American Journal of Traffic and Transportation Engineering
2025, Vol. 10, No. 1, pp. 11-21
https://doi.org/10.11648/j.ajtte.20251001.12

Research Article

Roundabout Accessibility: A Canadian View

Omotunde Adeniran*, Juan Pernia

Department of Civil Engineering, Lakehead University, Thunder Bay, Canada

Abstract

Roundabouts are used for traffic calming, have cheaper lifetime costs, and are environmentally friendly. For Persons with Vision Loss (PWVL), roundabouts are challenging when crossing streets due to lack of signalization and difficulties in differentiating sound cues. The objectives of this research were to investigate roundabout accessibility issues confronting PWVL and to evaluate a safe crossing solution. To achieve these objectives, a national workshop with the Canadian National Institute for the Blind (CNIB) clients, and a survey with volunteers were conducted to determine accessibility issues. For evaluation of the crossing solution, steps included using a 3D model of a roundabout, developing sound strips, testing them on a parking lot, installing and utilizing them at the roundabout, and conducting a post-experiment survey. CNIB staff facilitated local meetings, the national workshop and assistance with volunteers during field tests. Field studies were conducted with six volunteers during one day before sound strips were installed and one day after. Data collected at the roundabout included vehicle speed, vehicle yield for pedestrians, delay felt by pedestrians, and pedestrians' opinions. Results showed that sound strips provided PWVL with warnings of upcoming vehicles. Data analysis showed 57% of vehicles yielding to pedestrians before installation and 41% after. Also, the average delay experienced by pedestrians decreased from 41.39 seconds to 38.34 seconds. In reference to speed, a few vehicles traveling through the intersection exceeded the 40KPH posted speed prior and after installation of the strips, highlighting the need for continued safety measures. Furthermore, it was determined that using a 3D model was helpful in discussing accessibility issues with volunteers. These findings provide meaningful information about concerns and issues faced by PWVL at roundabouts, suggesting that treatment using sound strips is beneficial for this vulnerable group when navigating these locations. Overall, this research provides valuable insights into roundabout accessibility issues and offers a potential solution to improve safety and mobility for PWVL. A statistical analysis revealed changes in vehicle speeds across four approaches, with highly significant reductions ($p < 0.001$) observed before treatment on Approaches 1, 2, and 4. However, results after treatment were mixed, with marginal significance ($p = 0.072$ and $p = 0.084$) on Approaches 2 and 4. Due to the small sample size, findings should be interpreted with caution, and further research is needed to draw definitive conclusions.

Keywords

Roundabout, Accessibility, Persons, Vision, Loss, Rumble, Sound, Strip

1. Introduction

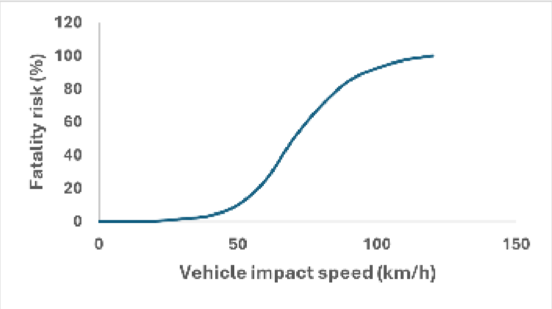
Globally, approximately 2.2 billion people live with visual impairments [1], with 1.5 million of that population in Canada [2]. Roundabouts pose significant accessibility challenges for PWVL due to the lack of standardized traffic signals and the reliance on auditory cues. PWVL find it challenging to cross streets at unsignalized intersections like roundabouts [3, 4] especially in urban

*Corresponding author: oadenira@lakeheadu.ca (Omotunde Adeniran)

Received: 4 February 2025; **Accepted:** 18 March 2025; **Published:** 31 March 2025

areas where speeds are typically lower than 40 KPH.

As shown in Figure 1, the probability of fatality increases exponentially with vehicle speeds exceeding 40 KPH [5]. Notably, PWVL and those using assistive devices tend to walk slower than average pedestrians [6], thereby heightening their vulnerability at intersections and underscoring the significant risks they face.



Impairment/Assistive Device	Average Walking Speed	
	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 1. Relationship between pedestrian risk of fatality and vehicle speed [5] (LHS). Walking speeds of impaired pedestrians or those using assistive devices [6] (RHS).

Roundabouts are designed with specific features to ensure safety and accessibility. According to the Manual of Uniform Traffic Control Devices (MUTCD) and Transportation Association of Canada (TAC) Design Guide, a sign like the one in Figure 2 is installed to clearly indicate crosswalk locations and prioritize pedestrians' right of way. Also, sufficient illumination in roundabouts enhances safety and accessibility for PWVL [7]. Additional features to consider include Rectangular Rapid Flashing Beacons (RRFBs) with Accessible Pedestrian Signals (APS) activated by push buttons (Figure 2), appropriate fencing of corridors and sidewalks, curb treatment installation, Tactile Walking Surface Indicators (TWSI), as well as pavement markings on roundabouts [8].

Figure 2. Rectangular Rapid Flashing Beacon (RRFB) with an Accessible Pedestrian Signal (APS) and push button on the pole, Thunder Bay.

US-based studies have explored sound-strips for pedestrian assistance at channelized turn lanes [9] and two-lane roundabouts using Poly Vinyl Chloride (PVC) pipe strips [10], emphasizing the need for Canada-specific research on this topic. This need is particularly pressing for PWVL, who face significant challenges navigating roundabouts due to the lack of signalization and difficulties in differentiating sound cues. As a result, PWVL experience decreased safety and mobility, despite the benefits of roundabouts, including traffic calming and environmental friendliness. However, the design of roundabouts can exacerbate accessibility issues for PWVL, underscoring the need for innovative solutions to address these concerns and promote inclusive and accessible transportation infrastructure.

2. Objectives

The objectives of this research are two-fold: to identify the concerns of PWVL about roundabouts and to evaluate the effectiveness of an accessibility measure designed to warn PWVL of incoming vehicles, enabling informed decision-making when navigating the intersection. To achieve these objectives, a workshop and survey will be conducted in collaboration with the CNIB, complemented by a field study considering volunteers before and after the safety measure is installed.

3. Methodology

This section describes the research design and methods used to conduct this pilot project.

3.1. National Workshop and Survey

To better understand the accessibility challenges faced by PWVL at roundabouts, a national workshop was co-hosted with CNIB staff. An opinion survey was distributed to CNIB clients during the workshop to gather valuable insights. Furthermore, a post-experiment survey was administered to volunteers who participated in the study, soliciting feedback on their experience at the site, which was then shared with the research team.

3.2. Selection of Volunteers and Site

The primary criterion for participant selection was vision loss, ensuring alignment with the pilot study's objectives and laying the groundwork for future research. To recruit participants, CNIB staff promoted the national workshop nationwide, and attendees were subsequently invited to complete a follow-up survey via Microsoft Forms. For the field study, CNIB staff in Thunder Bay directly contacted volunteers, selecting those interested in participating. However, several potential participants with vision loss declined, citing concerns about roundabout safety.

This research project centers on the roundabout located at the intersection of Edward Street and Redwood Avenue in Thunder Bay. The intersection comprises a four-lane Edward Street (with two lanes in each direction) and a two-lane Redwood Avenue (with one lane in each direction). Notably, this newly constructed roundabout incorporates various accessibility features. Edward Street, being the main thoroughfare, is equipped with crosswalks featuring Rectangular Rapid Flashing Beacons (RRFBs) and an Accessible Pedestrian Signal (APS) that provides audible warnings. Conversely, the crosswalks on Redwood Avenue lack these enhancements, specifically RRFBs and APS.

3.3. Printing and Using the 3-D Model

Building on a previous study that found 3D models can enhance wayfinding for PWVL [11], the research team explored a similar concept. The CNIB sourced a 3D model of a roundabout from the National Traffic Research Institute in the US and provided a pre-designed file, which the research team printed in a 7.5-inch by 7.5-inch size using blue and orange materials (Figure 3). These tactile models facilitated the identification of potential accessibility issues and effectively communicated roundabout details to volunteers and stakeholders, while also playing a crucial role in explaining the field study's data collection process to participants.

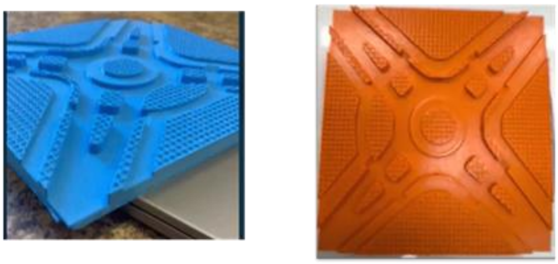


Figure 3. *3D model of a roundabout in blue and orange colors.*

3.4. Preparing the Sound Strips and Testing on Lakehead University (LU) Campus

The sound strip was designed and constructed based on the United States Federal Highway Administration's (FHWA) 2006 Report guidelines. According to the report, rumble strips are ineffective at speeds below 50 KPH. Consequently, researchers employed an alternative approach using Poly Vinyl Chloride (PVC) pipes as sound strips, combined with dowels, as seen in a comparable project involving a two-lane roundabout [10]. Similarly, the National Cooperative Highway Research Program (NCHRP) Report 674 utilized sound strips to enhance safety at Channelized Turn Lane (CTL) crossings in the United States [9]. The sound strip's composition is illustrated in Figure 4. Each strip consisted of a 3.81-centimeter (1.5-inch) diameter PVC (or ABS) pipe, cut into three equal parts, resulting in a 6-foot (1.82-meter) long strip. The sound strip and dowel assembly were secured to the pavement surface using adhesive tape shown in Figure 5.

Figure 4. *Pieces of strips and dowels displayed in the back of the laboratory.*

Figure 5. *Eterna Bond adhesive tape.*

To evaluate the sound strip installation technique, the research team conducted a trial assessment of the required installation time, performance, strength, and durability under various weather conditions. A test installation was set up in a parking lot on the Lakehead University (LU) campus, where the speed limit is 25 KPH. As shown in Figure 6, the setup consisted of two rows of strips, spaced 4 meters apart, simulating the intended roundabout configuration. A camera recorded vehicles passing over the strips, allowing researchers to estimate vehicle speed based on the time taken to travel a known distance. This setup enabled the evaluation of the strip's effectiveness at low speeds and determination of the maximum audible distance of the sound produced.

Figure 6. *Camera mounted on a stand at the entrance of parking lo (LHS). Strip-dowel assembly plastered to the pavement's surface (RHS).*

3.5. Traffic Monitoring on-Site Without Volunteers and no Treatment

The research team conducted a site visit to the Edward Street and Redwood Avenue roundabout to observe the interaction between vehicles and pedestrians. During this visit, camera positions and angles at all four approaches were tested and refined to optimize data collection. The primary objective of this step was to identify the safest approach for field study, considering the visual limitations of the volunteer participants. Safety was the top priority, and after careful consideration, four approaches were selected for the study.

3.6. Site Visit with Volunteers Without Strips

A site visit was conducted with volunteers at the roundabout, without the sound strips, to collect data on the four selected approaches. Due to funding constraints, data collection was limited to 6 hours in a single day. The six volunteers were divided into two groups of three, with each group participating for approximately three hours. The CNIB arranged and provided transportation for the volunteers to and from the site. Throughout the data collection process, two research team members and two CNIB staff members were always present to ensure volunteer safety and facilitate smooth data collection.

Data collection commenced on Edward Street's north side with southbound traffic, proceeded to Redwood Avenue's west side for westbound and eastbound traffic, and concluded on Edward Street's south side with southbound traffic. At each approach, volunteers made three crossing attempts, accompanied by a CNIB orientation and mobility specialist and a research team member. Each attempt was recorded by cameras positioned at each approach, as illustrated in Figure 7. This figure depicts the four considered approaches, with camera positions marked by red and blue squares, indicating the direction of the major and minor roads, respectively. Solid and broken lines with arrowheads represent the camera's vision field, monitoring the respective quadrants. Yellow lines in Figure 7 indicate the sound strip rows, with solid lines on inbound approaches 1 and 3, and broken lines on outbound approaches 2 and 4. The collected data included measurements of time spent activating the Accessible Pedestrian Signal (APS) and waiting for vehicles to yield, as well as instances when volunteers detected approaching vehicles and determined they had yielded.

Figure 7. *Showing Approaches and position for camera on the roundabout. (Photo Credit: City of Thunder Bay).*

3.7. Strips Setup and Installation on Site

The sound strips were installed at the roundabout (Figure 8) with assistance from the City of Thunder Bay and Pioneer Construction Company staff. A team of ten individuals completed the installation in approximately 2 hours on a cold, moist day, utilizing a blow torch to ensure a clean and dry pavement surface. As planned, two rows of sound strips were placed on each of the four approaches. Additionally, black and orange striped tape was applied on top of the strips to alert motorists and ensure their safety while navigating the monitored corridor.

Figure 8. *Early morning exercise as workers installed sound strips on the roundabout.*

To facilitate data collection, red color flags were utilized on the field. Figure 9 illustrates the positioning of these flags on the approach leading to the crosswalk. The figure shows the placement of the three flags: Flag 1, Flag 2 (aligned with the first row of sound strips), and Flag 3 (positioned at the second row of sound strips), followed by the crosswalk. These three red flags enabled easy tracking of vehicle movement.

Figure 9. *Two rows of strips installed, with three red flags positioned along the side of the road.*

3.8. Volunteers on Site with Strips Installed

Following the installation of sound strips, a site visit was conducted with volunteers to collect data on the four roundabout approaches. Over 6 hours, volunteers, divided into two groups, simulated crossings, reporting when they heard approaching vehicles and when they yielded, based on sounds from the strips. CNIB provided transportation and staff support for the volunteers. The multiple rows of strips per approach aimed at assisting the pedestrian in detecting approaching vehicles. By listening to the sound generated when a vehicle passes the first row of strips, PWVL can determine if vehicles are approaching the crosswalk. A second sound from the second row of strips may indicate that the vehicle did not yield, whereas no sound within a certain timeframe suggests the vehicle yielded, allowing safe crossing. Data collection involved recording pedestrian interactions to measure the time elapsed between pressing the Accessible Pedestrian Signal (APS) button and waiting for vehicles to yield. Figure 10 presents the measured distances between flags and rows of strips. Video recordings were used to estimate time and calculate vehicle speeds, specifically Speed 1 (between Flag 1 and Flag 2) and Speed 2 (between Flag 2 and Flag 3), using the distance/time ratio.

	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

Figure 10. *The array of numbers representing distances between flags and rows of strips for the various approaches.*

3.9. Removal of Sound Strips and Road Restoration

After completing data collection, the research team and Lakehead University colleagues removed the sound strips and accessories, cleaned up the site, and restored the road to its original condition. Meanwhile, City of Thunder Bay staff provided traffic control support. This collaborative effort is illustrated in Figure 11.

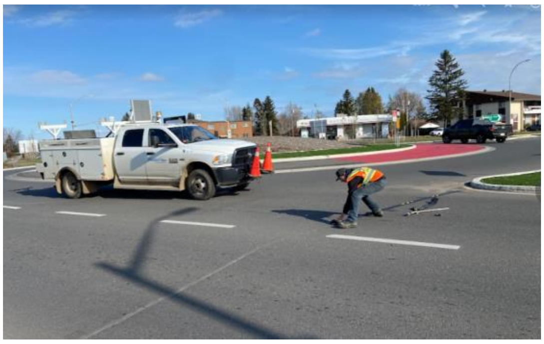


Figure 11. *Removing the strip and cleaning up.*

3.10. Estimated Parameters from Collected Data

To collect data, flags were placed at predetermined distances, and video recordings were analyzed to extract key parameters, including event occurrence time, vehicle travel time, and calculated vehicle speed. Additionally, pedestrian-related metrics were recorded, such as time spent on the Accessible Pedestrian Signal (APS), waiting time for vehicles to yield, and total delay time. Participants shared their perceptions of traffic gaps, enabling the research team to assess their experienced delays. The data facilitated estimates of vehicle yielding rates, comparing yielding and non-yielding vehicles. Further analysis revealed average vehicle speed values and corresponding two-tailed statistical significance P-values. However, due to the limited sample size collected within the allotted time frame at the intersection, caution should be exercised when interpreting the P-values to avoid premature conclusions.

4. Results

This section presents the findings of the pilot project, highlighting the key results and outcomes.

4.1. National Workshop and Survey

The national workshop convened 18 participants, 4 CNIB staff members, and the research team to discuss roundabout accessibility. Participants voiced concerns, emphasizing the need for motorist education on yielding at crosswalks, regular maintenance, and geometric redesigns to facilitate better accessibility. They urged organizations like the Transportation Association of Canada (TAC) to prioritize these redesigns. Workshop participants highlighted the often-overlooked needs of PWVL at roundabouts. A follow-up survey of seven participants revealed that four respondents desired accessibility aids to assist in detecting traffic gaps, as summarized in Figure 12.

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 12. *Summary of the feedback received on the opinion survey.*

4.2. Selection of Volunteers for Survey and Field Study

Following a presentation at the CNIB office in Thunder Bay, six volunteers were selected to participate in the project based on their expressed interest. Although other clients were initially interested, some cited concerns about roundabout safety and ultimately decided not to participate in the field data collection.

4.3. Use of 3D Model

A preliminary meeting was held at the CNIB office with volunteers for the field study. The research team provided a detailed explanation of the research process and used a 3D model of a roundabout to help volunteers understand the study location. The model proved highly effective in facilitating stakeholders' understanding of the roundabout, enabling them to better visualize and comprehend the layout.

4.4. Site Selection

The selected roundabout features accessibility elements, including the Tactile Walking Surface Indicator (TWSI) and Rectangular Rapid Flashing Beacon (RRFB) with the Accessible Pedestrian Signal (APS). These features enable the evaluation of their effectiveness in accommodating PWVL. Additionally, sound strips will be installed to assess their contribution to decision-making for PWVL when crossing streets at the roundabout.

4.5. Strip – Testing on LU Campus

Testing the sound strip installation and data collection process at the university parking lot created a valuable template for the project. This phase saved time, money, and energy, but most importantly, it enhanced safety during data collection when the project shifted to the roundabout.

4.6. Site Visit Without Volunteers and Without Sound Strip Installed

A site visit to the roundabout was conducted to determine the optimal camera position and most efficient data collection method prior to when volunteers were present. This phase ensured the safety of volunteers during data collection and helped identify the best approach for the process.

4.7. Onsite with Volunteers – Before and After Strips Installation

This section presents comments from volunteers and compares data collected before and after the sound strips were installed.

4.7.1. Comments Made by Volunteers

Before the sound strips were installed, volunteers expressed difficulty determining when vehicles were approaching the crosswalk they intended to cross. They felt safe crossing only when there was complete silence, indicating no traffic in any direction. Volunteers preferred avoiding roundabouts altogether, citing safety concerns.

After the strips were installed, volunteers reported increased confidence due to the warning sound indicating approaching vehicles. Some suggested extending the monitored corridor, particularly at roundabout exit points, to provide more reaction time for pedestrians with visual loss. However, the proximity of exit lanes to crosswalks limits the effectiveness of the warning sound from the strips.

Volunteers also recommended prolonging the timing of the Rectangular Rapid Flashing Beacon (RRFB) and Accessible Pedestrian Signal (APS) sounds, as the current duration was insufficient for PWVL to confidently cross the road. This concern was consistent across all approaches with these accessibility features, highlighting that the existing timing does not account for the extra time PWVL need to feel secure before starting to cross the road.

4.7.2. Speed

Figures 13 and 14 display the speed data for Approach 1, with two speeds represented: Speed 1 (blue dot and line), the initial speed of vehicles approaching the crosswalk, and Speed 2 (red dot and line), the final speed closer to the crosswalk. The graphs reveal that Speed 2 often surpasses Speed 1, indicating that vehicles tend to accelerate near the crosswalk.

In Figure 13, the average Speed 1 was 7.93 KPH, while Speed 2 averaged 30.97 KPH, with a p-value of less than 0.001. Similarly, in Figure 14, Speed 1 averaged 12.98 KPH, and Speed 2 averaged 21.20 KPH, with a p-value of 0.001.

Notably, some vehicles exceeded the 40 KPH speed limit near the crosswalk. This speeding may be attributed to drivers' lack of understanding about expected driving behaviors when approaching the crosswalk, particularly when entering the intersection at the first approach.

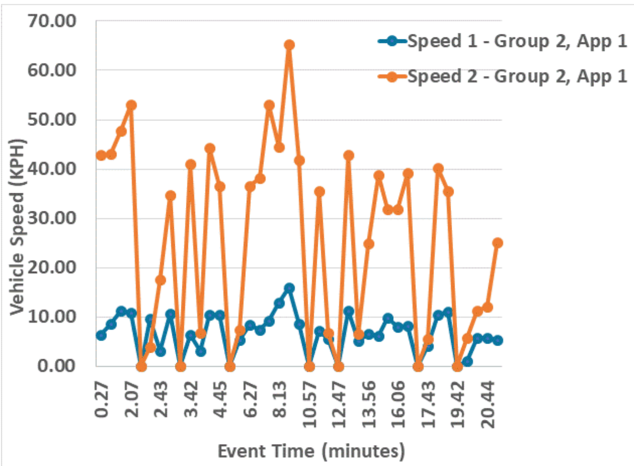


Figure 13. *Speed Plot for Sample data where volunteers participated on the first approach without strip treatment – Group 2 Approach 1.*

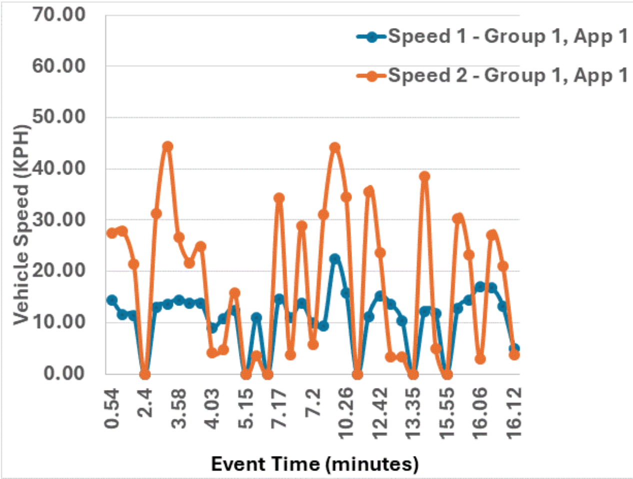


Figure 14. *Speed Plot for Sample data where volunteers participated on the first approach with strip treatment – Group 1 Approach 1.*

Before the installation of strips (Figure 15), the average Speed 1 was 10.47 KPH, while Speed 2 averaged 21.03 KPH, with a p-value of less than 0.001. After installation (Figure 16), Speed 1 averaged 20.77 KPH, and Speed 2 averaged 24.54 KPH, with a p-value of 0.084.

Notably, some vehicles exceeded the 40 KPH speed limit on this approach. This speed may be attributed to drivers' lack of understanding about expected driving behaviors or a design that enables acceleration as drivers approach the crosswalk, particularly when exiting the intersection at the fourth approach.

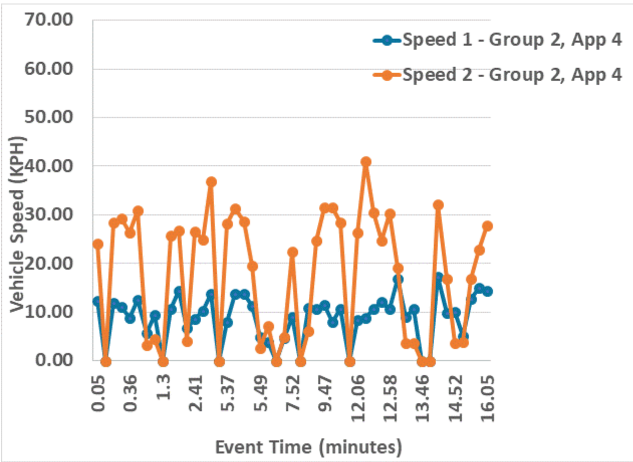


Figure 15. *Speed Plot for Sample data where volunteers participated on the fourth approach without strip treatment – Group 2 Approach 4.*

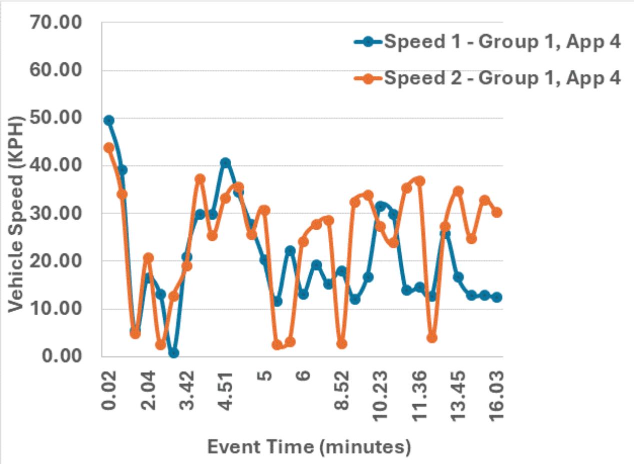


Figure 16. *Speed Plot for Sample data where volunteers participated on the fourth approach with strip treatment– Group 1 Approach 4.*

Approach 2 showed a significant change in vehicle speeds before treatment, with Speed 1 averaging 6.32 KPH and Speed 2 averaging 14.34 KPH ($p < 0.001$). After treatment, speeds increased, with Speed 1 averaging 16.82 KPH and Speed 2 averaging 20.20 KPH ($p = 0.072$).

On Approach 3, vehicle speeds before treatment averaged 6.74 KPH (Speed 1) and 14.82 KPH (Speed 2), with a significant change ($p < 0.006$). After treatment, speeds increased to 12.33 KPH (Speed 1) and 13.30 KPH (Speed 2), but the change was not significant ($p = 0.704$).

4.7.3. Total Time Delayed

The total time delayed was calculated by considering the time pedestrians spent activating the Accessible Pedestrian Signal (APS) and waiting for vehicles to yield.

As shown in Figures 17 and 18, total time delayed considering Approaches 1 to 4 combined was 28.28 minutes for 41 attempts before the sound strip treatment, and 24.92 minutes for 39 attempts after the treatment. The data is presented collectively for the four approaches, as the focus is on the overall impact of the sound strip treatment on pedestrian delay times, rather than approach-specific differences.

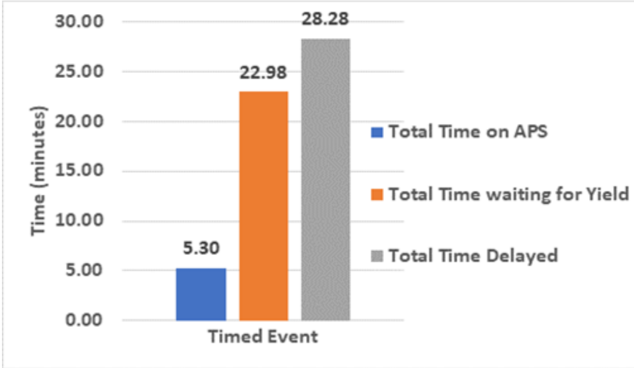


Figure 17. *Comparison of time spent by the pedestrian to activate the RRFB with APS, time spent waiting for vehicles to yield, and total delay time at the crosswalk before the strip treatment was applied.*

Figure 18. *Showing the time spent by the pedestrian to activate the RRFB with APS, the time spent waiting for vehicles to yield, and the total delay time at the crosswalk after the strip treatment was applied.*

The average delay per attempt by the pedestrian at the crossing, as shown in Tables 1 and 2, decreased from 0.69 minutes (41.39 seconds) before the sound strips were installed to 0.64 minutes (38.34 seconds) after installation.

This reduction in delays can be attributed, in part, to the sound strips enabling PWVL to detect gaps in traffic faster, facilitating safer and more efficient crossings.

Table 1. *The average Total Time Delayed felt by pedestrians before Treatment was applied.*

	Time spent on APS	Time spent waiting for vehicles yield	Total Time delayed	
Average =	7.77	33.62	41.39	seconds/pedestrian-attempt
	0.13	0.56	0.69	minutes/pedestrian-attempt

Table 2. The average Total Time Delayed felt by pedestrians after Treatment was applied.

	Time spent on APS	Time spent waiting for vehicles yield	Total Time delayed	
Average =	6.34	32.00	38.34	seconds/pedestrian-attempt
	0.11	0.53	0.64	minutes/pedestrian-attempt

4.7.4. Vehicles Yielding

To assess driver behavior, the total number of vehicles encountered by PWVL at all four approaches together was considered to calculate the percentage of vehicles that yielded to pedestrians.

The results, shown in Tables 3 and 4, indicate that the percentage of vehicles yielding to pedestrians decreased from 57.33% before the sound strips were installed to 40.60% after installation. The low percentage of vehicles yielding to pedestrians may be due to drivers' failure to acknowledge and respond to pedestrians waiting to cross the street. This is particularly concerning, as one volunteer was accompanied by a guide dog and three others used white canes, visible indicators of their need for extra caution. Furthermore, the decline in vehicle yielding after the installation of the strips is likely unrelated to the strips themselves, suggesting that driver behavior remains the primary factor.

Table 3. Percentage of vehicles that yielded as pedestrians attempted to cross the street before the strip was installed on the crosswalk.

Yield	No Yield	Percent Yield (%)
43	32	57.33

Table 4. Percentage of vehicles that yielded as pedestrians attempted to cross the street after the strip was installed on the crosswalk.

Yield	No Yield	Percent Yield (%)
54	79	40.60

4.7.5. Vehicles Stopping Short of the Strip

Data collection revealed a notable scenario where vehicles stopped short of the sound strips furthest from the crosswalk. Figure 19 shows that 2 out of 54 vehicles that yielded to pedestrians after installation stopped before the first row of strips, failing to trigger the sound effect and leaving pedestrians unaware of their approach. This occurred on Approach 2, the Redwood Avenue exit, where limited space between the exit point and crosswalk forced vehicles to yield without passing the first row of strips.

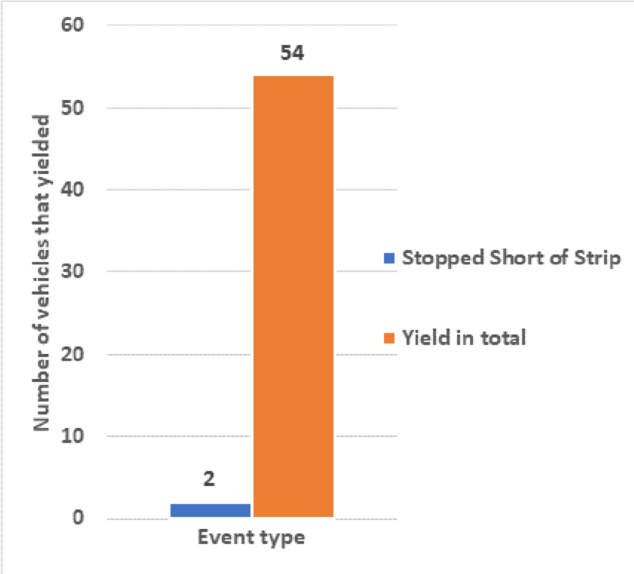


Figure 19. Number of vehicles that stopped short of reaching the first row of strips compared to the total number of vehicles that yielded for pedestrians to cross the street on the crosswalk.

4.7.6. Comparisons of Results to Other Studies

Consistent with a previous US study, the 3D printed material proved beneficial. A comparison with the NCHRP Report 674 reveals that, while both studies showed a reduction in pedestrian delay times after treatment, the magnitude of reduction differed. Specifically, the NCHRP reported a decrease from 23.4 seconds to 12.2 seconds, whereas this research observed a decrease from 41.39 seconds to 38.34 seconds. In contrast, the FHWA 2006 Report found that many vehicles yielded before reaching the row of strips, leading the researchers to conclude that their treatment had limited effectiveness.

4.8. Post-Field Data Collection Survey

Following data collection, the volunteers were optimistic about the pilot project, believing it was a step in the right direction. They recognized that this initiative was a precursor to further research, and hoped that policymakers would take their concerns seriously, ultimately leading to improved accessibility at roundabouts for PWVL.

5. Conclusions

In conclusion, this pilot study identified concerns of PWVL regarding roundabouts and investigated the effectiveness of sound strips improving their accessibility at these locations. Final comments from volunteers suggest that the sound strips provided PWVL with greater confidence in detecting approaching vehicles. Further, results show a reduction in average total time delayed per attempt to cross the street for PWVL from 0.69 minutes (41.39 seconds) to 0.64 minutes (38.34 seconds) which seems to reflect the effect of the warning of upcoming vehicles to PWVL. Additionally, data showed that vehicles tended to accelerate as they approached the crosswalk, with final Speed 2 exceeding initial Speed 1 in most cases. More concerning was that some vehicles exceeded the 40 KPH speed limit of the roundabout which endanger pedestrians, especially PWVL. Moreover, the study also revealed concerning driver behavior and compliance with yield regulations, with low percentage of vehicles yielding to pedestrians with 57.33% before the sound strips were installed and 40.60% after installation. Furthermore, the fact that 2 out of 54 vehicles yielded short of the sound strips highlights the need for further research on the concept of warning PWVL with other possible measures. Overall, this study shows the possibility of enhancing roundabout accessibility for PWVL and emphasizes the importance of continued research and collaboration with stakeholders to address the needs of this special population group.

A statistical analysis revealed changes in vehicle speeds across four approaches. Approach 1 showed highly significant changes before ($p < 0.001$) and after treatment ($p = 0.001$). Approaches 2 and 4 had highly significant changes before treatment ($p < 0.001$), but only marginal significance after treatment ($p = 0.072$ and $p = 0.084$, respectively). Approach 3 showed significant changes before treatment ($p < 0.006$), but no significant change after treatment ($p = 0.704$). However, it is essential to note that these findings are based on a small sample size, which limits the reliability and generalizability of the results. Therefore, caution should be exercised when interpreting these findings, and no definitive conclusions should be drawn until further research with larger sample sizes is conducted.

6. Limitation of the Study

This pilot study had several limitations that affected the scope and depth of its findings. Primarily, funding constraints hindered the project's progress, restricting the extent and breadth of its various phases.

One significant constraint was the limited data collection period, as the sound strips were only allowed on the roundabout for the day of installation. This restricted the amount of data that could be gathered, potentially affecting the reliability of the results.

Additional limitations included a low response rate to the survey, which may have resulted in a biased representation of participants' experiences and opinions. Furthermore, the project's limited budget hindered the use of advanced, sophisticated equipment for data collection and processing, potentially eroding the accuracy and precision of the findings.

The study's reliance on mechanical solution and the evaluation of only one site for treatment also limited the scope of the research. These constraints underscore the need for further investigation, preferably with a larger sample size, more advanced equipment, and multiple evaluation sites to validate and build upon the findings of this pilot study.

Abbreviations

3D	3-Dimension
ABS	Acrylonitrile Butadiene Styrene
APS	Accessible Pedestrian Signal
CNIB	Canadian National Institute for the Blind
CTL	Channelized Turn Lane
FHWA	Federal Highway Authority
KPH	Kilometer Per Hour (km/h)
LHS	Left Hand Side
LU	Lakehead University
MUTCD	Manual of Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
PVC	Poly Vinyl Chloride
PWVL	Persons with vision Loss
RHS	Right Hand Side
RRFB	Rectangular Rapid Flashing Beacon
TAC	Transportation Association of Canada
TWSI	Tactile Walking Surface Indicator
WHO	World Health Organization

Acknowledgments

Sincere gratitude goes to the Canadian National Institute for the Blind (CNIB) staff and clients who volunteered their time and expertise, as well as the City of Thunder Bay, Pioneer Construction Company, Lakehead University, and the Lakehead University Library Makerspace for their support and resources. Special thanks are also due to the individuals who assisted with this project. Their contributions were invaluable in investigating roundabout accessibility issues and evaluating a safe crossing solution for Persons with Vision Loss (PWVL).

Author Contributions

Omotunde Adeniran: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – editing

Juan Pernia: Project administration, Resources, Supervision, Validation, Writing – review

Funding

This work is not supported by any external funding.

Data Availability Statement

Not applicable.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] World Health Organization (WHO). (2019, October 8). Blindness and vision impairment. Retrieved from https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment#:~:text=eye%20care%20services.-,Causes,age%2Drelated%20macular%20degeneration

[2] CNIB Foundation. (2025, February 23). Blindness in Canada. Available at: https://www.cnib.ca/en/sight-loss-info/blindness/blindness-canada?region=on

[3] USDOT, FHWA (June 2000). Roundabouts: An Information Guide, Pub. No: FHWA-RD-00-067.

[4] Grana, A., (2011). An overview of safety effects on pedestrians at modern roundabouts. WIT Transactions on Ecology and the Environment. 150. 261-272. https://doi.org/10.2495/sdp110231

[5] Nie J., Li G., Yang J. (2014). A Study of Fatality Risk and Head Dynamic Response of Cyclist and Pedestrian Based on Passenger Car Accident Data Analysis and Simulations. Traffic injury prevention. 16:1, 76-83, https://doi.org/10.1080/15389588.2014.881477

[6] Perry, J., Gait Analysis, McGraw – Hill, New York NY, 1992.

[7] Sakshaug, L. (2009). Improving roundabouts for cyclists and visually impaired. Available at: https://lucris.lub.lu.se/ws/portalfiles/portal/3554814/1658147.pdf

[8] Schroeder, B., Salamati, K., Barlow, J. M., Shaw, J., Windle, S. J., May 2014. Roundabout Accessibility - What Designers Should Know About National Research and Policy. Institute for Transportation Research and Education – North Carolina State University.

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

[10] Federal Highway Administration (FHWA). 2006. Pedestrian Access to Roundabouts: Assessment of Motorists' Yielding to Visually Impaired Pedestrians and Potential Treatments to Improve Access. McLean, VA: Turner-Fairbank Highway Research Center. http://www.fhwa.dot.gov/publications/research/safety/pedbike/05080/05080.pdf

[11] Holloway, L., Butler, M., Marriott, K. 2022. 3D Printed Street Crossings: Supporting Orientation and Mobility Training with People who are Blind or have Low Vision. In CHI Conference on Human Factors in Computing Systems (CHI '22), April 29-May 5, 2022, New Orleans, LA, USA. ACM, New York, NY, USA 16 Pages. https://doi.org/10.1145/3491102.3502072

Biography

Omotunde Adeniran holds a BScE in Civil Engineering from the University of New Brunswick and an MSc Eng from Lakehead University. He is currently a PhD student at Lakehead University, pursuing research in Roundabout Accessibility for Persons with Vision Loss (PWVL).

Juan Pernia holds a BS in Civil Engineering from La Universidad de Los Andes, Venezuela, and a MSc and PhD of Civil Engineering from the University of South Florida, USA. Dr. Pernia is currently an Associate Professor at the Department of Civil Engineering at Lakehead University in Thunder Bay, ON, Canada. His areas of research include Accessibility in Transportation, Highway Safety, Traffic Operations and Pavement Performance. Dr. Pernia is currently working on projects related to the accessibility of people with vision loss at roundabouts and floating bus stops.

Research Field

Omotunde Adeniran: Roundabout Accessibility, Intelligent Transportation Systems, Virtual Reality application in Transportation Accessibility, Road Safety, Energy and Infrastructure Asset Management.

Juan Pernia: Roundabout Accessibility, Intelligent Transportation Systems, Highway Safety, Traffic Operations and Pavement Performance.