - III a: Vehicle Speed versus Time of Event's Occurrence with Treatment - Group 1 Approach 1

Table - IV a: Some Speed Statistics - Volunteer Group 1 on Approach 1 After Treatment

After Treatment **Group 1, Approach 1**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	12.98	21.20
Standard Deviation (KPH)	3.04	13.45
Statistical Significance	0.001	Two Tail

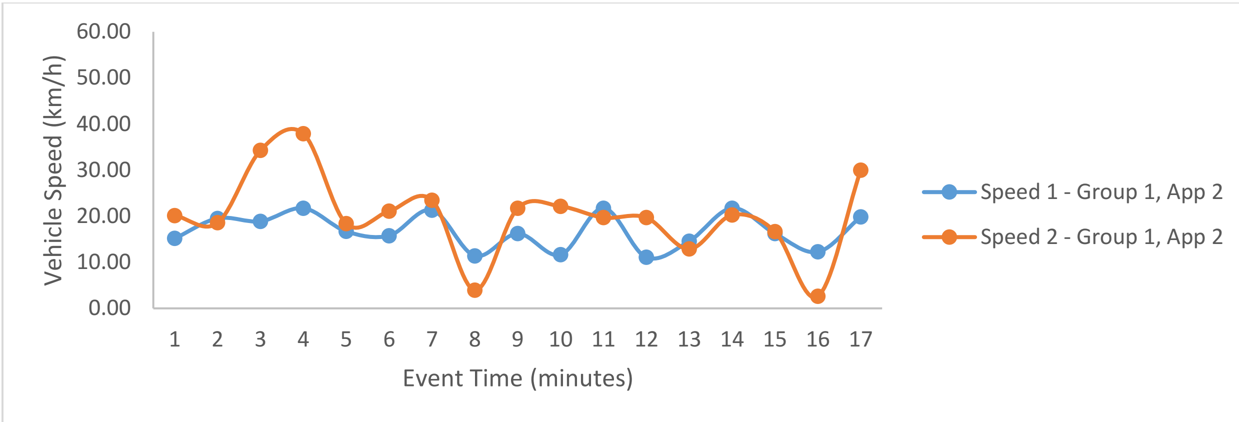


Figure - III b: Vehicle Speed versus Time of Event's Occurrence with Treatment - Group 1 Approach 2

Table - IV b: Some Speed Statistics - Volunteer Group 1 on Approach 2 After Treatment

After Treatment **Group 1, Approach 2**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	16.82	20.20
Standard Deviation (KPH)	3.82	8.91
Statistical Significance	0.072	Two Tail

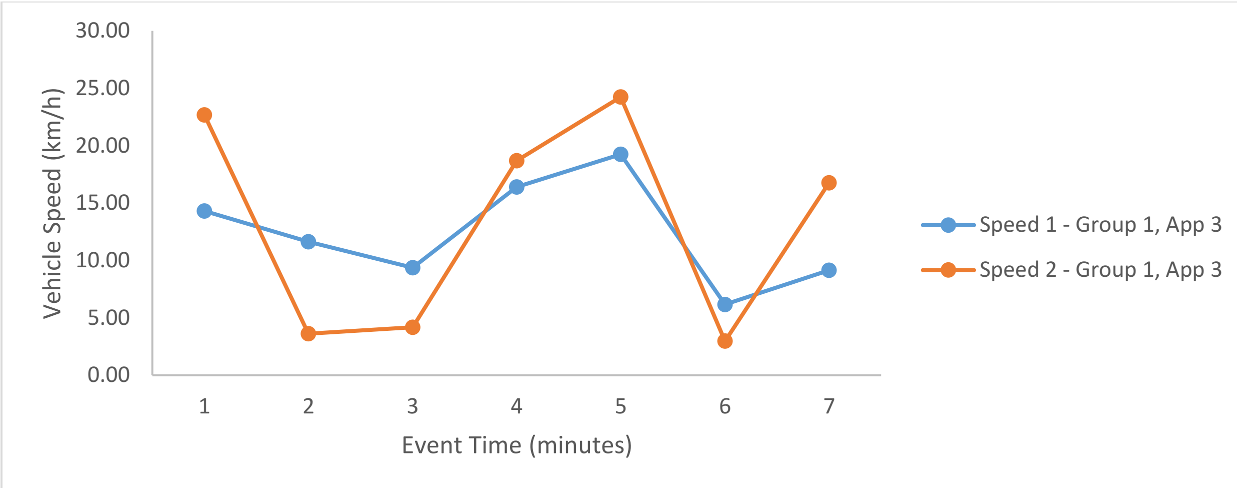


Figure - III c: Vehicle Speed versus Time of Event's Occurrence with Treatment - Group 1 Approach 3

Table - IV c: Some Speed Statistics - Volunteer Group 1 on Approach 3 After Treatment

After Treatment **Group 1, Approach 3**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	12.33	13.30
Standard Deviation (KPH)	4.58	9.42
Statistical Significance	0.704	Two Tail

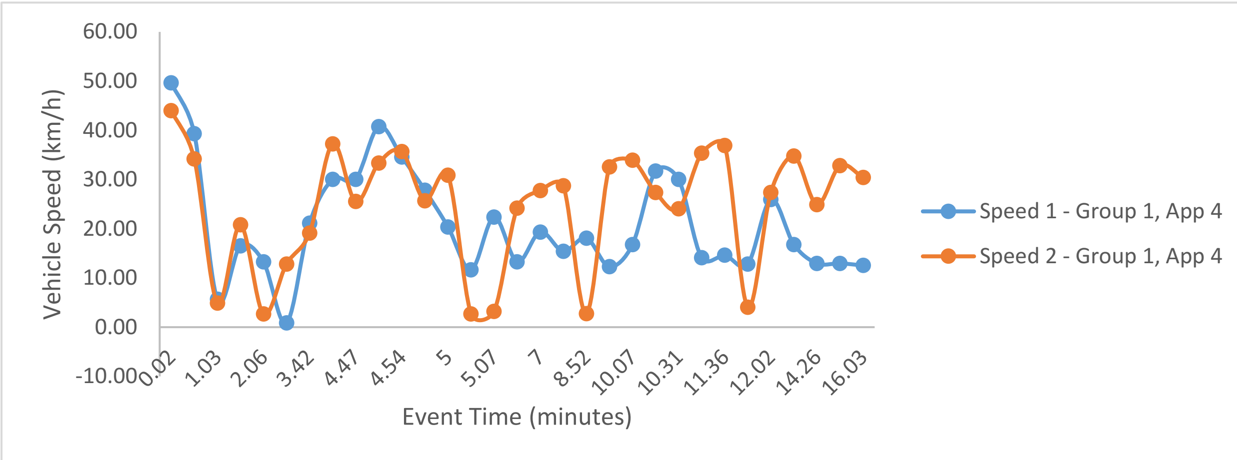


Figure - III d: Vehicle Speed versus Time of Event's Occurrence with Treatment - Group 1 Approach 4

Table - IV d: Some Speed Statistics - Volunteer Group 1 on Approach 4 After Treatment

After Treatment **Group 1, Approach 4**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	20.77	24.54
Standard Deviation (KPH)	10.86	12.14
Statistical Significance	0.084	Two Tail

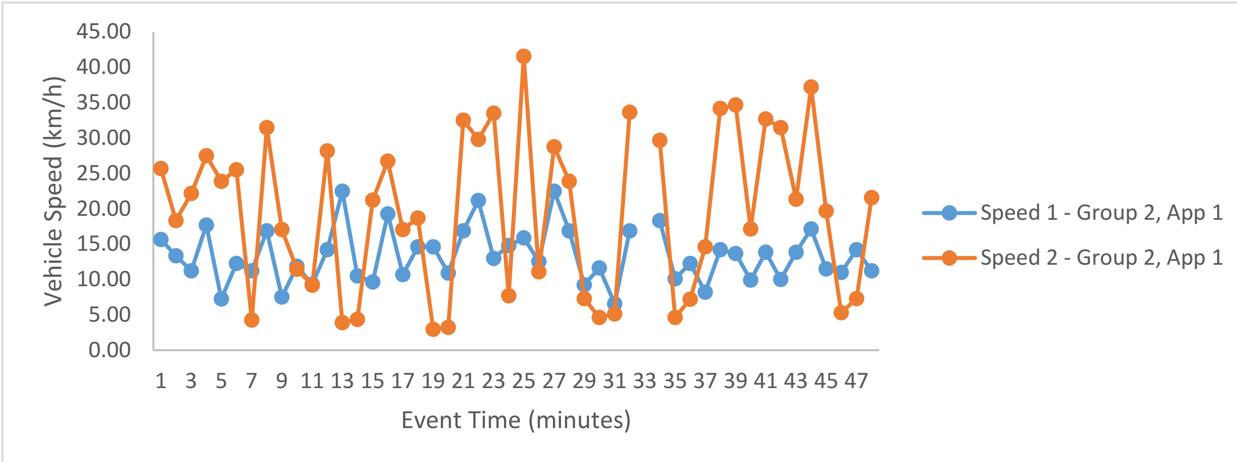


Figure - III e: Vehicle Speed versus Time of Event's Occurrence with Treatment - Group 2 Approach 1

Table - IV e: Some Speed Statistics - Volunteer Group 2 on Approach 1 After Treatment

After Treatment **Group 2, Approach 1**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	13.72	18.82
Standard Deviation (KPH)	4.20	11.22
Statistical Significance	0.008	Two Tail

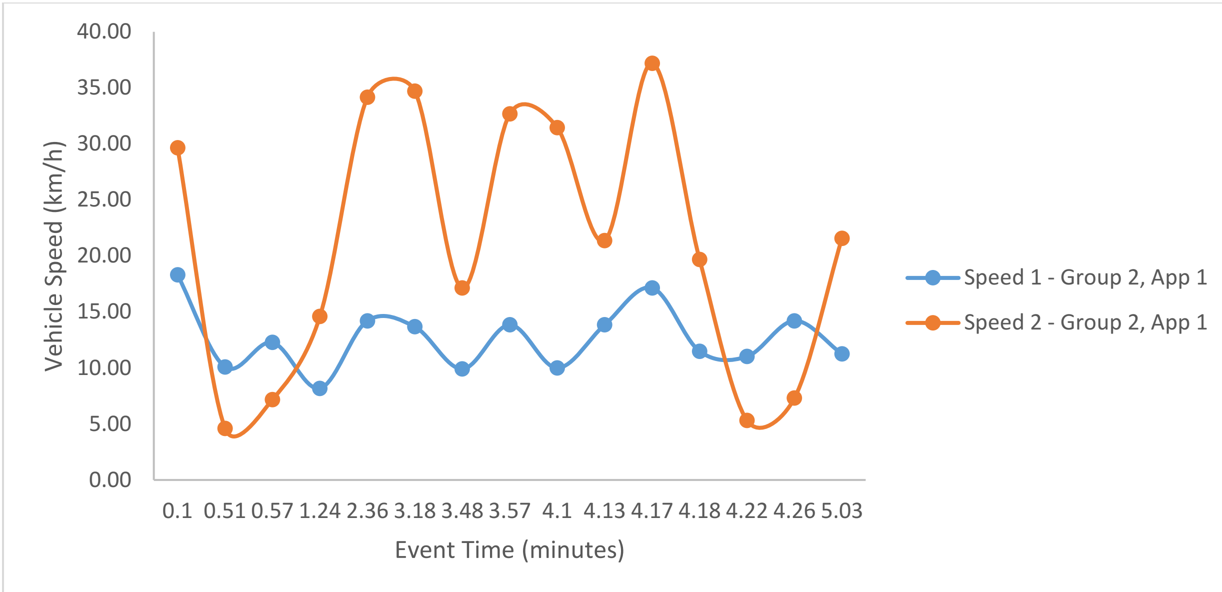


Figure - III f: Vehicle Speed versus Time of Event's Occurrence with Treatment - Group 2 Approach 1 – Repeated

Table - IV f: Some Speed Statistics - Volunteer Group 2 on Approach 1 After Treatment - Repeated

After Treatment **Group 2, Approach 1 - Repeat**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	12.63	21.24
Standard Deviation (KPH)	2.78	11.63
Statistical Significance	0.007	Two Tail

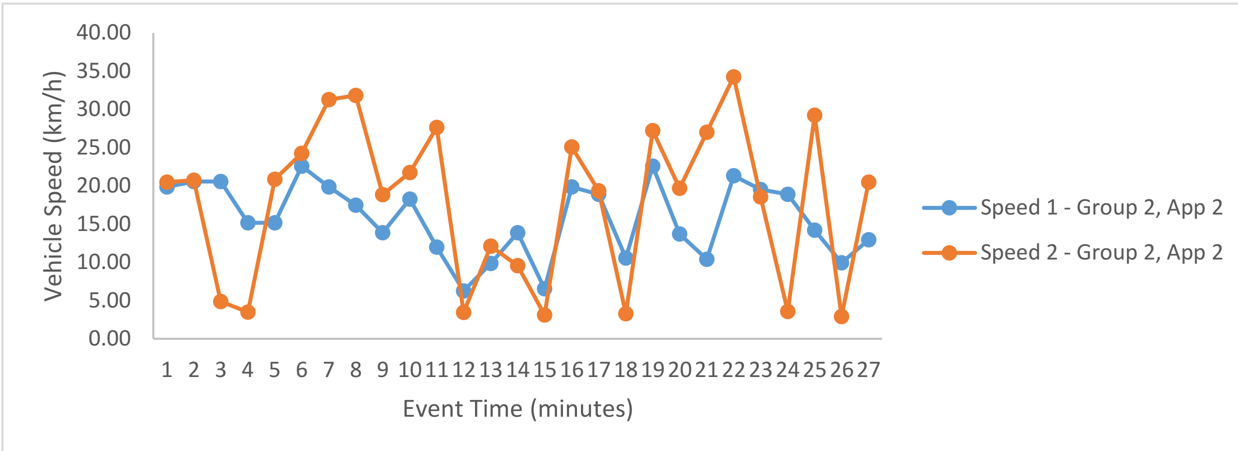


Figure - III g: Vehicle Speed versus Time of Event's Occurrence with Treatment - Group 2 Approach 2

Table - IV g: Some Speed Statistics - Volunteer Group 2 on Approach 2 After Treatment

After Treatment **Group 2, Approach 2**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	15.73	17.96
Standard Deviation (KPH)	4.81	10.24
Statistical Significance	0.104	Two Tail

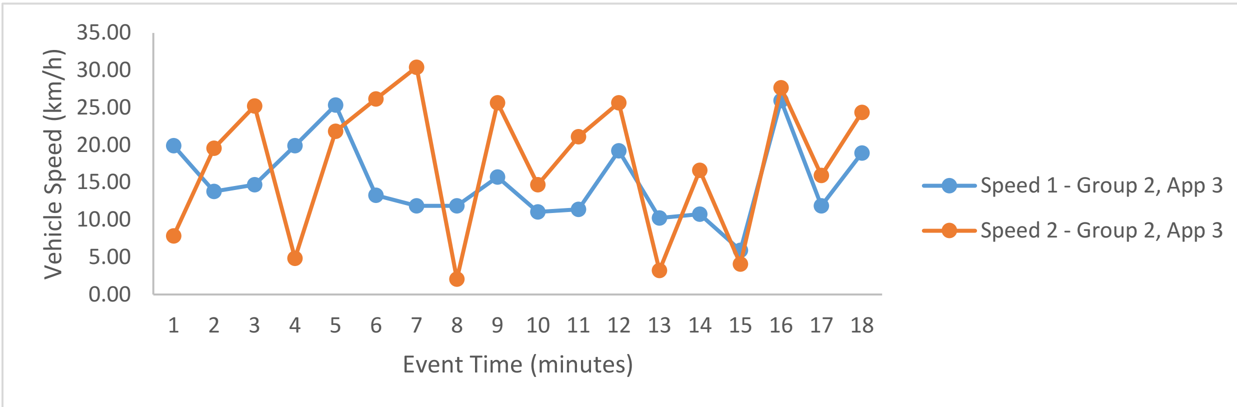


Figure - III h: Vehicle Speed versus Time of Event's Occurrence with Treatment - Group 2 Approach 3

Table - IV h: Some Speed Statistics - Volunteer Group 2 on Approach 3 After Treatment

After Treatment **Group 2, Approach 3**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	15.10	17.61
Standard Deviation (KPH)	5.40	9.42
Statistical Significance	0.129	One Tail
Statistical Significance	0.258	Two Tail

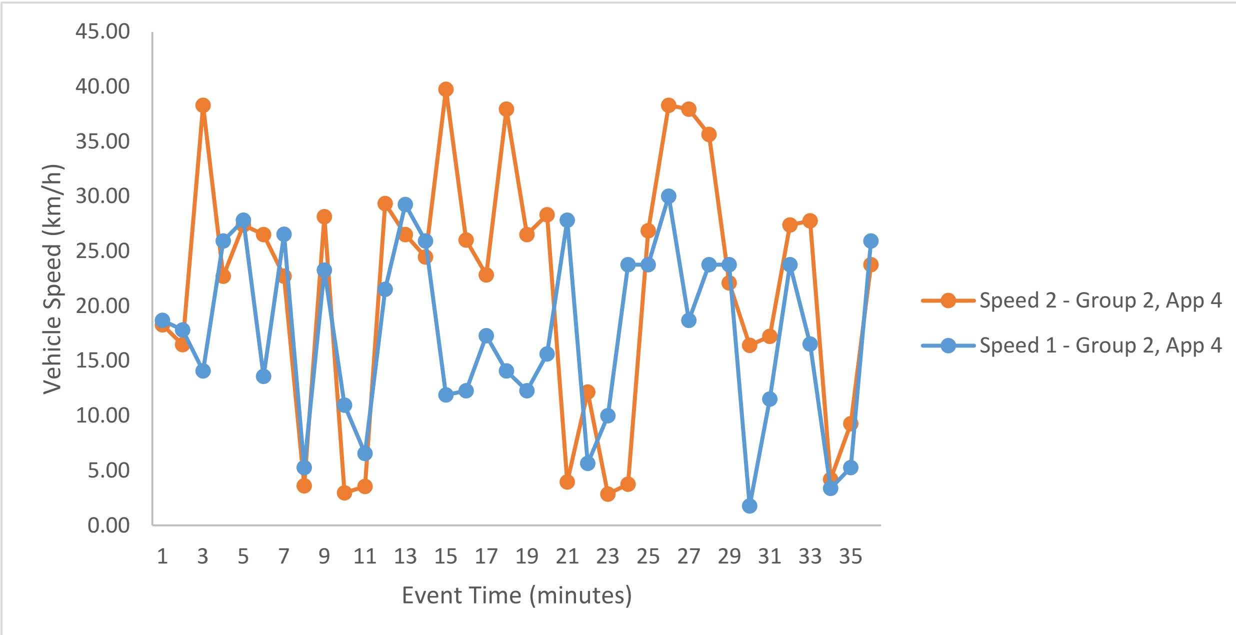


Figure - III i: Vehicle Speed versus Time of Event's Occurrence with Treatment - Group 2 Approach 4

Table - IV i: Some Speed Statistics - Volunteer Group 2 on Approach 4 After Treatment

After Treatment **Group 2, Approach 4**		
Serial Number	**Speed 1 (KPH)**	**Speed 2 (KPH)**
Average Speed (KPH)	17.40	21.73
Standard Deviation (KPH)	8.15	11.48

Statistical Significance	0.024	Two Tail

4.3.3.3 Acceleration

The acceleration profile for the vehicles per approach on the roundabout after the treatment was applied is shown in Figure – IVa, Figure – IVb, Figure – IVc and Figure – IVd below, with corresponding information about average acceleration and standard deviation for all provided in Table – Va, Table – Vb, Table – Vc and Table – Vd on the respective approaches for the first group of volunteers.

Similarly, Figure – IVe, Figure – IVf, Figure – IVg, Figure – IVh and Figure – IVi with the corresponding Table – Ve, Table – Vf, Table – Vg, Table – Vh and Table – Vi show information regarding the second group of volunteers on the respective approaches. The number of observations considered ranged from 7 to 36 vehicles.

Similar to the results from acceleration from vehicles without treatment installed, looking at the graphs shows that the acceleration plotted on the positive y-axis is more dominant than deceleration on the negative y-axis. Thus, making it easy to believe that most vehicles observed did accelerate more than they decelerated as they approached the crosswalk.

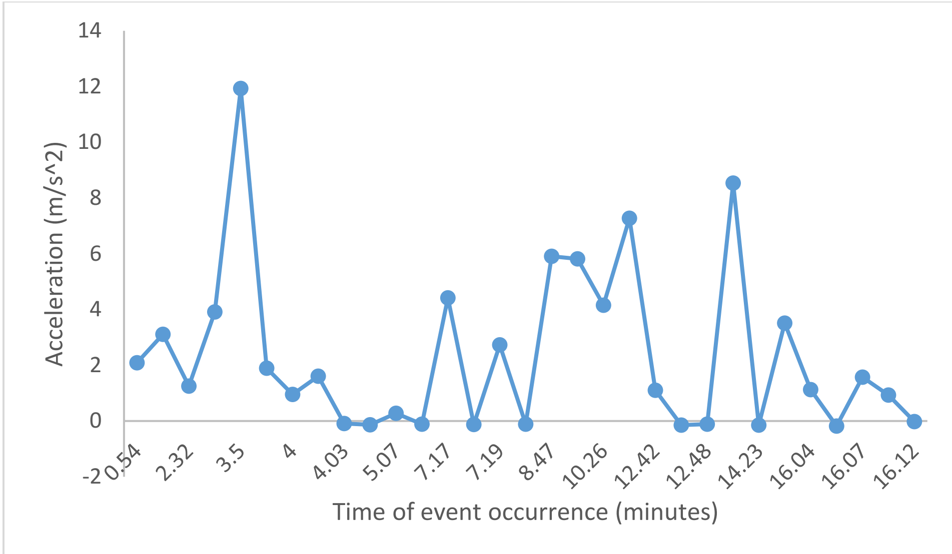


Figure - IV a: Vehicle Acceleration versus Time of Event's Occurrence with Treatment - Group 1 Approach 1

Table - V a: Some Acceleration Statistics - Volunteer Group 1 on Approach 1 After Treatment

After Treatment **Group 1, Approach 1**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	2.35
Standard Deviation (m/s^2)	2.98

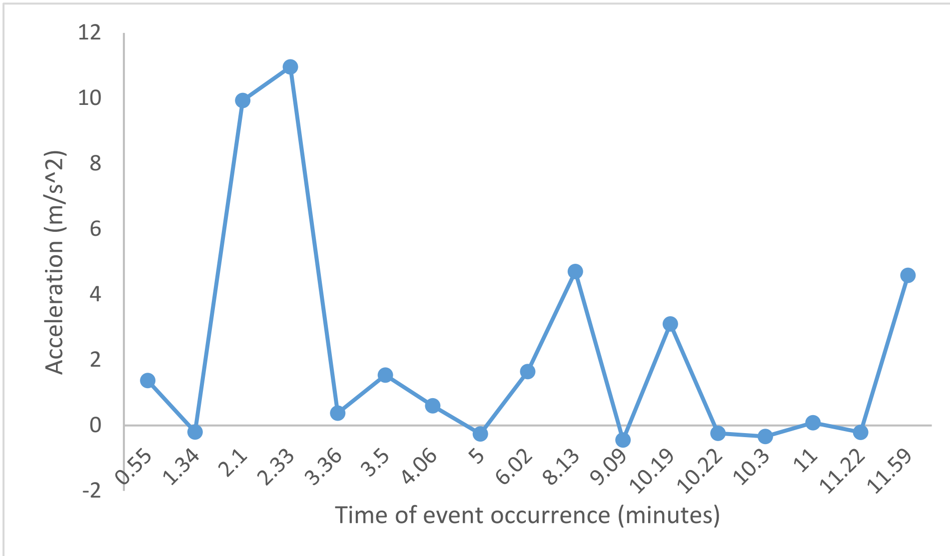


Figure - IV b: Vehicle Acceleration versus Time of Event's Occurrence with Treatment - Group 1 Approach 2

Table - V b: Some Acceleration Statistics - Volunteer Group 1 on Approach 2 After Treatment

After Treatment **Group 1, Approach 2**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	2.19
Standard Deviation (m/s^2)	3.52

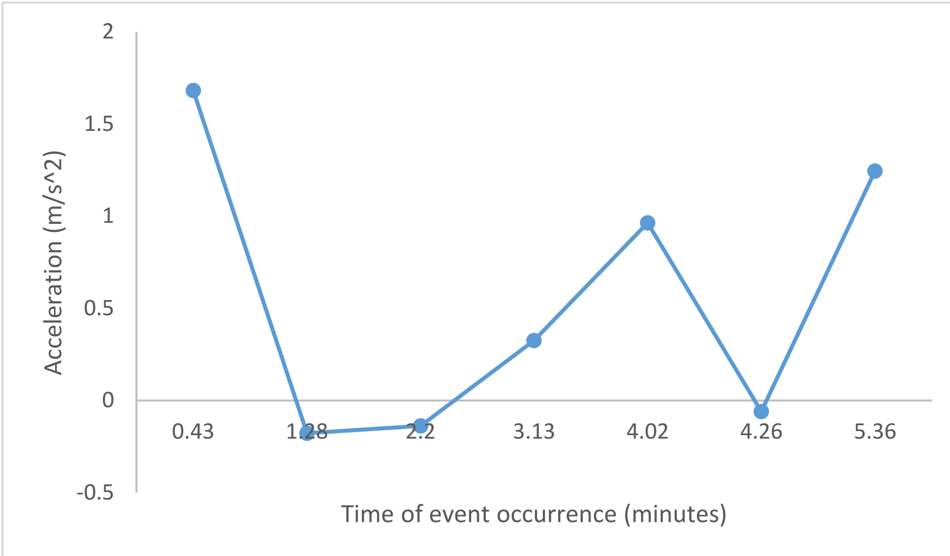


Figure - IV c: Vehicle Acceleration versus Time of Event's Occurrence with Treatment - Group 1 Approach 3

Table - V c: Some Acceleration Statistics - Volunteer Group 1 on Approach 3 After Treatment

After Treatment **Group 1, Approach 3**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	0.55
Standard Deviation (m/s^2)	0.75

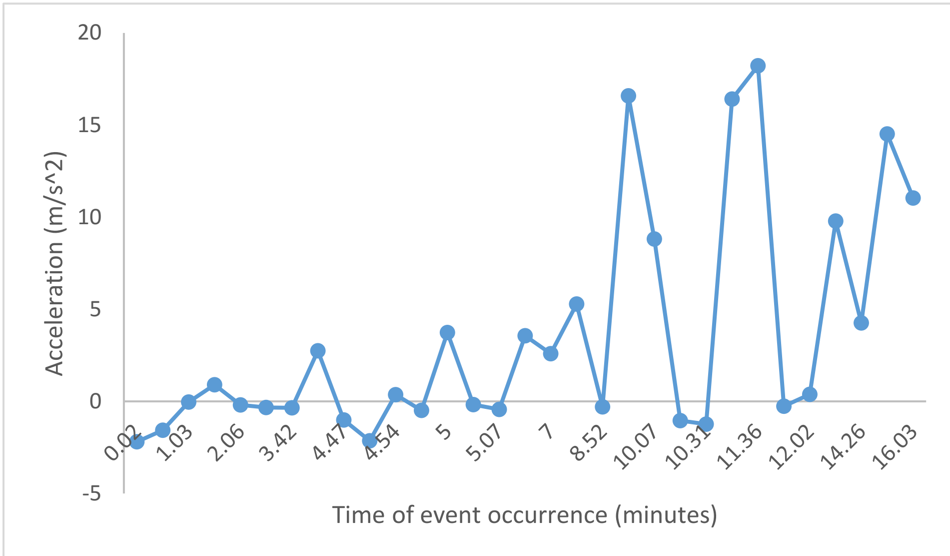


Figure - IV d: Vehicle Acceleration versus Time of Event's Occurrence with Treatment - Group 1 Approach 4

Table - V d: Some Acceleration Statistics - Volunteer Group 1 on Approach 4 After Treatment

After Treatment **Group 1, Approach 4**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	3.47
Standard Deviation (m/s^2)	6.09

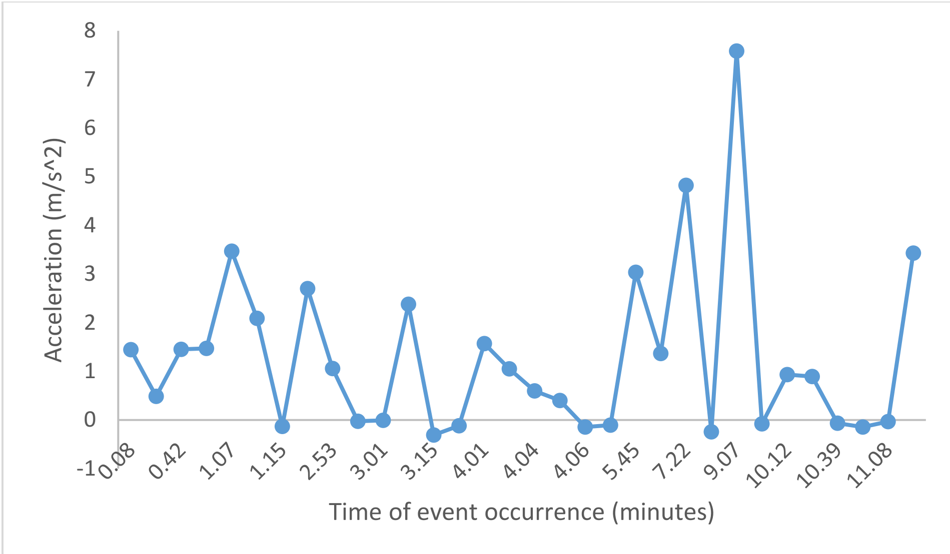


Figure - IV e: Vehicle Acceleration versus Time of Event's Occurrence with Treatment - Group 2 Approach 1

Table - V e: Some Acceleration Statistics - Volunteer Group 2 on Approach 1 After Treatment

After Treatment **Group 2, Approach 1**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	1.28
Standard Deviation (m/s^2)	1.75

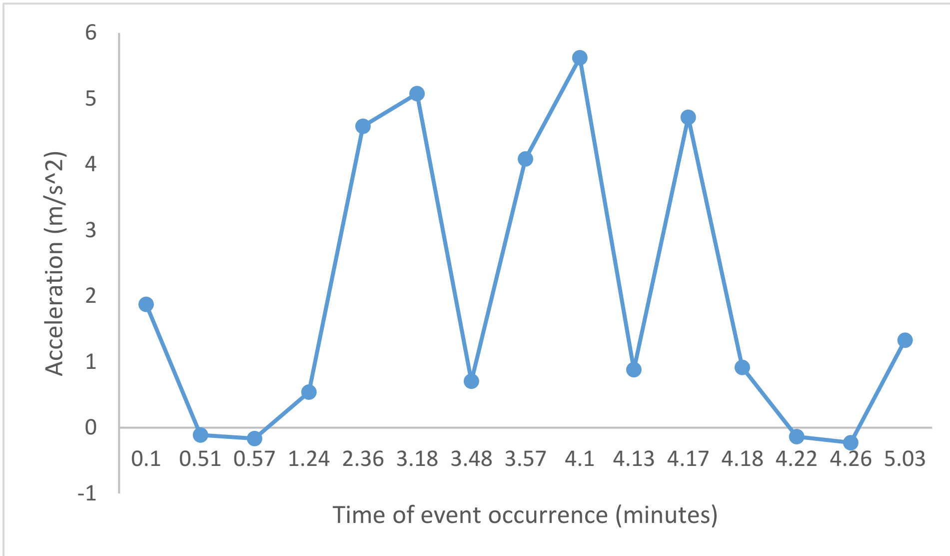


Figure - IV f: Vehicle Acceleration versus Time of Event's Occurrence with Treatment - Group 2 Approach 1 - Repeated

Table - V f: Some Acceleration Statistics - Volunteer Group 2 on Approach 1 After Treatment - Repeated

After Treatment **Group 2, Approach 1 (Repeated)**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	1.98
Standard Deviation (m/s^2)	2.18

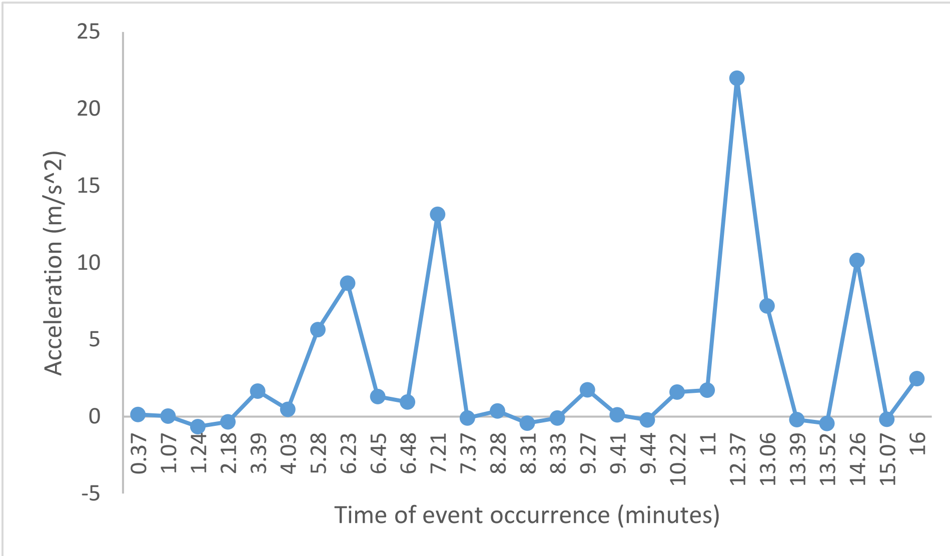


Figure - IV g: Vehicle Acceleration versus Time of Event's Occurrence with Treatment - Group 2 Approach 2

Table - V g: Some Acceleration Statistics - Group 2 on Approach 2 After Treatment

After Treatment **Group 2, Approach 2**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	2.84
Standard Deviation (m/s^2)	5.27

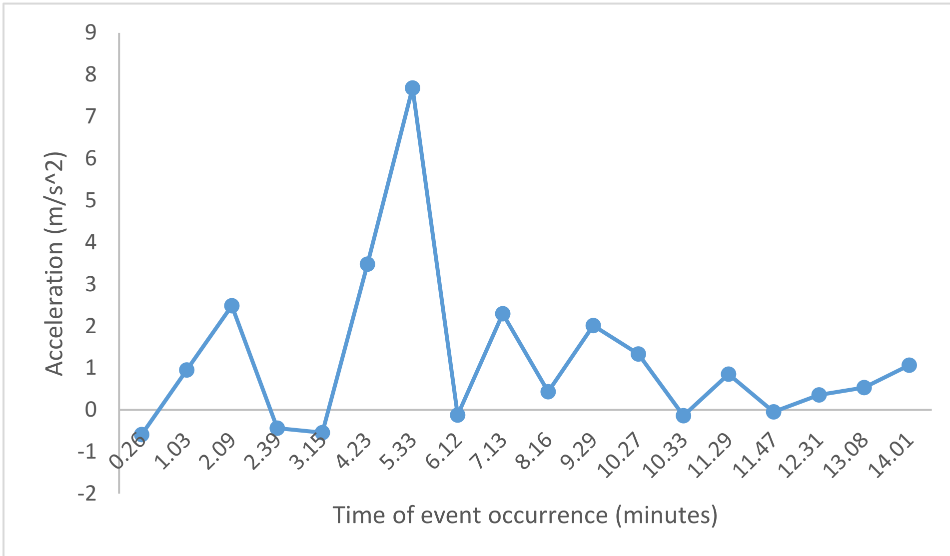


Figure - IV h: Vehicle Acceleration versus Time of Event's Occurrence with Treatment - Group 2 Approach 3

Table - V h: Some Acceleration Statistics - Volunteer Group 2 on Approach 3 After Treatment

After Treatment **Group 2, Approach 3**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	1.20
Standard Deviation (m/s^2)	1.98

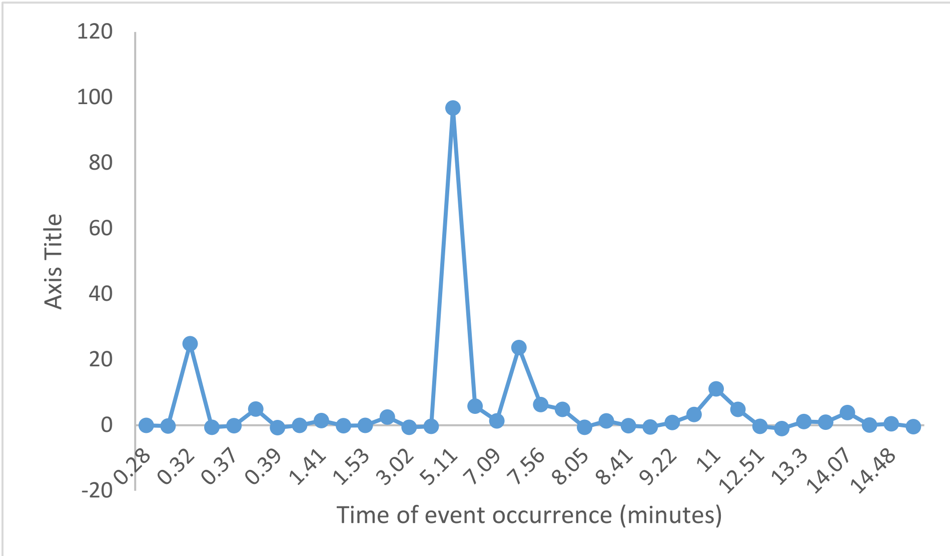


Figure - IV i: Vehicle Acceleration versus Time of Event's Occurrence with Treatment - Group 2 Approach 4

Table - V i: Some Acceleration Statistics - Volunteer Group 2 on Approach 4 After Treatment

After Treatment **Group 2, Approach 4**	
Serial Number	**Acceleration (m/s^2)**
Average Acceleration (m/s^2)	5.39
Standard Deviation (m/s^2)	16.75

4.3.3.4 Delays

The amount of time each group of PWVL spent activating the RRFBs with the APS, waiting for gaps in traffic, and the delay felt on the crosswalk are shown in Figure 33. Also shown in this figure are other information such as pedestrian grouping, the approaches where the group was, the number of attempts made by the pedestrians at crossing the road, the delay felt in seconds on the APS, or whilst waiting for vehicles to yield, the total delay experienced, as well as the average delay felt per pedestrian. Figure 34 shows the total delay felt by pedestrians plotted on a histogram, while the average delay felt by the pedestrian is summarized further in Figure 35.

Similar to previous section, the amount of time taken by the pedestrian to align on the crosswalk at Approaches 2 and 3 where there is no APS, has been interpreted and shown as if it was spent on pushing the button on the pole to activate the non-existing APS.

Group	Approach	Number of attempts by PWVL	Delay on APS (sec)	Delay waiting for Yield (sec)	Total Delay (sec)	Average Delay (sec/ped)
1	1	6	27.24	255.98	283.22	47.20
	2	2	16.59	241.59	258.18	129.09
	3	3	12.49	29.72	42.21	14.07
	4	5	23.62	117.67	141.29	28.26
2	1	6	53.60	215.84	269.44	44.91
	2	7	18.40	171.03	189.43	27.06
	3	4	16.90	148.80	165.70	41.43
	4	6	78.37	67.22	145.59	24.27
Sum (sec)		39	247.21 (= 4.12 min)	1247.85 (= 20.80 min)	1495.06 (= 24.92 min)	
Average Delay felt (sec/ped)			6.34	5.05	38.33	

Figure 33: Number of attempts made by groups of pedestrians on different approaches and the delay felt after treatment was applied

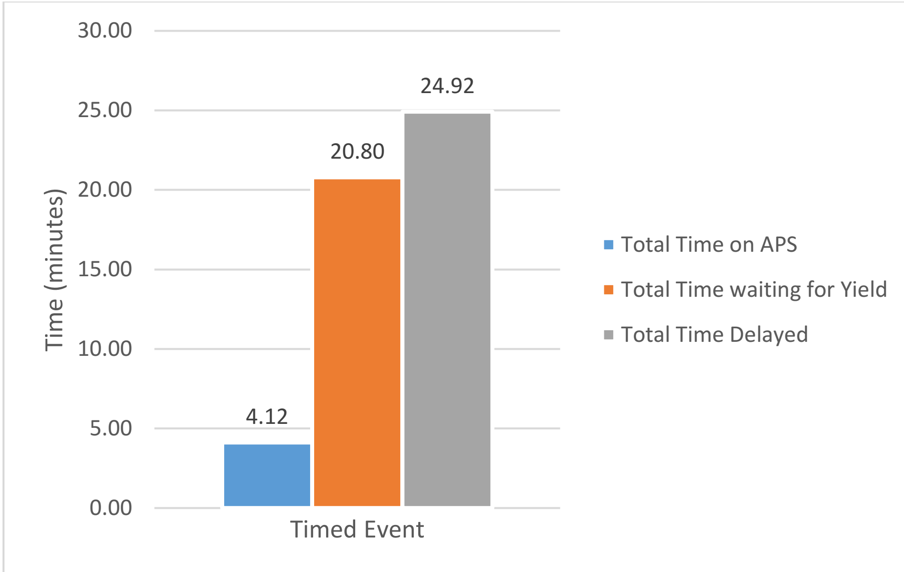


Figure 34: Chart showing the time spent on APS, waiting for a gap, and total delay after treatment was applied

Average time spent on the APS, waiting for vehicle yield or delayed altogether for each of the 39 attempts made by pedestrians to cross the road on the roundabout after treatment.				
	Time spent on APS	Time spent waiting for vehicle yield	Time delayed altogether	
Average =	6.34	32.00	38.34	seconds/pedestrian-attempt
	0.11	0.53	0.64	minutes/pedestrian-attempt

Figure 35: Average time spent by each pedestrian at each attempt on the APS, waiting for yield and delayed altogether after treatment was applied

4.3.3.5 Vehicles Yield versus No-Yield

When computed, the percentage of vehicles that yielded to pedestrians versus those that did not, provides an insight into driver's behavior. With the sound strips installed, associated pieces of information are provided on Table – VIa, Table – VIb, Table – VIc and Table – VId for the first group of PWVL as they stood at the crosswalk on the respective approaches. Similarly, the information pertaining to the second group of pedestrians is shown on Table – VIe, Table – VIf, Table – VIg and Table – VIh.

Table - VI a: Showing vehicles' percent yield after treatment – Group 1 on Approach 1

Vehicles Percent Yield – After Treatment Group 1 on Approach 1			
The number of vehicles that yielded	**The number of vehicles that did not yield**	**Percent Yield**	
10	**14**	**41.67**	**%**

Table - VI b: Showing vehicles' percent yield after treatment – Group 1 on Approach 2

Vehicles Percent Yield – After Treatment Group 1 on Approach 2

The number of vehicles that yielded	The number of vehicles that did not yield	Percent Yield	
2	7	22.22	%

Table - VI c: Showing vehicles' percent yield after treatment – Group 1 on Approach 3

Vehicles Percent Yield – After Treatment Group 1 on Approach 3			
The number of vehicles that yielded	The number of vehicles that did not yield	Percent Yield	
3	0	100	%

Table - VI d: Showing vehicles' percent yield after treatment – Group 1 on Approach 4

Vehicles Percent Yield – After Treatment Group 1 on Approach 4		
The number of vehicles that yielded	The number of vehicles that did not yield	Percent Yield

7	**10**	**41.18**	**%**

Table - VI e: Showing vehicles' percent yield after treatment – Group 2 on Approach 1

Vehicles Percent Yield – After Treatment Group 2 on Approach 1			
The number of vehicles that yielded	**The number of vehicles that did not yield**	**Percent Yield**	
11	**24**	**31.43**	**%**

Table - VI f: Showing vehicles' percent yield after treatment – Group 2 on Approach 2

Vehicles Percent Yield – After Treatment Group 2 on Approach 2			
The number of vehicles that yielded	**The number of vehicles that did not yield**	**Percent Yield**	
7	**8**	**46.67**	**%**

Table - VI g: Showing vehicles' percent yield after treatment – Group 2 on Approach 3

Vehicles Percent Yield – After Treatment Group 2 on Approach 3			
The number of vehicles that yielded	The number of vehicles that did not yield	Percent Yield	
4	2	66.67	%

Table - VI h: Showing vehicles' percent yield after treatment – Group 2 on Approach 4

Vehicles Percent Yield – After Treatment Group 2 on Approach 4			
The number of vehicles that yielded	The number of vehicles that did not yield	Percent Yield	
10	14	41.67	%

Based on the information shown in the above tables, the total number of vehicles that yielded to PWVL is 54, with 79 vehicles not yielding and hence a 40.60 percent yield on the approaches at the roundabout where the treatment was applied. Again, this is considered a low number when one would have expected drivers to yield at all times conceding to pedestrians the right deserved when crossing the street. It has to be re-emphasized here as indicated before, that the installed sound strips should not have an effect on these findings since they would not affect drivers' behavior.

4.3.3.6 Yielding before reaching the strip due to the position of the strip relative to the crosswalk

The position of the first row of strips installed on the pavement, as well as its proximity to the second row of strips and the crosswalk would have impacted the effectiveness of this safety and accessibility-enhancing measure being tested. As discussed previously, the positioning of the rows of strips was constrained by the geometry and design of the roundabout which becomes a challenge that has to be accepted and the effect mitigated by keeping the first row of strips as far away as possible from the second row of strips, and as close as possible to the circulatory roadway. The impact of this restriction of how far the first row of sound strips is located is that vehicles, when exiting the circulatory roadway on the roundabout, could be stopping inside the circulatory roadway, and short of actually crossing the first row of strips on the pavement. When this happens, as noticed at the exit points on Approaches 2 and 4, PWVL standing on the respective crosswalk had difficulty noticing the vehicles stopped since the vehicles were not crossing the first row of strips and they may have no idea that there is even a vehicle there. Figure 36 below shows the only 2 vehicles that yielded before reaching the first row of strips compared to 54 vehicles in total that yielded to PWVL in this research.

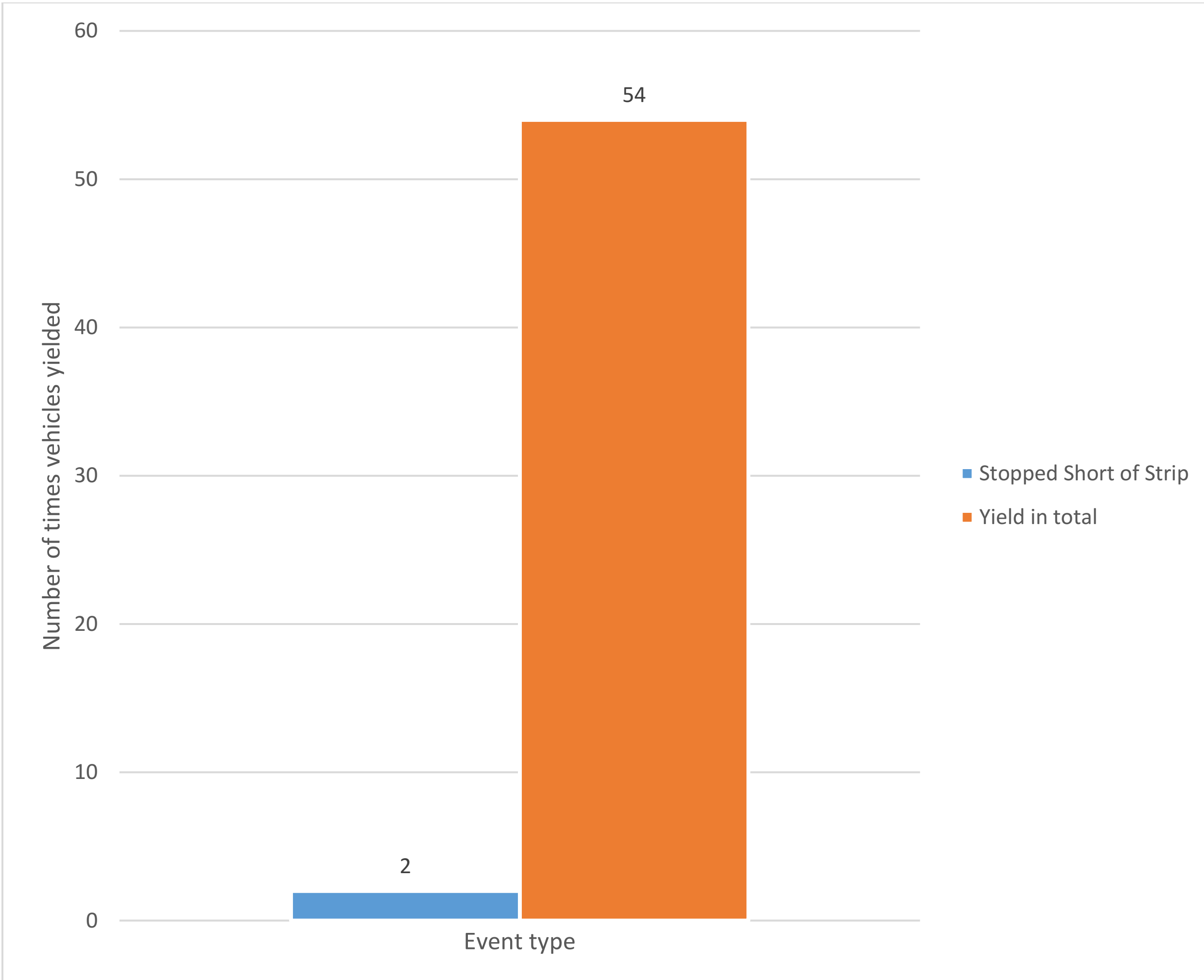


Figure 36: Total number of times that vehicles yielded vs. times that vehicles fell short of strip

4.4 The 3D Model

This subsection presents findings pertaining to the use of the 3D model at various stages of this project. The results and data here are qualitative, since they were verbally communicated.

4.4.1 3D Model use at CNIB

The model enabled easy description of the features of the roundabout such as the central island, splitter island, and others related to important places where the field data collection portion of the research would be taking place. The feedback received from CNIB staff was positive regarding the 3D model that was presented to their clients. Furthermore, clients indicated that the model was helpful for them to have a good sense of the tasks on hand for the research.

4.4.2 3D Model use at TAC 2022

The 3D model was tested at the TAC Annual conference in Edmonton in October, 2022. During breakout sessions where accessibility issues on roundabouts were being discussed, the 3D model was passed around for conference attendees in the room to see and feel. This visual aspect of the model made a lasting impression about roundabout accessibility on the minds of participants who commented to the research team about how useful the 3D model had been.

4.5 Police Collision Reports

This research also considered the safety performance of the intersection prior to when the roundabout was built up to a short while after it was built. For that purpose, three years of collision reports ranging from June 2018 until June 2021, the period before building the roundabout, combined with almost a year of reports from December 2021 to November 2022 for the period after the roundabout was built, were obtained upon request from the Thunder Bay Police Department. Table 3 below shows the number of collisions observed, with the average collision per year, before the roundabout was developed versus those collisions that occurred after the roundabout was built. Historically, only one vehicle-pedestrian collision occurred in the period of time prior to the construction of the roundabout, where a vehicle approaching from Redwood Avenue West turned left into Edward Street North, and in the process crossed paths with a pedestrian who was there on the crosswalk at Edward Street North. Although, according to the report, the vehicle involved traveled at 20 KPH, seemingly not very fast, the underlying issue for the collision could be speculated to have been that it was dark and potentially slippery with the incident happening at 20:05 on February 28, 2020. This intersection does not seem particularly hazardous to the average pedestrian in terms of collisions.

According to the information provided in the reports, the majority of the collisions at the intersection were rear-ends for the period of time before the roundabout was built, followed by angle collisions, sideswipes, and one perpendicular crash also known as T-Bone. For the time period considered since the roundabout has been built, the most common type of collision is the angle collision, then followed by sideswipes and rear-ends.

It was noticed, as expected on a roundabout, that there had been no T-Bone collisions there at the intersection since the roundabout was built. Eliminating the T-Bone collisions, one of the most severe types of collision in existence, however, is confirmation of how roundabout development can help solve some of the road safety issues.

Table 3: The number of collisions and the average per year before compared to after the roundabout was built

Type of Collision	**Number of Collisions Before Building the Roundabout (June 2, 2018, to June 21, 2021 = 3 years)**	**Number of Collisions After Building the Roundabout (December 1, 2021, to November 19, 2022 = 1 year)**
Rear-end	9	2
Sideswipe	4	3
Angle	6	4
Control Loss	0	1
T-Bone	1	0
Pedestrian	1	0
Head on	1	0
Total	**22**	**10**
Average (Collision/year)	**7.3**	**10**

Before building the roundabout, some of the issues prevalent on the reports were that drivers did not stop quickly enough when the signal light changed from green to yellow to red, and hence rear-end type of collision was common, especially in the winter season or raining season when the pavement surface was likely to be slippery. It would be reasonable to think that building a roundabout should have corrected such issue by lowering the travel speed for vehicles from 50 or 60 KPH to 40 KPH or less within the roundabout, and therefore enabling drivers to maintain better control of their vehicles especially on slippery surfaces.

After the roundabout was developed, several drivers observed on this research failed to yield to PWVL while the pedestrians waited in vain on the crosswalk for a gap in traffic in order to cross the street which is a major safety concern especially for this population group. Another issue with the roundabout for PWVL is that the time allowed for crossing, programmed into the RRFB and the APS, appeared to be insufficient for PWVL when crossing. Furthermore, it became obvious to the research team that PWVL required a little more time than the average pedestrian or people with other disabilities with full sight as soon as the RRFB started flashing and the APS started sounding audibly, just because the PWVL would first have to ascertain it was safe to cross before stepping forward to cross the road.

4.5.1 Collision Diagrams

Collision diagrams were also made for the before and after periods when the roundabout had been built, to determine if any specific safety pattern with respect to collisions on the intersection could be identified graphically. Figure 37 below shows the graphical representation of types of collisions that occurred at the intersection before the roundabout was built, while Figure 38 is depiction of the situation after the roundabout was built. More details about the collision diagrams are shown in Appendix Figure A18 and Figure A19, respectively.

This graphical representations in Figure 37 and Figure 38 are visual illustrations of what has been summarized and tabulated in Table 3 above. The diagrams further showed the date, time, conditions of pavement, lighting condition, and the speed of vehicles that were involved when collision occurred. The legend partly contained a summary section where details about the severity of collision, ranging from property damage only to injury or fatality, were recorded.

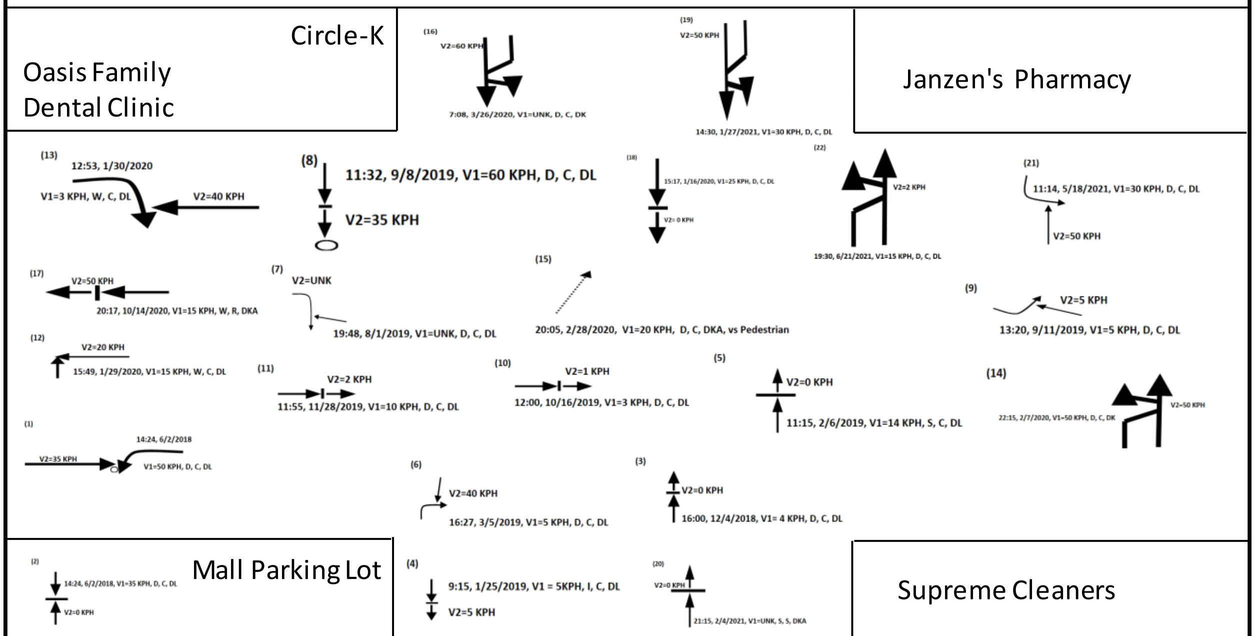
In brief, there were 19 property damage only, 3 injury and no fatality, of the 22 total collisions that occurred before the roundabout was built. 17 of those collisions happened during the day, with only 5 occurring at night. In contrast, there were 10 property damage only, with neither injury nor fatality, of the 10 collisions in total since the roundabout was built, with 9 of those occurring in day time and only 1 at night.

Although there were more severe collisions at the intersection before the roundabout was built compared to after it was built, it was observed that the average collision rate increased from 7.3 collisions per year before the roundabout was built to 10 collisions per year since it was built.

COLLISION DIAGRAM	LOCATION	EDWARD STREET @ REDWOOD AVE, THUNDER BAY. ON		
TRAFFIC ENGINEERING	PERIOD (D/M/Y)	FROM DATE June 2, 2018	TO DATE	June 21, 2021

DRAWN BY	O.ADENIRAN
DATE	Mar 13, 2023
PAGE	1 of 2

NORTH



COLLISION SYMBOLS		CONDITION & OTHER CODES
VEHICLE PATH	REAR-END COLLISION	PAVEMENT CONDITION:
BACKING VEHICLE	HEAD-ON COLLISION	D = DRY W = WET I = ICY K = CONSTRUCTION
NON-INVOLVED VEH	SIDE SWIPE	WEATHER CONDITION:
VEHICLE - PEDESTRIAN	OUT OF CONTROL	C = CLEAR R = RAIN F = FOG S = SNOW
FIXED OBJECT	OVERTURNED VEHICLE	LIGHT CONDITION:
PARKED VEHICLE	ANGLE COLLISION	DL = DAYLIGHT SL = STREETLIGHT DK = DARK
PERSONAL INJURY	RIGHT-ANGLE COLLISION	DKA = DARK - ARTIFICIAL
FATALITY	BICYCLE	COLLISION SERIAL NUMBER
		SPEED (KPH) DATE TIME

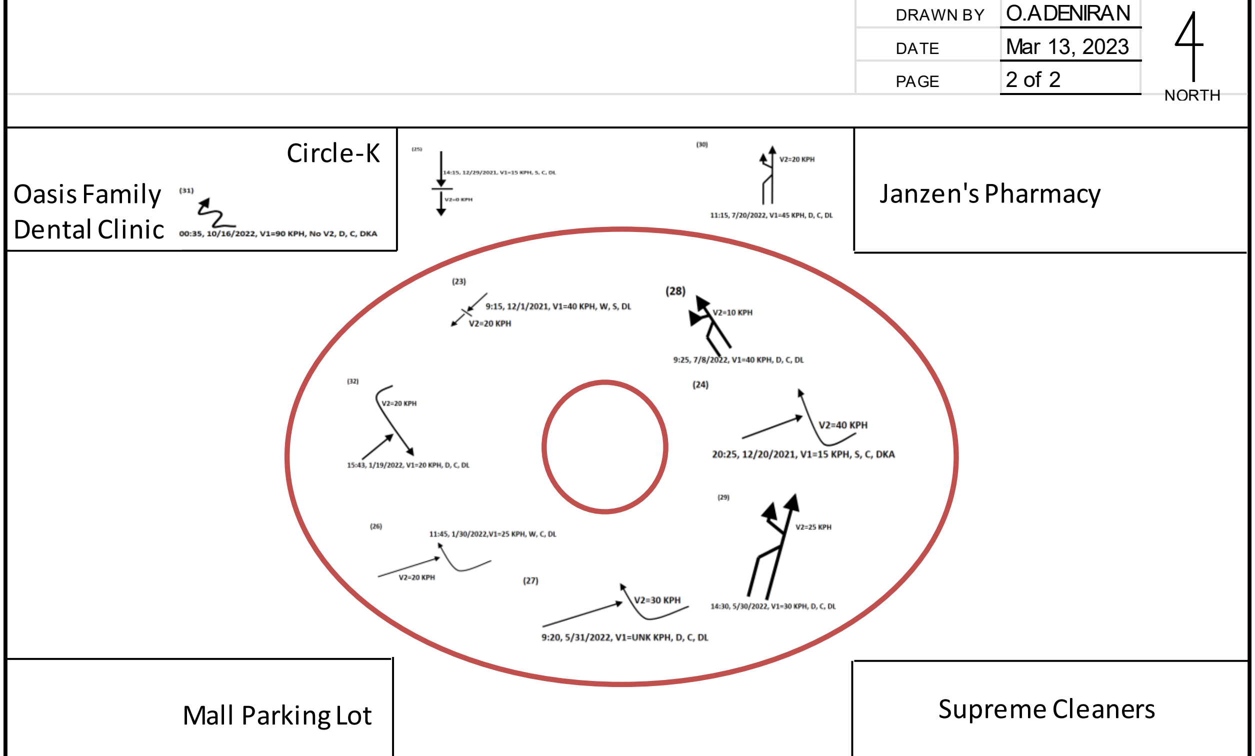
ACCIDENT SUMMARY	PROP. DMG ONLY	INJURY	FATAL	TOTAL
DAYTIME	14	3	0	17
NIGHTTIME	5	0	0	5
TOTAL	19	3	0	22

Figure 37: Collision Diagram for the intersection - Before Roundabout Construction

COLLISION DIAGRAM

TRAFFIC ENGINEERING

LOCATION	EDWARD STREET @ REDWOOD AVE, THUNDER BAY. ON
PERIOD (D/M/Y)	FROM DATE December 1, 2021 — TO DATE November 19, 2022
DRAWN BY	O.ADENIRAN
DATE	Mar 13, 2023
PAGE	2 of 2



COLLISION SYMBOLS		CONDITION & OTHER CODES
VEHICLE PATH	REAR-END COLLISION	PAVEMENT CONDITION:
BACKING VEHICLE	HEAD-ON COLLISION	D = DRY W = WET I = ICY K = CONSTRUCTION
NON-INVOLVED VEH	SIDE SWIPE	WEATHER CONDITION:
VEHICLE - PEDESTRIAN	OUT OF CONTROL	C = CLEAR R = RAIN F = FOG S = SNOW
FIXED OBJECT	OVERTURNED VEHICLE	LIGHT CONDITION:
PARKED VEHICLE	ANGLE COLLISION	DL = DAYLIGHT SL = STREETLIGHT DK = DARK
PERSONAL INJURY	RIGHT-ANGLE COLLISION	DKA = DARK - ARTIFICIAL
FATALITY	BICYCLE	COLLISION SERIAL NUMBER
		SPEED (KPH) DATE TIME

ACCIDENT SUMMARY

	PROP. DMG ONLY	INJURY	FATAL	TOTAL
DAYTIME	9	0	0	9
NIGHTTIME	1	0	0	1
TOTAL	10	0	0	10

Figure 38: Collision Diagram for the intersection - After Roundabout Construction

4.5.2 Impact of COVID-19 Pandemic on the Safety Assessment

One main topic that can be considered for future studies is the extent to which the COVID-19 pandemic and lockdowns affected people and activities related to possible safety issues at the roundabout in Thunder Bay and any other location in the transportation network for that manner. For this safety assessment at this roundabout, this will have to include the time period spanning about 16 months before, and a few months after the roundabout was built.

Regarding this project, the effect of the pandemic is not included in the safety assessment. At the moment, it could be said in general that during those months of lockdown, the number of collisions might have reduced significantly because fewer people were traveling on roads.

CHAPTER 5. Summary, Conclusions, and Recommendations

This chapter presents a summary of the research effort as well as some conclusions and recommendations for this project.

5.1 Summary

When compared to the conventional signalized intersection, the roundabout is believed to be great for traffic calming, safer for vehicles, better for the environment, less costly for its lifetime, hence many municipalities and road agencies favor roundabouts, but more still needs to be done to make roundabouts more accessible.

This research work considered the issues and challenges of PWVL by conducting a national workshop, and a survey with clients from CNIB. The research also evaluated the effectiveness of a mechanical treatment in helping PWVL determine a gap in traffic in order to cross the streets with a field study where volunteers from CNIB participated. Data was collected before and after the sound strips were installed. The data collected from the survey and direct discussion with volunteers at the site led to very important information regarding the issues and challenges that PWVL have at roundabouts. The results showed the usefulness of sound strips considered as the mechanical treatment.

Using a couple of 3D model for illustration in discussions about roundabout safety and accessibility yielded a positive result, where all stakeholders saw value in having such models.

Although this project was not funded and operated on limited budget, in a way affecting the quality and quantity of data collected, the findings, however, were quite remarkable. It is hoped that the work will form the foundation for more research in this area in the near future.

5.2 Conclusions

This subsection presents the main findings of the research based on the results of the data analysis.

- The participants at the national workshop expressed the opinion that it would be helpful if transportation agencies would continue with public awareness and education on roundabouts and crosswalk accessibility. Participants think there is a lot to do through public enlightenment in changing drivers' behavior so they are more inclined and willing to yield to pedestrians. Similarly, education on this topic should also extend to pedestrians.
- The participants felt that municipalities and transportation agencies should be proactive in maintaining roads on the roundabout, including removal of snow banks during winter months. Safety and accessibility for blind pedestrians improved when all impedances are removed from the pathway of the PWVL. Also, responding in timely manner, addressing complaints raised by PWVL in their communities would give a boost to accessibility and safety on the roundabout.
- For PWVL, the APS tone and position should be set with consistency across the country. A way of boosting accessibility on roundabouts is the removal of ambiguity or confusion caused by the multiple tones setting currently in place on APS across Canada, which hitherto are meant to convey different messages to PWVL. Also,

the timing set for the RRFB and APS should be made more adequate to compensate for the peculiarity of the need by PWVL to find gaps in traffic. This particular group of pedestrian population are asking for a more equitable timing on the crosswalk.

- Where APS tone can be drowned in the ambient sound on roundabouts, the use of vibrating cones should be considered as an addition or replacement to the APS used on the roundabout. Sometimes, the noise level on roundabouts is too high for some people when standing at the crosswalk, preventing them from hearing clearly the sound coming from the APS, and therefore justifying the need for the vibrating cone.
- The respondents to the opinion survey would love to see a device assisting them in finding gaps in traffic on the roundabout. The known type of system that gives gap to the pedestrian is the green-orange-red signal that defaults to green light for vehicles, which upon activation at the crosswalk turns red, meaning “stop”, for vehicles and green, meaning “proceed”, for the pedestrian.
- 3D models could be helpful for illustration purposes when discussing issues pertaining to roundabout safety and accessibility for PWVL. Such models could be used in mobility training of PWVL about features and how to navigate the roundabout. The topography and height changes in terrain, as well as where pedestrians should walk versus where vehicles should drive within the space on the roundabout are easily described using the model.
- Most vehicles observed on the roundabout were speeding up. That is, accelerating as they approached the crosswalks with a few of the vehicles exceeding the maximum allowed speed of 40 KPH. The explanation for why vehicles tend to

accelerate while entering the roundabout on Approaches 1 and 3 could be because drivers had a clear view seeing there were no vehicles ahead or inside the roundabout, and thus an incentive to speed through the scene. Even when the speed was low, it still resulted in positive acceleration since the initial speed was less than the final speed in the area being monitored. For approaches 2 and 4, the acceleration could be related to the fact that vehicles were exiting the roundabout with drivers naturally feeling the need for increased speed. To keep speed low until vehicles have gone past the crosswalk on the roundabout, innovative means must be devised to force drivers to reduce their speed even further as they approach the crosswalk on roundabouts. One way is to raise the crosswalk, thereby making pedestrian who are crossing the road more visible to drivers, as well as creating a hump for vehicles, which require passing vehicles to slowly navigate.

- The rate at which vehicles yielded to pedestrians on the crosswalk was 57.33 percent without any treatment applied to the road, which declined to 40.60 percent after the treatment was applied. Those numbers are low, implying drivers are not so considerate of pedestrians trying to cross the street on the roundabout in Thunder Bay. As already discussed, public education can help. Another way to make improvement is with deterrence. Since pedestrians have the right of way, indicated by the signages, at crosswalk. Violation of such rights by drivers could be checked using cameras. Also, policing and taking punitive measures against offenders could help boost accessibility on roundabouts.
- After the sound strip has been installed, perception of traffic on the roundabout seems to improve for PWVL, with the average delay on each attempt of crossing went down from 41.39 seconds to 38.34 seconds per pedestrian. This reduction in

delay should not be solely attributed to the placement of the sound strips since there wasn't sufficient amount of data available for statistical test and confirmation. Hence, no definite conclusion could be made. Helping PWVL determine pattern and flow of traffic will lower the amount of time spent in verifying when vehicles have yielded.

For PWVL, it is necessary to keep track of silent vehicles as they increase in number on the road. Canada does not have laws in place dictating minimum level of sound generated by Electric Vehicles (EVs). With the help of the sound strips installed, it is most likely that silent EVs or Autonomous Vehicles (AVs) could not have gone undetected by PWVL.

- The sound strips would likely be beneficial to seniors, as well as those pedestrians distracted by the use of cell phone and other mobile electronic devices, to stay aware of oncoming traffic on the roundabout.
- Roundabout should be geometrically designed to ensure that crosswalks, as much as possible, are positioned far away from the exit point on the circulatory roadway to give longer perception-reaction time to PWVL.

The findings from this project exposed some of the issues and challenges faced by PWVL on roundabouts. The data and results from the pilot study could be interpreted to mean, although not definitively, that using sound strips is helpful for PWVL. This safety measure for boosting accessibility seems promising and is worth investigating further.

5.3 Recommendations

The following subsections show recommendations on areas where improvement could be made in the future, as well as some of the limitations experienced on this project.

5.3.1 Making Improvements to Workshop and Opinion Survey Participation

The national workshop was very good and provided useful information on what the research team believes could be built upon for future research efforts. However, having only seven people participate in this opinion survey would be something to have amended and possibly boosted next time. It might be useful to first identify people who use or want to use roundabouts. Also placing telephone calls to do an opinion survey may enhance participation in the future. This and other ways of increasing respondents' involvement could be discussed with the staff at CNIB. Finally, in future work, pertinent information regarding participants will be requested.

5.3.2 Potential for Mechanical Solution

Embedding the sound strip into the pavement is a way of continuing with the mechanical solution in addressing PWVL's difficulty on the roundabout. If the strip is placed below the pavement surface, the winter cleaning task will continue unhindered, while simultaneously alerting PWVL of traffic condition and warning them of vehicles going over the strips.

5.3.3 Potential for Non-Mechanical Treatment

In the future, the non-mechanical methods could be explored as a solution to the challenges faced by PWVL on the roundabout. An electrical-electronics-based treatment instead of the mechanical approach will be worth trying.

5.3.4 Collecting and Analyzing Data Digitally

Using digital equipment for data collection and processing in future research work will likely remove the tendency for errors that might have occurred without such equipment.

Furthermore, using Artificial Intelligence (AI) for data collection and analysis may yield more accurate results on this topic.

5.3.5 Verifying other conditions

Attempts should be made in future projects to test scenarios during day or night time to see how different lighting conditions might affect the experiment. Also, the impact of different weather conditions on the work should be examined. There could, however, be other conditions beyond just the weather and lights that might influence or affect the research.

5.3.6 Limitations to the study

It has to be emphasized that this research effort was not funded and as such limiting the feasibility of using certain types of equipment. Also, for different reasons, there were limitations in the amount of data that could be collected or the time available for the exercise. Other factors that affected the research were human error in taking measurements, combined with errors arising from the use of relatively unsophisticated equipment for data collection.

Another limitation is regarding PWVL becoming familiar with the situation before evaluating the treatment. For future work, groups of volunteers will be considered for field studies with and without treatment concurrently in order to counterbalance the data collection process and thus minimizing the bias.

Also, drawing undue attention to the people on site could have affected the driver behavior and hence a limitation to the study. Some drivers were yielding even when the pedestrians were not ready to cross the street and having conversation with the mobility trainer and the research team member there at the crosswalk. Similarly, the presence of media crew with their big cameras made the drivers yield to pedestrians on the crosswalk in pretense, unlike drivers' behaviour before the media crew arrived or after they left the scene. Any of these distractions and limitations could have affected the work and results negatively. Finally, a major limitation to the research was the inability to push the rows of strips farther apart, thus hindering the possibility of testing how PWVL might have felt under such circumstance. Regardless all the limitations felt, the objective of empowering PWVL to become better aware of the traffic situation on the roundabout was accomplished.

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Theme	Journal Ident Number
Safety Issues in Accessibility	[1], [2], [4], [5], [6], [7], [12], [14], [15], [32]
Rumble Strip	[8], [9]
Signalization	[10], [28], [29]
Regulatory and Guidelines	[3], [11], [16], [22], [23], **[24]**, [25], [26], [27], [43], [46]
Wayfinding and Orientation	[13], [17], [18], [19], [20], [21], [31], [35], [37], [39], [41], [43], [44], [45]
International	[30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [42], [43]

Electric and Autonomous Vehicles	[33], [34]

Figure 39: Catalog for References

APPENDICES

Appendix A of Figures (Questionnaires, Certificates, Letters, Forms, and Others)

Agenda

- Introduction - by **Facilitators (Ben, Tanis, Kiri)**
- Project description and presentation – 10 minutes – by **Dr. Pernia and Tunde Adeniran**
- Questions and Answers (Attendees' story) - 50 minutes – by **Facilitators**
- Vote of Thanks to attendees, facilitators (Tanis, Kiri, Ben) and Lui – by **Dr. Pernia**

Qs

About Roundabouts

1. Is a roundabout within a kilometer radius/distance of your home?
2. Do you have to cross a roundabout often?
3. Are there positive things you feel about roundabouts?
4. Are there negative things you perceive in roundabouts?
5. Do you deliberately avoid roundabouts?
6. What is the ideal roundabout you are hoping for?

General

1. When you have complaints about road, intersection, roundabouts, etcetera how do you register that complaint?
2. Do you find the method easy?
3. Is the response effective and satisfactory?
4. Would you like to have a more effective method?

About Regular Intersections

1. What are the positive things you see in regular intersections?
2. Are there negative things you perceive in regular intersections?

Figure A1: Agenda and workshop discussion Questions

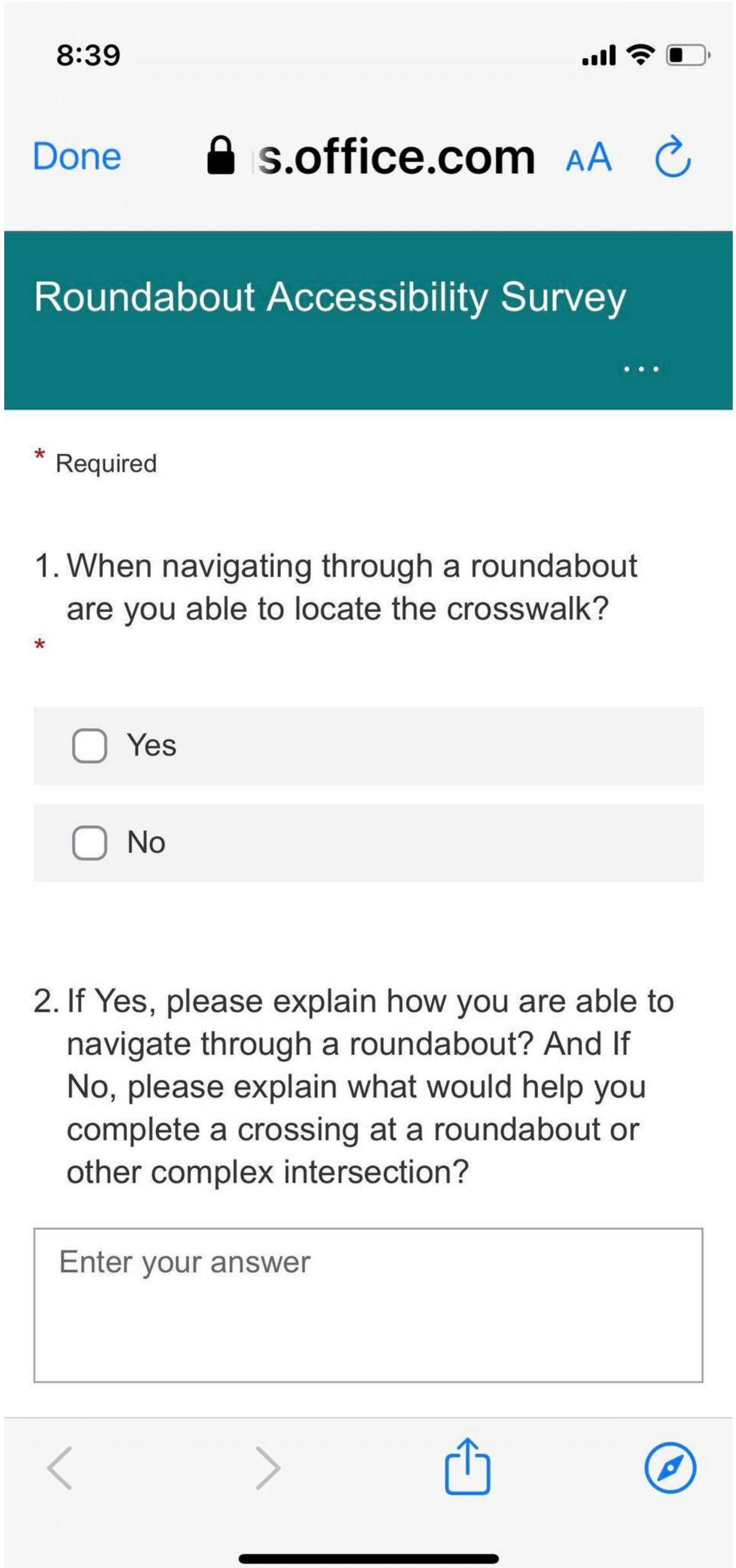
8:39
Done
s.office.com
AA
Roundabout Accessibility Survey
* Required
1. When navigating through a roundabout are you able to locate the crosswalk?
*
Yes
No
2. If Yes, please explain how you are able to navigate through a roundabout? And If No, please explain what would help you complete a crossing at a roundabout or other complex intersection?
Enter your answer

Figure A2: Sample Survey Question on Microsoft Forms

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE 2022

Certificate of Completion

This document certifies that

Omotunde Adeniran

successfully completed the Course on Research Ethics based on the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2: CORE 2022)

Certificate # 0000832939

17 July, 2022

Figure A3: Certificate of Completion for Course on Research Ethics (CORE 2022)

Lakehead UNIVERSITY

Department of Civil Engineering
tel: (807) 343-8684
fax: (807) 346-7943

July 15, 2022

Dear Potential Participant:

You are invited to participated in the project related to Roundabouts and Accessibility. You are considered as a participant since this study focus on people with visual impairment/blind and their concerns regarding crossing streets at roundabouts.

Taking part in this study is voluntary. Before you decide whether or not you would like to take part in this study, please read this letter carefully to understand what is involved. After you have read the letter, please ask any questions you may have.

PURPOSE

The purpose of this study is to identify concerns that people with visual impairment/blind may have in regards to the use of roundabouts as well as to evaluate a possible safety measure at the roundabout located at Edwards Street North and Redwood Avenue in Thunder Bay. The research team consists of Dr. Juan Pernia and Mr. Omotunde Adeniran, associate professor and graduate student at the Department of Civil Engineering at Lakehead University respectively.

WHAT INFORMATION WILL BE COLLECTED?

For this project, a survey will be conducted to collect information regarding concerns that participants may have related to roundabouts in reference to accessibility. A field study will also be performed at the roundabout of Edward Street North and Redwood Avenues in order to collect data regarding the effectiveness of a safety measure at this type of intersections.

WHAT IS REQUESTED OF ME AS A PARTICIPANT?

As a participant, you will be asked to fill out the survey and to participate in the field study. For the field study, the research team will bring the participants to the roundabout and asked to evaluate the effectiveness of a safety measure at the site. The safety measure consists of rumble strips and the possibility of providing warning to the participant when a vehicle is approaching a specific crosswalk. Data collection will be scheduled in time frames of 2 hours for four different days. The data is expected to be collected during the month of August of 2022.

Figure A4: Information and Consent Letter for Volunteers

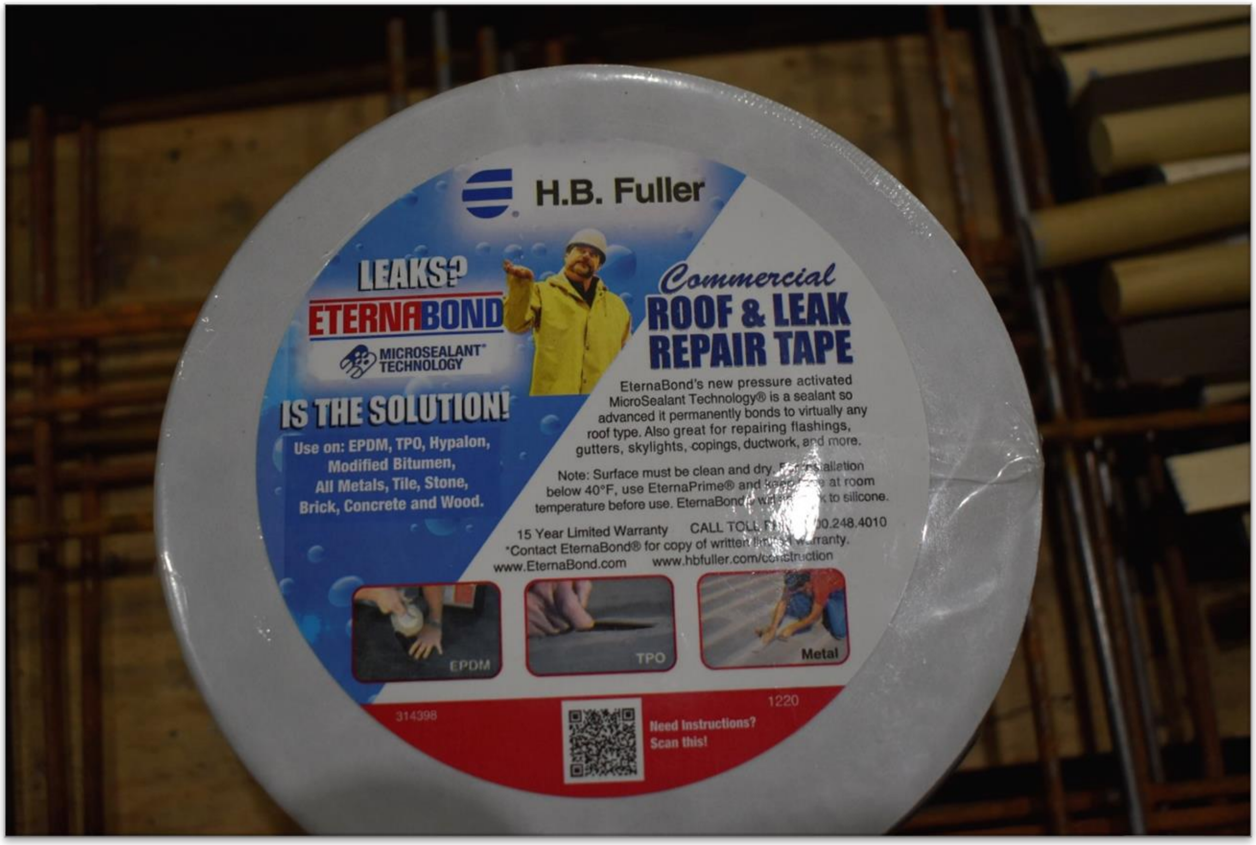

Figure A5: Eterna Bond" tape used to seal the strip and dowel to the pavement

Figure A6: Some of the electronic equipment tried for data collection. The voice recorder is at the top of the page, the speed radar gun is in the middle, and the decibel meter is at the bottom

Quadrant	Approach	A = Distance (in ft) of closer row of strips from Crosswalk of interest	B = Distance (in ft) of farther row of strips from Crosswalk of interest	C = Total Length (in ft) of closer row of strips positioned from Crosswalk of interest	D = Total Length (in ft) of farther row of strips positioned from Crosswalk of interest	Number of pieces of strips (each being 6ft long)	Number of rolls of 4 inches wide tape. (In LU Parking LOT 5, usage: 5 pieces => 2 rolls, 1 piece => 2/5 rolls)
1	1 = Inbound EDW. (Green Shaded Box)	14	14 + 61 = 75	24 (approx. **4** pieces of strip * 6 ft/piece)	24 (approx. **4** pieces of strip * 6 ft/piece)	**8**	8 * (2/5) = **3.2**
1	2 = Outbound RED. (Brown Shaded Box)	12	12 + 46 = 58	18 (approx. **3** pieces of strip * 6 ft/piece)	21 approx. 24 (approx. **4** pieces of strip * 6 ft/piece)	**7**	7 * (2/5) = **2.8**
2	3 = Inbound RED. (Yellow Shaded Box)	12	12 + 43 = 55	18 (approx. **3** pieces of strip * 6 ft/piece)	18 (approx. **3** pieces of strip * 6 ft/piece)	**6**	6 * (2/5) = **2.4**
2	4 = Outbound EDW. (Blue Shaded Box)	11	11 + 40 = 51	24 (approx. **4** pieces of strip * 6 ft/piece	34 approx. 36 (approx. **6** pieces of strip * 6 ft/piece	**10**	10 * (2/5) = **4.0**
Grand Total						**31**	**12.4**

Figure A7: Matrix containing the estimated length of strips and rolls of tapes, judging by the experience in Lot 5, required for pavement treatment based on details given in Figures 23 and 24

Group	Person	Round	Turn of Events and Location explored and the time spent in minutes								
			Turn of Event(s)	In-bound Edward (i)	Turn of Event(s)	Out-bound Redwood (ii)	Turn of Event(s)	In-bound Redwood (iii)	Turn of Event(s)	Out-bound Edward (iv)	Comment: Events go in Alphabetical and Numerical order
I	A	1	A1i	2 min	A1ii	2 min	A1iii	2 min	A1iv	2 min	
		2	A2i	2	A2ii	2	A2iii	2	A2iv	2	
		3	A3i	2	A3ii	2	A3iii	2	A3iv	2	
I	B	1	B1i	2	B1ii	2	B1iii	2	B1iv	2	
		2	B2i	2	B2ii	2	B2iii	2	B2iv	2	
		3	B3i	2	B3ii	2	B3iii	2	B3iv	2	
II	C	1	C1i	2	C1ii	2	C1iii	2	C1iv	2	
		2	C2i	2	C2ii	2	C2iii	2	C2iv	2	
		3	C3i	2	C3ii	2	C3iii	2	C3iv	2	
II	D	1	D1i	2	D1ii	2	D1iii	2	D1iv	2	
		2	D2i	2	D2ii	2	D2iii	2	D2iv	2	
		3	D3i	2	D3ii	2	D3iii	2	D3iv	2	

Figure A8: Showing the turn of events on site. That is order, priority and the time allocated to each of the volunteers visiting the site. The estimated time for each attempt the pedestrian makes is about 2 minutes.

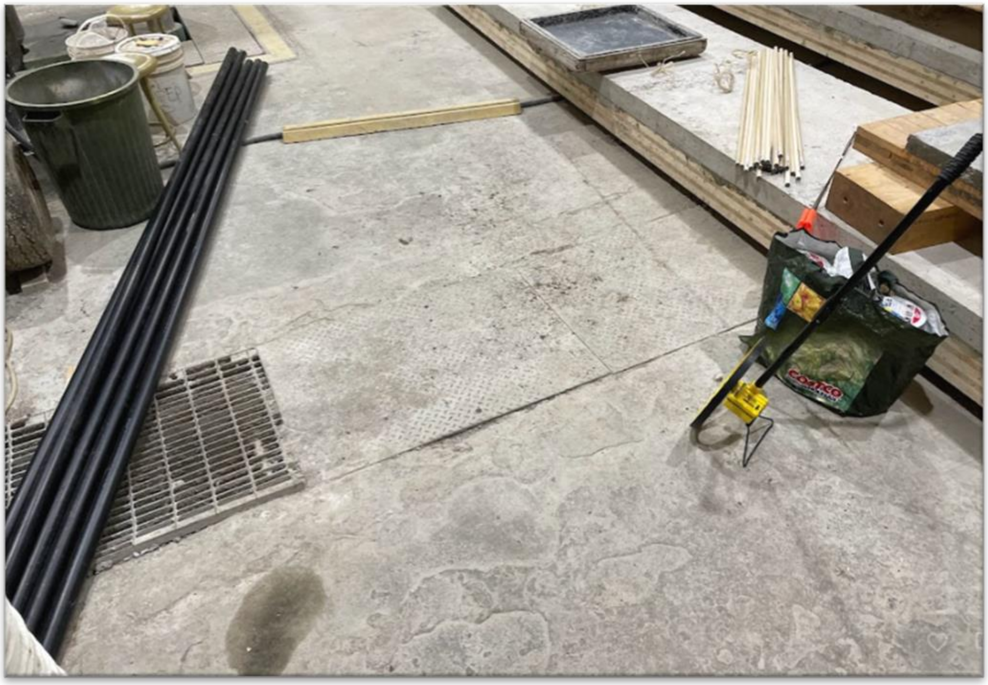

Figure A9: Pipes and pieces of dowel yet to be cut in the lab

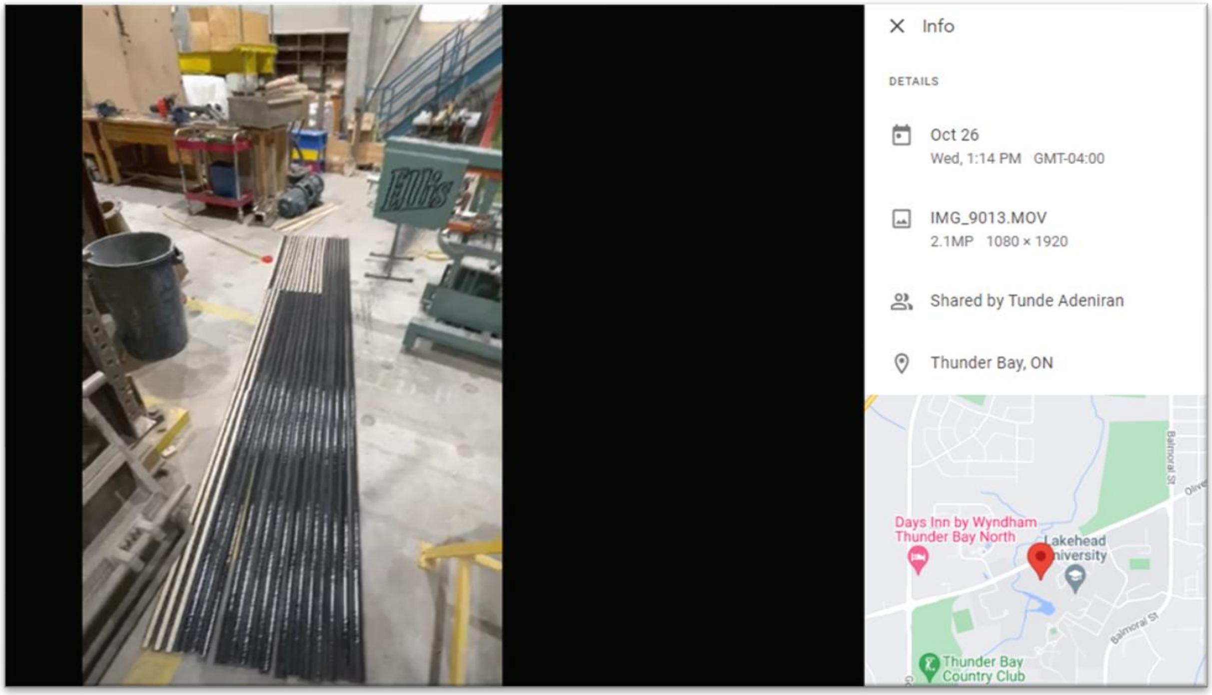

Figure A10: Sliced pipes and dowel in the lab

Figure A11: Weather conditions reported on Sunday, October 23, 2022.

Figure A12: Testing the material under early morning conditions on Sunday, October 23, 2022

Figure A13: Cleaning the surface with a broom, followed by drying the surface with a blow torch before installing the strips at about 5 am local time on Thursday, October 27, 2022

Figure A14: Installing the strips on the pavement.

Figure A15: Work in progress onsite

Event	National Workshop on Roundabout Safety and Accessibility			
Date	September 8, 2022			
Time	1:30 – 2:30 pm (Eastern Standard Time)			
Venue	Zoom			
Facilitators	Kiri Butter, Tanis Boardman, Lui Greco, Benard Akuoko			
Presenters	Dr. Juan Pernia, Mr. Omotunde Adeniran			
NB	18 people participated - aside facilitators and presenters			
Question	Name	Location	Participant's answer or Remark	Summary/Recommendations
Is there a roundabout in a kilometer of your location? Do you	Milena Khazanavicius	Halifax NS	1. Roundabout within one km 2. Uses it as little as possible	1. Stakeholders need to acknowledge the fact that traffic circles, similar to Roundabouts create discomfort

<table>
<tr>
<td rowspan="3">often use the roundabout?</td>
<td>Abby</td>
<td>Moncton NB</td>
<td>1. There is a traffic circle made accessible
2. There is a roundabout not very far, but has not used it, because not feeling comfortable</td>
<td rowspan="3">for pedestrians especially people with vision disability.
2. Agencies need to educate drivers, general public and pedestrians with disability on what a roundabout is and how to navigate or cross them
3. Agencies need to check the curbs and do regular maintenance/repair of damaged parts
4. Agencies need to provide straight lines/curb cuts – for crosswalks – on circular traffic calming structures including those in</td>
</tr>
<tr>
<td>Maria</td>
<td>BC</td>
<td>1. Has a “roundabout” within a kilometer
2. Nobody pays attention, they run over it.</td>
</tr>
<tr>
<td>Darla</td>
<td>TBay</td>
<td>1. Asked what the protocol is for a</td>
</tr>
</table>

			roundabout. To cross a street, one needs to look both ways 2. Ben the moderator tapped on Lui for an answer 3. Lui deferred to the "Engineers" because, as he said, he had no idea what the answer is 4. Dr. Pernia said that the Pedestrian has right of way	residential area, so that blind pedestrians can become lined up properly, when orientating for crossing 5. Agencies need to provide means of transmitting audible cues to pedestrians with vision impairment to stay aware of traffic movement in a roundabout where vehicular movement isn't for the most part (Possible solution: LU sound strip project) 6. Agencies need to keep pedestrian

			theoretically, needs to cross in the direction one is going, be aware of vehicles that are coming. They might not stop. Depending on the type of roundabout, pedestrian may have a place to stop in the middle and the gap they may have for crossing	crosswalks far away from where vehicles are just about accelerating (Options: Placing the crosswalk at about half a block distance away as is reportedly done in UBC or alternatively, with the current configuration of roundabouts where the crosswalk is on the outbound approach, that is, in the shadow of the roundabout, placing the LU sound strips covered with yellow/black

	Linda Bartram	Victoria, BC	1. Asked a follow up question. There is no roundabout, but there used to be one in Victoria. Asked for a description of what a roundabout is. 2. Dr. Pernia described the roundabout as an island where vehicles come in, circulate around to	striped cautioning tape at the exit point where vehicles are about to leave the circular part of the roundabout, would create an awareness on the driver of still traveling in a low speed zone, and the strip acting as speed bump altogether taming driver behavior, calming traffic even as the sound wave transmitted helps the pedestrian to stay aware of traffic situation situation) 7. Agencies need to provide vibrating

			go straight or turn. It helps capacity because vehicles are not stopping. You are not crossing over the central island. Just crossing over the roads that lead in/out of the roundabout 3. Tunde added that the pedestrian crosses the	cones, in addition to any other measures they might have implemented. The guess is, the cone vibration aren't guarantees that drivers stopped for pedestrian. Cone vibration is better than the audio/sound effect that is drowned out in noisy background. 8. Agencies should provide raised crosswalk. 9. The process of making complaints works well if you are known in the city. For the

			crosswalk on the leg of the roundabout (4 leg, or different type), dealing first with traffic that goes in one direction, could take a rest at the splitter island or keep going until the set of traffic in the opposite direction is crossed.	average person, the process is slow and frustrating, the response to complaints is disappointing. The process in some places needs to be overhauled or optimized. Possible solution: Need for the research team to ultimately come up with AI driven computer/mobile Application system that is more accessible for people with disability. The system should share data with relevant agencies,

			4. Dr. Pernia said when crossing the street, it is straight crosswalk, but going around the roundabout is not a 90 - degree path, but circular. So, it is a bit harder finding the way to go.	regularly follow-up to possibly see to it that action is promptly expedited. 10. Agencies should have cameras installed, as far as the law permits, on major intersections monitoring incidents for pedestrian safety, and that also serving as evidence when complaints are made by the affected pedestrian. Cameras deter offenders and criminals 11. Agencies should ensure that APS is
	Brian	North Bay Ontario	1. One is 2 km distance of home. Done it a few times, but no way of crossing at	

			the roundabout. 2. Goes a block away on either intersection to cross, because nobody is stopping at the roundabout. Also, because it is an open space, it is hard to say, "is that car coming from the left?" Because it is busy, the	located at consistent position to make it easy for pedestrians with vision impairment. The APS should be at a reasonable height, where the sound energy can be more useful for guiding persons with vision disability. Consistency in tone is equally important. If there is count down displayed visually, same must be available audibly and for equal amount of time. 12. Agencies to deter aggressive drivers'

			sound of vehicles is hard to tell what is coming or what is going. 3. Used to drive truck when there was no vision problem (Now totally blind). Finding the curbs on the edge, made of concrete are always "chewed up" by tractor trailers'	behavior who block off pedestrian path at the crosswalk while drivers wait for gap in traffic. Perhaps installation of cameras would solve this problem. 13. Agencies to check the drivers who whip through pedestrian crossing at unsignalized intersection. Maybe installing sound strip would solve this problem

			wheels that are – half the time – on or rubbing the curb	
	Marika Prokosh	Winnipeg	1. None in her neighborhood, but one near where the parents live. Reframed it as, there is a street where each intersection is with a "roundabout", except for where the parents live.	

			2. Feels comfortable crossing them, being where the childhood was. It is a quiet street and not sure why they put them in 3. Partially sighted and when it is not so busy, can still use the residual vision. The busier/noisier it is or the less familiar it is with the space, the less likely	

			the sight can be used.	
	Maria	BC	1. Within 2 km of the home, on a (residential ?) street, radius of 4 blocks, with one roundabout in each corner. Not a busy street, just a moderate one. The municipality keeps adding the roundabout s. In the speaker's area there is	

			plenty of them. 2. People go right through the middle of half of these structures	
	Linda Bartram	Victoria, BC	1. Mentioned that the discussion at this event is assumed to be about major traffic intersections and not just the traffic calming type of roundabouts	

			2. Dr. Pernia said it is good to hear about both the traffic calming circular structures that are in residential areas, as well as the standard roundabouts that are on busy roads. So, anyone who would collaborate is welcome 3. Linda said the problem with the	

			residential ones is lining oneself up to cross because it is a curve, with curved curbs around it 4. On the major roundabouts, when there is no traffic light, no pedestrian signal, blind pedestrians rely on surges in traffic. If traffic flow	

			is constant, then the cues are not there	
	Matthew	Langley, BC	1. Traffic circle within a km. It has a high curb and quite easy to become oriented with 2. The traffic circles in Maria's area are hard (impossible) to be oriented with because of the way they have been built	

Are there positives that you feel about roundabouts?	Everyone		"NO"	
	Milena Khazanavicius	Halifax NS	1. Completely blind 28 years 2. Was a driver. Roundabouts have positives on major highways. Los Angeles, New York, on major highways where there are no pedestrians. 3. There are no positives when dealing with pedestrians with	

			disabilities – Blind and partially sighted especially, on roundabouts and traffic circles 4. Milena is "involved" with Lui on the East Coast. (Lui clarified, they are working together, not "involved"). 5. Traffic circle is for traffic calming. It is similar to	

			having a "button" in the residential area. They are a little bit useless. To cross the traffic circle at the curb, because the curb is cut back. So, it is hard to hear the traffic because one is not at the corner, regardless it is a busy or quiet street	
	Kat Hamilton	Ottawa	1. Worked on the	

			advocacy team at the Royal National Institute for Blind people RNIB 2. Accessibility issue doesn't exist because the roundabout infrastructures are well constructed in the UK 3. In Canada at Gatineau, Quebec where they have a (pilot, the only?? TBay	

			too) roundabout with signalized crossing on the exit road. As the driver is about accelerating to leave the roundabout , there is a red light on the crosswalk stopping the driver who abruptly slams on the brake for the pedestrian.	

			Kat does not believe that the above - described measure at Gatineau is safe. Signalizatio n (of crosswalk) shouldn't be in the shadow (exit approach) of the roundabout	
	Marika Prokosh	Winnipe g	1. Speeding is a problem in Winnipeg. Adding roundabout to calm	

			speed is positive 2. Compared to the audible APS at Canadian pedestrian crosswalk, where the sound easily is drowned by ambient noise in the background, Marika believes that the spinning cones on intersections in the UK are better. The pedestrian	

			stands next to the box on the tactile curb cut, pushes the button under the box, and the cone starts to spin, suggesting to the pedestrian that it is safe to cross	
	Karim	Burnaby	1. There is no roundabout within a kilometer of Karim's home, but there is a four - lane roundabout	

			on the UBC campus where Karim worked. 2. At UBC, there is no crosswalk in the shadow of the roundabout, but the pedestrian must go about half a block around the corner to reach the next pedestrian crosswalk 3. In the UK, according to	

			Karim, crossing the small traffic circles – similar to buttons in the center of the road – is easy. Same as crossing a regular intersection. Karim did not try to cross the much larger roundabout ones. Too scared to go near walking	
	Brian Bibeault		1. Reiterated what has	

			been said by speaker from Ottawa (Kat) and Burnaby (Karim). In the U.K., with the cones one is able to cross in the roundabout, whereas in Canada, the pedestrian has to go to one side street or another to cross. 2. Drivers, showing lack of	

			knowledge and understanding that the pedestrian wants to cross, do not stop. In Canada, the lights keep the traffic stopped. Roundabouts are designed to keep the flow going, but for pedestrians, keep the flow stopped	

What is the ideal roundabout that you are hoping for?	Milena Khazanavicius	Halifax NS	1. Raised (by one or two inches) crosswalks that is properly installed and properly marked – potentially would assist pedestrians in crossing whilst slowing vehicles down. This is an extra - expanded speed bump. Enhanced safety	

			measure. Pedestrians can be seen better on the raised elevation 2. Lui clarified that the raised crosswalk is the platform on which the pedestrian walks when crossing. This elevation for pedestrians makes them more conspicuous	

			for drivers to see 3. Marika favors the idea. The best roundabout is something that is not roundabout. 4. Someone asked if that is done somewhere already 5. Milena said there are already some raised crosswalks around the country -	

			curb to curb across multi lane roads. They are piloting such idea on a straight road on the peninsula somewhere in Halifax. Milena said that POTENTIALLY, a raised crosswalk might work on a roundabout.	
	Linda Bartram	Victoria, BC	1. Regardless the measures put in place,	

			the one that gives information and control to the pedestrian about what is going on an intersection is the greatest. It is good to modify driver behavior, but Linda doesn't feel confident when relying on drivers to show courtesy.	

			Bicycles in Victoria don’t stop for pedestrians even with raised crosswalks. Linda believes that, similar to the spinning cone, if/when implemented, the rumble strip pilot project at Lakehead University would give more safety – enhancing	

			information and control to the pedestrian. Linda imagines that an overpass for pedestrian, would separate them completely from traffic and harm. Providing more information in audible signal, or cone vibration, as well as with tactile,	

			would be some of the ways of empowering pedestrians, putting them in control of their own safety	
	Maria	BC	1. An audible warning signal for the driver to know that there is someone in the crosswalk is necessary. It is similar to a straight crossing and	

			rounded circle which is analogous to adding a round peg to a square hole 2. Thinks that the crosswalk should be at a half block away where the street is straight, rather than being adjacent to the roundabout	
When you have a complaint about an intersection,	Maria	BC	1. Made a complaint to the City of Maple	

roundabout or etc. how do register this complaint, do you find this method easy, is the response effective/satisfactory, or would you prefer to have a more effective method?			Ridge. Started since 2018, coming to be front burner now with many obstacles to handle in between. The process is not easy to do. It is a 50 - 50 chance. Wasted a lot of time. Had 3 different lawyers representing the case, because Maria couldn't	

			afford to pay one personally, hence it has taken this long.	
	Someone		1. Has had a lot of issues with crossing, light not working, putting in beeper light. Went with husband and met with the city. Tried but difficult having them to understand	

			where and when to put the traffic and beeper light etcetera. It is a lot of frustration. The city agreed to put traffic light and beeper lights, but they are still not putting the beeper lights. There is no much support there	
	Linda Bartram	Victoria BC	1. The City of Victoria website has	

			a way of registering concerns. It seems to work quite well. Complainant receives a response right away, not that issue is resolved already, and in some cases, issues are resolved fairly quickly. That is possibly because Linda is fairly well	

			known as the former Chair of the Accessibility Group there. Other things seem to take forever to be resolved. It is a mess in Victoria 2. Having an online way of registering a concern seems to work. Having a way to connect with the engineering	

			department, through some sort of telephone system, would even be more accessible to more people.	
	Milena Khazanavicius	Halifax NS	1. Backtracked to Maria, encouraging Maria to not feel that the time was wasted. It can reach a point of exhaustion and anger 2. In Halifax, if the pedestrian	

			remembers the complaint going from grocery store to home, there is a number 311 to call, or instantly dialing 311 from the cellphone. 3. The complaint goes into the system, and within 48 business hours there ought to be a response from "such and such"	

			department. It is okay but not right, for people with disability to be chasing down the problems. Milena is a little too known with the Halifax Regional Municipality Engineers, and also on the Active Transportation Advisory Committee. Things move a little bit quicker	

			knowing where the Engineers are, and Milena can reach them. Same is not the case with everyone else. 4. Milena's relatives living in the UK said that there are cameras that spot drivers who offend and be penalized subsequently. Why isn't	

			Canada installing cameras on every major intersection to start with, therefore the incidents are caught. It is not for the pedestrian to wear cameras on their bodies. It is for the engineer to do the monitoring of incidents. The government	

			should find some money and provide the cameras for pedestrian safety. The camera recording serves as evidence if and when the pedestrian lodges complaints, thus providing more specifics on intersection address and time relating to	

			where an incident might have occurred	
	Maria	BC	1. There is a light that is installed for Maria near the home, on a 3-way (T) crossing, and the residents want to turn it off on a busy road. The residents/city were taken to the mediation and human right panel. The light	

			should not be turned off. Maria sits on the Accessibility Committee in the city. The residents go to the to the facility and put an electrical tape on the equipment speaker to block off the sound from the Audible Signal. Complainant phoned the city, and the city	

			asked complainant to call the police - who claimed to not know if the perpetrator is a resident. The police refused to install a camera there saying it is an “invasion” of people’s space, and that it is illegal to put a camera out in the neighborhood to figure	

			out who is blocking the audible signal	
	Randy Netherton		1. Broke the News of the Passing of the Queen of England. May Her soul Rest In Peace.	
Is there any positive or negative seen in regular intersection?	Veronica		1. Sound signals are a big help 2. Sometimes the poles are located in different places depending on intersection and "having	

			to memorize that is the fun part" 3. The voice comes in different types – Birds, Cuckoo, and melody sounding ones. Not very intuitive, hence asking on this forum why there are different types 4. Milena?? responded	

			by saying that CNIB is looking at a universal sound	
	Brian		1. There are 6 different types of A.P.S. signal in Canada. In the "small" city of 55 thousand people where Brian lives, there are about 4 different types of A.P.S – countdown, cuckoo, etc.	

			it is annoying. whereas, in Australia, they used only one type of APS signal in the entire country since 1998 2. Keeping the speaker for the sound way up in the air sends the sound all over the place, thus annoying people who live in the area.	

			Meanwhile, it is hard for the person with disability to align self with where the sound is coming from. By adhering to a standard height that is used in Australia, 8 feet in the air, then the pedestrian can easily locate it. 3. Someone in the audience added to	

			what Brian was saying, in that case, the Australian style works better even if there is a lot of noise in the background. Brian and the other speaker said the sound doesn't become drowned out if there is noise in the background coming from diesel	

			engine or construction site.	
	Linda		1. Consistency and predictability are great and important, given that there is a lot to remember 2. Locator tones on the poles, to be able to find the poles, even when the poles can't consistently be in the same	

			locations due to infrastructure criteria. 3. Traffic signals mostly work, counting down visually and not audibly. The engineer often sets the audio signal to last a shorter period of time than the visual signal lasts. This type of setting	

			makes the signal useless to the pedestrian who can’t see. The audio signal should countdown and work in the same way as the visual phase of the signal. It isn’t a great design when Linda or any pedestrian with disability is being told	

			that it is safe to go – since the visual signal is still counting down – whereas, the audio isn't counting down at the same time.	
	Marika		1. Agrees that audio crossings are great. They are fairly consistent in the city where Marika lives but not just	

			enough of them. Therefore, consistency and ubiquity are good to have. 2. Marika hopes that more advocacy is done regarding drivers who inch their way into pedestrian crosswalk, thus blocking it and hindering pedestrians' movement,	

			when the drivers are stuck or waiting for gap in traffic. 3. Also, drivers, really fast, whipping through split lanes, where separate lanes branch off diagonally from the main road. With no traffic light at the intersection. It will be	

			incredibly helpful to have some tools that give more information to pedestrians on how to deal with drivers at intersections, as already discussed (alluding to the noise strip).	
Future steps	Dr. Pernia		1. Survey - please participate to help the research 2. App developme	

			nt for people with vision loss and other disabilities to submit concerns or issues related to transportation and accessibility, which will be monitored by the team and shared with relevant agencies to expedite action 3. Doing a pilot field study	

			to test the treatment idea in Thunder Bay and later expand nationally, as well as testing under other conditions. 4. Thanks to all participants at the workshop, hopefully more will come. 5. Thanks to Tanis, Kiri, Ben and Lui for helping to facilitate this.	

Other announcements	Tanis		1. Thanks to all participants for candid thoughts shared at the workshop 2. Any new ideas that come to mind can still be shared later by email. Send such to Tanis and it will be relayed to the research team 3. Survey will be sent out very shortly	

Figure A16: The report and minutes of meeting compiled on the workshop with conclusions reached

Comments without rumble strip:

Approach 1

- It is difficult to determine the direction of vehcicles moving at the roundabout
- It is difficult to know if vehicles comng on the approach are stopping
- If you can determine if a vehicle stop in one of the lanes, it is difficult to safely know if the other lane has no vehicles moving
- Time of crossing with the flashing beacons is not enough since it has to be determined first if the volunteer can start crossing

Approach 2

- Not able to determine when vehicles are exiting the roundabout in the direction of the crosswalk the volunteer is waiting to cross
- Only feel safe to cross if there is no vehicle at all in the roundabout
- Not able to determine if it is a two-stage crossing and where the island is
-

Approach 3

- More likely to determine when vehicles are exising the roundabout in the direction of the crosswalk the voluneteer is waiting

Approach 4

- Not able to determine if vehicles are exiting the roundabout in the direction of the crosswalk the volunteer is waiting to cross

Comments with rumble strips:

Approach 1

- Able to hear the farthest strip and then the closer strips which allowed to know if vehicles where stopping
- Still need time to start crossing to ensure the vehicles are not moving
- Cannot determine if vehicle stop with certainty if the middle trip was not crossed by vehicle

Approach 2

- Not able to determine if vehicles are stopping if they do not cross the farthest stip

Approach 3

- No problem to determine if vehicles are coming and stopping

Approach 4

- Farthest strip is helpful at to certain point if vehicles crossed but still difficult to determine if a vehicle on the other lane is stopping
- Time of crossing with the flashing beacons is not enough since it has to be determined first if the volunteer can start crossing

Figure A17: Comments made by PWVL Before and After Strips Installation

Serial No = Collision No, Date (MM/DD/YYYY), Time, V1 & V2 Speed, Road Surface, Weather, Lighting, Collision - Injury

1 = P18043193, 6/2/2018, 2:24:00 PM, V1=50 KPH, V2=35 KPH, D, C, DL, Angle, - 1 Slightly injured

2 = P18043516, 6/2/2018, 2:24:00 PM, V1=35 KPH, V2=0 KPH, D, C, DL, HeadOn.

3 = P18675791, 12/4/2018, 4:00:00 PM, V1=4 KPH, V2=0 KPH, D, C, DL, Rear End

4 = P19024155, 1/25/2019, 9:15:00 AM, V1=5 KPH, V2=5 KPH, I, C, DL, Rear End

5 = P19028562, 2/6/2019, 11:15:00 AM, V1=14 KPH, V2=0 KPH, S, C, DL, Rear End

6 = P19030137, 3/5/2019, 4:27:00 PM, V1=5 KPH, V2=40 KPH, D, C, DL, Angle

7 = P19055246, 8/1/2019, 7:48:00 PM, V1=UNK KPH, V2=UNK KPH, D, C, DL, Angle

8 = P19061976, 9/8/2019, 11:32:00 AM, V1=60 KPH, V2=35 KPH, D, C, DL, Rear End - 2 Slightly injured

9 = P19066390, 9/11/2019, 1:20:00 PM, V1=5 KPH, V2=5 KPH, D, C, DL, Angle

10 = P19071512, 10/16/2019, 12:00:00 PM, V1=3 KPH, V2=1 KPH, D, C, DL, Rear End

11 = P19077088, 11/28/2019, 11:55:00 AM, V1=10 KPH, V2=2 KPH, D, C, DL, Rear End

12 = P20024880, 1/29/2020, 3:49:00 PM, V1=15 KPH, V2=20 KPH, W, C, DL, T-Boned

13 = P20027103, 1/30/2020, 12:53:00 PM, V1=3 KPH, V2=40 KPH, W, C, DL, Angle

14 = P20027641, 2/7/2020, 10:15:00 PM, V1=50 KPH, V2=50 KPH, D, C, DK, Sideswipe but looks like Angle

15 = P20029959, 2/28/2020, 8:05:00 PM, V1=20 KPH, D, C, DKA, Collided with a Pedestrian

16 = P20035137, 3/26/2020, 7:08:00 AM, V1=UNK, V2=60 KPH, D, C, DK, Sideswipe but looks like Angle

17 = P20065068, 10/14/2020, 8:17:00 PM, V1=15 KPH, V2=50 KPH, W, R, DKA, Rear End symbol, looks like Angle

18 = P20070505, 11/16/2020, 3:17:00 PM, V1=25 KPH, V2= 0 KPH, D, C, DL, Rear End

19 = P21025385, 1/27/2021, 2:30:00 PM, V1=30 KPH, V2=50 KPH, D, C, DL, Sideswipe

20 = P21027684, 2/4/2021, 9:15:00 PM, V1=UNK, V2=0 KPH, S, S, DKA, Rear End

21 = P21041337, 5/18/2021, 11:14:00 AM, V1=30 KPH, V2=50 KPH, D, C, DL, Angle

22 = P21049498, 6/21/2021, 7:30:00 PM, V1=15 KPH, V2=2 KPH, D, C, DL, Sideswipe looks like Angle

Figure A18: Collision Diagram's key - Before Roundabout Construction

	Serial No = Collision No, Date (MM/DD/YYYY), Time, V1 & V2 Speed, Road Surface, Weather, Lighting, Collision - Injury
	23 = P21073407, 12/1/2021, 9:15:00 AM, V1=40 KPH, V2=20 KPH, W, S, DL, Angle or Rear End
	24 = P21076626, 12/20/2021, 8:25:00 PM, V1=15 KPH, V2=40 KPH, S, C, DKA, Turning Moment or Angle
	25 = P21077507, 12/29/2021, 2:15:00 PM, V1=15 KPH, V2=0 KPH, S, C, DL, Rear End
	26 = P22024149, 1/30/2022, 11:45:00 AM, V1=25 KPH, V2=20 KPH, W, C, DL, Angle
	27 = P22041520, 5/31/2022, 9:20:00 AM, V1=UNK KPH, V2=30 KPH, D, C, DL, Angle or Rear End
	28 = P22047409, 7/8/2022, 9:25:00 AM, V1=40 KPH, V2=10 KPH, D, C, DL, Sideswipe
	29 = P22045048, 5/30/2022, 2:30:00 PM, V1=30 KPH, V2=25 KPH, D, C, DL, Sideswipe
	30 = TB22053926, 7/20/2022, 11:15:00 AM, V1=45 KPH, V2=20 KPH, D, C, DL, Sideswipe
	31 = TB22061725, 10/16/2022, 12:35:00 AM, V1=90 KPH, No other vehicle, D, C, DKA, Lost control
	32 = TB22066596, 11/19/2022, 3:43:00 PM, V1=20 KPH, V2=20 KPH, D, C, DL, Angle

Figure A19: Collision Diagram's key - After Roundabout Construction

Appendix B of Tables

Table B1: The sequence that events followed for PWVL Group 1 on October 13, 2022, without strips installed

Time of the Day	Volunteer Group Number	Approach on Roundabout	Volunteer	Video File Number	Event Occurrence Time on Camera	Attempts made by Volunteers to cross the road
11.00 am	1	1	1	DSC-0001	0.19	1st
			1		6.05	2nd
			2		10.35	1
			2		12.29	2
			3		16.55	1
			3		19.30	2
		2	1	DSC-0002	0.49	1
			2		4.26	1
			2		6.30	2
			3		10.00	1
		3	1	DSC-0003	1.23	1
			1		3.05	2

			1		**4.40**	**3**
		4	**1**	**DSC-0004**	**2.38**	**1**
			1		**4.08**	**2**

Table B2: The sequence that events followed for PWVL Group 2 on October 13, 2022, without strips installed

Time of the Day	Volunteer Group Number	Approach on Roundabout	Volunteer	Video File Number	Event Occurrence Time on Camera	Attempts made by Volunteers to cross the road
	2	**1**	**1**	**DSC-0005**	**2.22**	**1st**
			1		**3.40**	**2nd**
			1		**5.14**	**3rd**
			2		**10.57**	**1**
			2		**12.47**	**2**
			3		**17.20**	**1**
			3		**19.42**	**2**
		2	**1**	**DSC-0006**	**1.50**	**1**
			1		**3.58**	**2**
			2		**6.54**	**1**
			2		**8.22**	**2**
			3		**13.40**	**1**
			3		**15.30**	**2**
		3	**1**	**DSC-0007**	**1.20**	**1**
			1		**2.40**	**2**

			2		**5.20**	**1**
			2		**5.55**	**2**
			3		**10.55**	**1**
			3		**12.16**	**2**
		4	**1**	**DSC-0008**	**0.18**	**1**
			1		**1.30**	**2**
			2		**5.05**	**1**
			2		**6.50**	**2**
			2		**7.55**	**3**
			3		**11.25**	**1**
			3		**14.45**	**2**

Table B3: The sequence that events followed for PWVL Group 1 on October 27, 2022, with strips installed

Time of the Day	Volunteer Group Number	Approach on Roundabout	Volunteer	Video File Number	Event Occurrence Time on Camera	Attempts made by Volunteers to cross the road
10.53 am	1	1	1	DSC-0056	2.40	1st
			1		5.15	2nd
			1		6.40	3rd
			2		11.40	1
			2		13.35	2
			2		15.55	3
		2	1	DSC-0057	2.51	1
			2		9.19	1
		3	1	DSC-0060	1.00	1
			1		2.15	2
			2		4.19	1

		4	**1**	**DSC-0061**	**0.54**	**1**
			1		**1.56**	**2**
			1		**4.43**	**3**
			2		**8.25**	**1**
			2		**10.18**	**2**

Table B4: The sequence that events followed for PWVL Group 2 on October 27, 2022, with strips installed

Time of the Day	**Volunteer Group Number**	**Approach on Roundabout**	**Volunteer**	**Video File Number**	**Event Occurrence Time on Camera**	**Attempts made by Volunteers to cross the road**
12.08 pm	**2**	**1**	**1**	**DSC-0063**	**0.30**	**1**
			1		**2.47**	**2**
			1		**4.00**	**3**
			2		**9.42**	**1**
		1	**3**	**DSC-0065**	**0.51**	**1**
			3		**2.57**	**2**
		2	**1**	**DSC-0064**	**0.45**	**1**
			1		**2.07**	**2**
			2		**6.43**	**1**
			2		**8.08**	**2**
			2		**9.41**	**3**

			3		**13.15**	**1**
			3		**14.51**	**2**
		3	**1**	**DSC-0066**	**1.15**	**1**
			2		**5.55**	**1**
			3		**9.50**	**1**
			3		**11.39**	**2**
		4	**1**	**DSC-0069**	**0.25**	**1**
			1		**1.30**	**2**
			2		**7.49**	**1**
			2		**8.38**	**2**
			3		**12.51**	**1**
			3		**13.37**	**2**