Inter-University Workshop 2025

October 4, 2025

Round-a-doubt: At the intersection of safety and mobility

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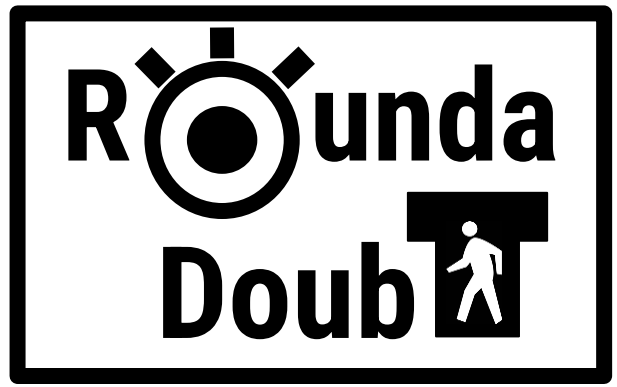


Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

HFES
Systems That Work for Humans
University of Toronto Student Chapter

HFIG
Human Factors Interest Group

Outline

1. Introduction, Scope and Objectives
2. Engineering Design Process
3. Driving Simulator
4. Engineering Solutions
5. Conclusions and Recomendations

1. Introduction, Scope and Objectives

Background & Literature Review Summary

Roundabouts* **reduce vehicle speed** and **reduce conflict points with pedestrians**.
This makes them **safer for all road users****, **including pedestrians*****

** single lane ** in the UK (North American drivers behave differently) *** not including blind / mobility impaired pedestrian*

2 Key areas for innovation

(while reducing financial, safety & legal risk)

1. Roundabout Signalling

*"Care must be taken to **ensure that vehicles yield** to waiting or crossing pedestrians… designing **exit legs** to ensure **adequate sight lines** and keep exiting **vehicle speeds to a minimum**".*

- D. L. Harkey and D. L. Carter, "Observational analysis of pedestrian, bicyclist, and motorist behaviors at roundabouts in the United States," Transportation Research Record: Journal of the Transportation Research Board, vol. 1982, no. 1, pp. 155–165, Jan. 2006. doi:10.1177/0361198106198200120

2. Data Collection

*"A primary objective of future work should be to develop a broader and **better pedestrian accident database for roundabouts**".*

- "The effects of roundabouts on pedestrian safety - national ...," National Association of City Transportation Officials, https://nacto.org/wp-content/uploads/2015/04/effects_roundabouts_pedestrian_safety_stone.pdf (accessed Dec. 6, 2024)

Motivation

Tuesday, May. 21, 2024

Waterloo man charged with impaired driving after driving over roundabout

A driver from Waterloo has been charged after Waterloo regional police responded to reports of an impaired driver.

Thursday, May. 9, 2024

Car flips over during Kitchener crash

A dramatic crash shut down a busy Kitchener road on Wednesday.

Wednesday, Mar. 13, 2024

Hydro pole down, road closed at Kitchener roundabout

A crash next to a Kitchener roundabout has closed down part of the road and knocked down a hydro pole.

Saturday, Mar. 2, 2024

Kitchener roundabout re-opened following collision investigation

At around 10:55 a.m. Sunday, emergency services responded to the area of Block Line Road and Homer Watson Boulevard in Kitchener for reports of a two-vehicle collision.

Sunday, Feb. 11, 2024

Pedestrian hit at Waterloo roundabout

One person was taken to hospital with non-life-threatening injuries after a crash Tuesday morning. CTV's Jeff Pickel explains.

Tuesday, Jul. 11, 2023

Another pedestrian hit at Erb and Ira Needles roundabout

A pedestrian has been taken to hospital with non-life-threatening injuries after being hit by a vehicle in Waterloo, Waterloo regional police say.

Tuesday, Jul. 11, 2023

CTV News Search Page for Roundabouts

Residents feel unsafe, but **concerns remain unaddressed** by region

CAA's 2024 survey ranked Ira Needles the 4th worst road in Southwest Ontario – **7 roundabouts in 3km**

Region of Waterloo report puts roundabout safety under the microscope

Roundabouts are under the microscope in Waterloo region as regional councillors are reviewing the safety of the road design following a pair of serious collisions involving pedestrians.

Tuesday, Feb. 7, 2023

Roundabouts under microscope in Waterloo Region

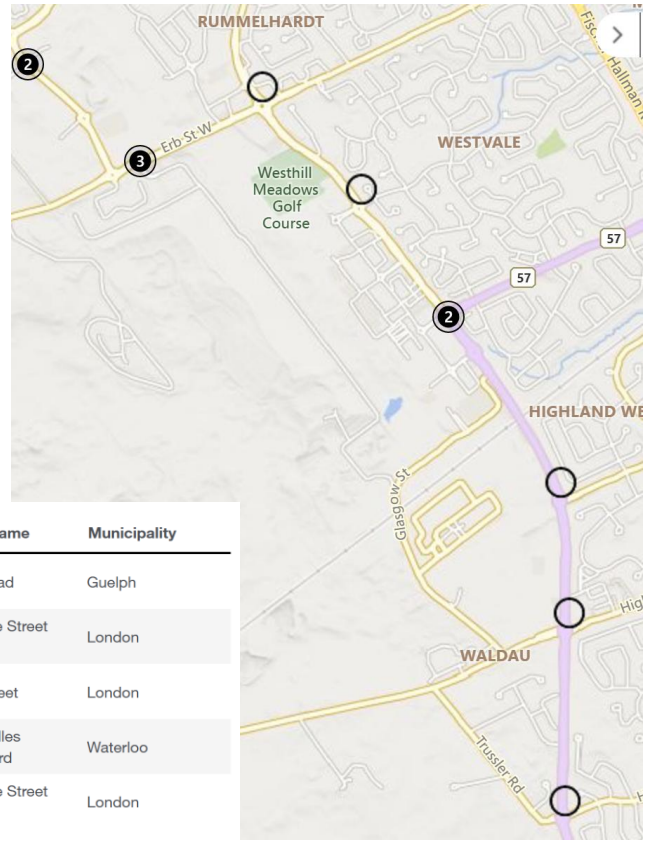
Regional councillors are reviewing roundabout safety after a pair of serious collisions. Ricardo Veneza reports.

Tuesday, Feb. 7, 2023

CTV News Search Page for Roundabouts

Rank	Road Name	Municipality
1	York Road	Guelph
2	Adelaide Street North	London
3	York Street	London
4	Ira Needles Boulevard	Waterloo
5	Adelaide Street South	London

Worst Roads in Western Ontario Data



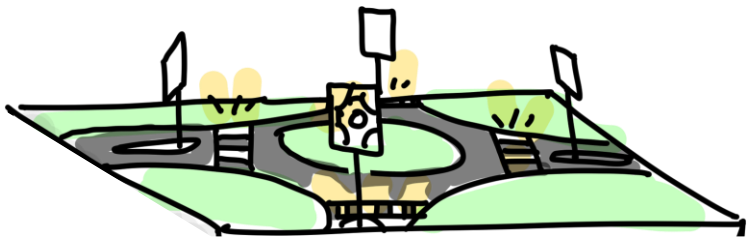
Map of Waterloo Roundabouts

"Roads in Guelph and Waterloo earn spots on CAA's worst roads list," Kitchener, https://kitchener.ctvnews.ca/roads-in-guelph-and-waterloo-earn-spots-on-caa-s-worst-roads-list-1.6903218#:~:text=Top%2010%20worst%20roads%20in%20Ontario&text=Waterloo%20also%20made%20an%20appearance,worst%20road%20in%20the%20province (accessed Dec. 3, 2024).
CTV Kitchener search results for 'Roundabout,'" Kitchener, https://kitchener.ctvnews.ca/2.744/ctv-kitchener-search-7.112?q=roundabout&ftype=&fpage=&sortOrder=date&fdate=&page=0 (accessed Dec. 3, 2024).

Objectives

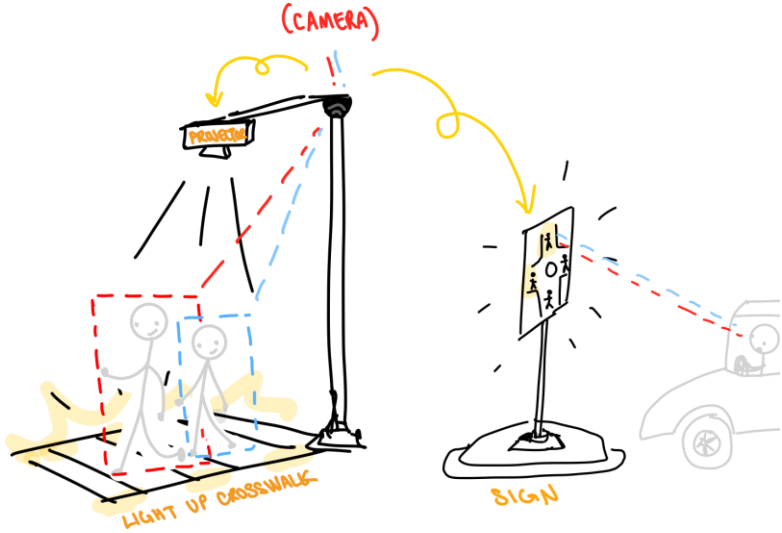
GOAL: Improve pedestrian safety at 2-lane roundabouts

1. Design a research-backed novel alerting system to increase driver awareness of pedestrians
(stakeholders, literature review, survey data, real-world observational data)



2. Create and evaluate multiple design variants of this system in a high-fidelity driving simulator
Use the AVRIL driving simulator to evaluate real-time behaviour of drivers

3. Develop a physical proof-of-concept prototype
Computer vision camera to control system, detecting pedestrian presence while prioritizing efficiency



2. Engineering Design Process

Stakeholder Interviews & QFD Analysis

Expert and Stakeholder Interviews

Name	Position	Meeting Notes
Lisa Aultman-Hall	Chair, Systems Design Engineering, UWaterloo	Many: 09-16 Meeti…
Siby Samuel	Professor, Systems Design Engineering, UWaterloo	10-10 Prof. …
Pete Wachirawit Umpaipant	Newly Graduated Grad Student, AVRIL - SYDE, UWaterloo	10-22 Pete …
Addie Denison	Engineer, Sr. PM Miovision	09-24 Miovi…
Sina Radmard	Software Development Manager, Miovision	10-01 Miovi…
Liping Fu	Professor, Department of Civil Engineering, UWaterloo	09-25 Prof. …
Bruce Hellinga	Professor, Department of Civil Engineering, UWaterloo	09-24 Prof. …
Tyson Moore	Project Manager, GO Transit Train Control System … Metrolinx	
Vicentzo Pacioaga	Sr. Manager, S&C, Level Crossings Engineering & Asset Management, Metrolinx	
Dragana Guida	Director - E&AM Signals & Communications- Projec…	
Dave Wilson	Dave Wilson, C.E.T. Analyst, Traffic Systems Mana… Regional Municipality of Waterloo	
Peter Burns	Chief, Human Factors and Crash Avoidance Resea… Safety and Vehicle Regulations Transport Canada / Government of Canada	
Sayan Sivapathasundaram	**P.Eng.** Transportation Engineer, Cycling and Pedestrian Pr… City of Toronto	
Kate Hagerman	Planning Specialist, Former Manger, Environmental… Sustainability, Region of Waterloo	
Andrew Farr	Commissioner of Public Works at Halton Region	10-22 Sust…

Call with stakeholder

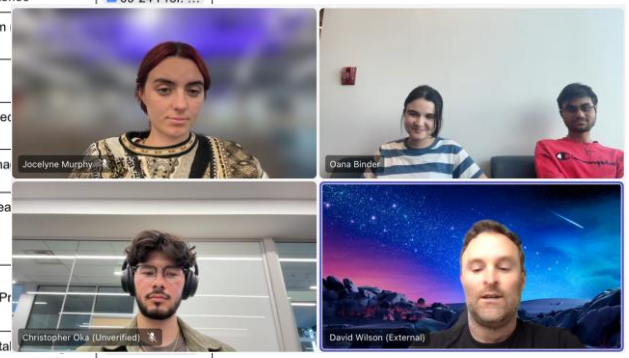


Table of contacts

QFD Analysis

What	Who																				
Design Requirements / Customer Requirements	Pedestrians / Bikers	Drivers	City Planners / Buyers	Successful pedestrian crossings	Driver ignoring pedestrian waiting to cross	Near collisions	Collisions	Time until looking at sign	Time until looking at pedestrian / crosswalk	Duration looking at sign	Duration looking at pedestrian / crosswalk	Time to brake	Duration of braking	Sign visibility	Pedestrian / light up crosswalk visibility	Community surveying / research costs	Materials and manufacturing costs	Installation and maintenance service costs	Electricity and operational costs	Healthcare / policing / legal cost burden	Ideal Value
				↑	↓	↓	↓	↓	↓	range	range	range	range	↑	↑	↓	↓	↓	↓	↓	
Real safety Minimizing collisions	4.875	5	4.875	9	9	9	9	3	9	3	9	9	9	3	9	0	0	0	0	1	
Minimizing near-collisions	4.375	4.5	3	9	9	9	9	3	9	3	9	9	9	3	9	0	0	0	0	1	
Percieved Minimizing pedestrian anxiety	3.375	2.5	3.5	9	9	9	9	3	9	3	9	9	9	3	3	0	0	0	0	9	
Minimizing driver anxiety	2.625	4.25	3.625	9	3	9	9	9	9	3	9	9	9	3	3	0	0	0	0	9	
Advance notice of pedestrian (design of signage) Large size	3.75	4.125	4.125	9	9	9	9	9	0	9	0	9	9	9	0	3	9	9	9	3	
Convenient location	4.375	4.75	4.5	9	9	9	9	9	0	9	0	9	3	9	0	0	0	3	1	0	
Notable colour	3.875	3.875	3.875	3	3	9	9	9	0	9	0	9	3	9	0	1	9	3	0	1	
Flashing	3.75	3.625	3.375	1	3	3	9	9	0	3	0	3	3	9	0	3	9	9	9	3	
Familiar icons	3.125	3.625	4.25	1	1	1	3	3	0	3	0	3	3	3	0	0	3	1	1	0	
Descriptive text	2.5	2.75	3.5	1	1	1	3	1	0	3	0	3	3	3	0	0	1	1	0	0	
Real time pedestrian visibility (at crosswalk) Crosswalk (ground) lighting	3.75	3.5	3.25	3	9	9	9	0	9	0	9	9	9	0	9	9	9	3	9	1	
Overhead lighting (visible from far	3.875	4.5	4.5	3	9	9	9	0	9	0	3	3	3	0	9	3	9	3	9	1	
Four-season visibility (e.g. snow)	4.25	4.125	4.625	1	3	3	3	0	9	0	9	9	3	0	9	3	3	9	9	0	
Night time visibility	4.375	4.75	4.625	3	9	3	3	0	9	0	9	9	3	0	9	1	3	3	9	0	
Technical Importance: Absolute	**Pedestrians / Bikers**			267.38	331.13	343.88	377.63	215.13	245.25	181.88	222.00	358.13	282.38	204.38	209.25	76.13	196.00	133.88	183.00	97.25	
	Drivers			286.00	344.25	364.50	399.00	235.25	261.00	193.50	234.00	378.75	298.50	215.25	220.50	76.88	204.50	140.25	192.88	105.38	
	City Planners / Buyers			272.50	331.75	349.00	384.75	225.88	246.38	190.88	219.38	365.25	287.25	211.13	203.63	73.75	202.25	137.50	187.63	106.13	
Technical Importance: Relative	**Pedestrians / Bikers**			0.07	0.08	0.09	0.10	0.05	0.06	0.05	0.06	0.09	0.07	0.05	0.05	0.02	0.05	0.03	0.05	0.02	
	Drivers			0.07	0.08	0.09	0.10	0.06	0.06	0.05	0.06	0.09	0.07	0.05	0.05	0.02	0.05	0.03	0.05	0.03	
	City Planners / Buyers			0.07	0.08	0.09	0.10	0.06	0.06	0.05	0.05	0.09	0.07	0.05	0.05	0.02	0.05	0.03	0.05	0.03	
Importance Rank	**Pedestrians / Bikers**			3	2	2	1	4	4	5	4	2	3	5	5	7	5	6	5	6	
	Drivers			4	3	2	1	5	5	6	5	2	4	6	6	8	6	7	6	7	
	City Planners / Buyers			4	3	2	1	5	5	6	5	2	4	6	6	9	6	7	6	8	
Average Level of Importance				4	3	2	1	5	5	6	5	2	4	6	6	8	6	7	6	7	

Importance Level Scale

Not Important — Important

Engineering Specifications

Specifications

1) Minimize collisions

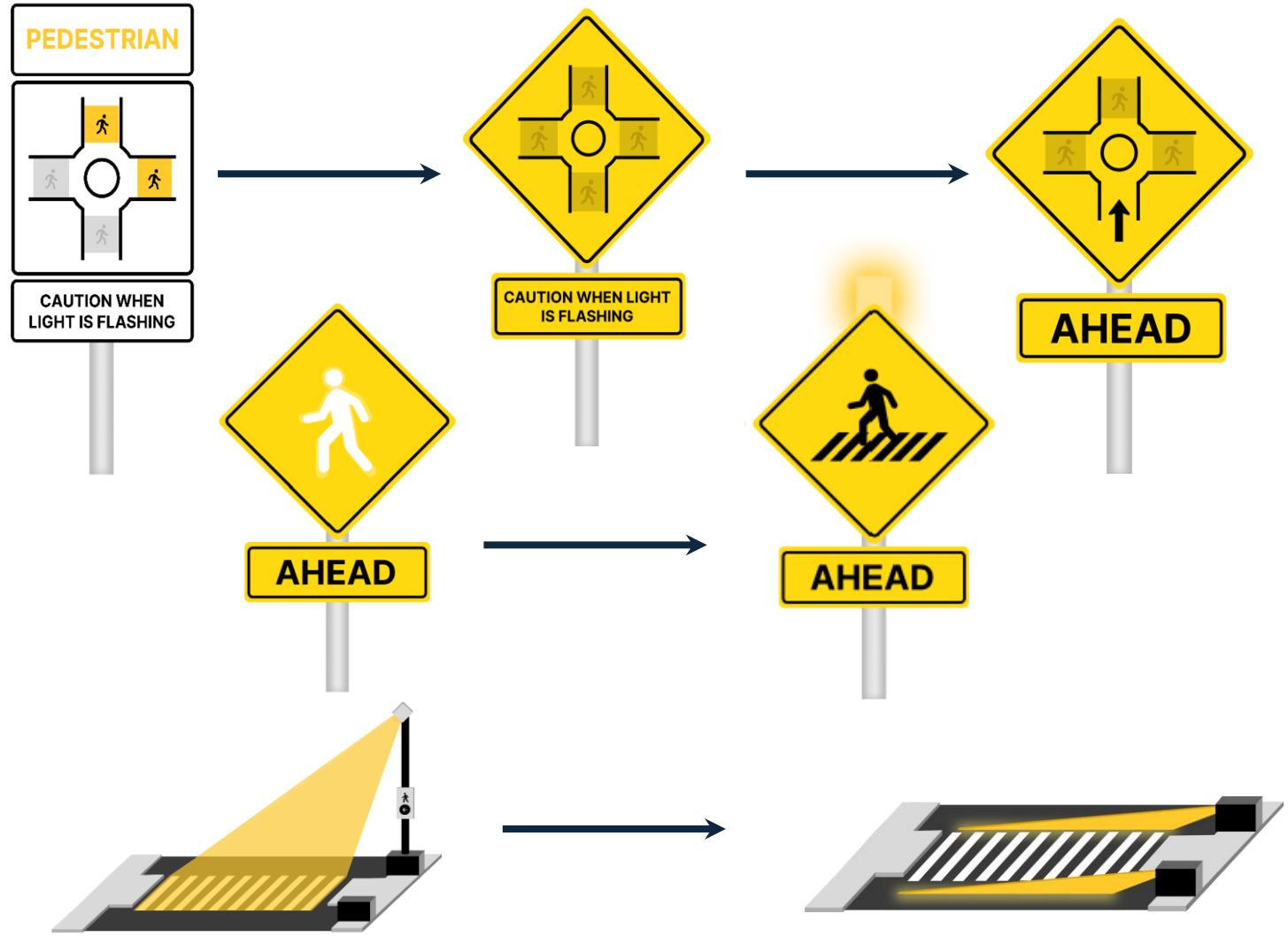
2) Maximize driver yielding rates

3) Minimize driver distraction

Metrics (to measure specifications)

Braking Deceleration	**"Hard braking events"** show significant correlation with crash locations [13]
Speed through Roundabout	From stakeholder interviews, municipalities identified **high-speed roundabouts** **as the most problematic**.
Gaze & Fixation Data	Alerts should be noticeable but **not overly demanding**. Long fixation durations may indicate confusion [12, 14].
Participant Comments	Subjective feedback provides insight into how **understandable and feasible** each alert it.

Prototype Iteration



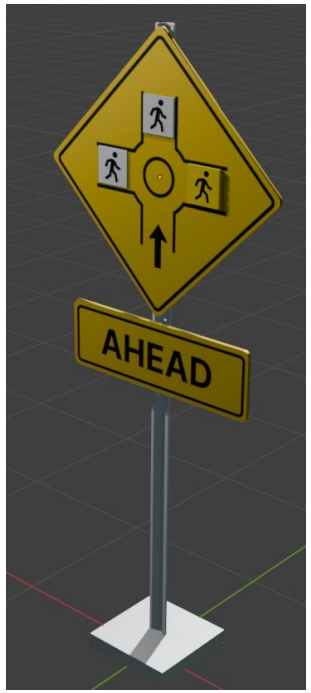
Driving Simulator 3D Asset Creation

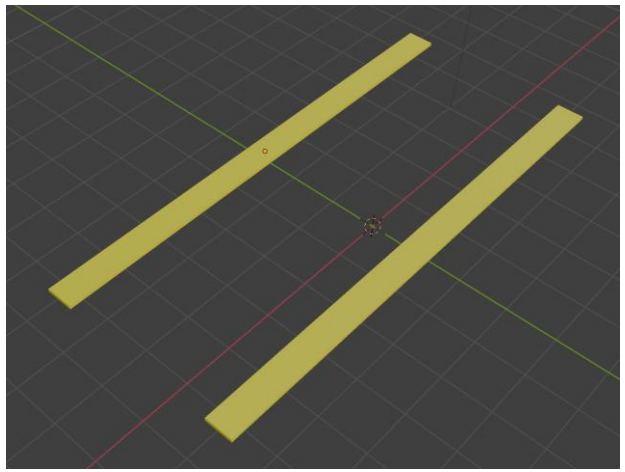
Real

Simulated

Matlab Roadrunner

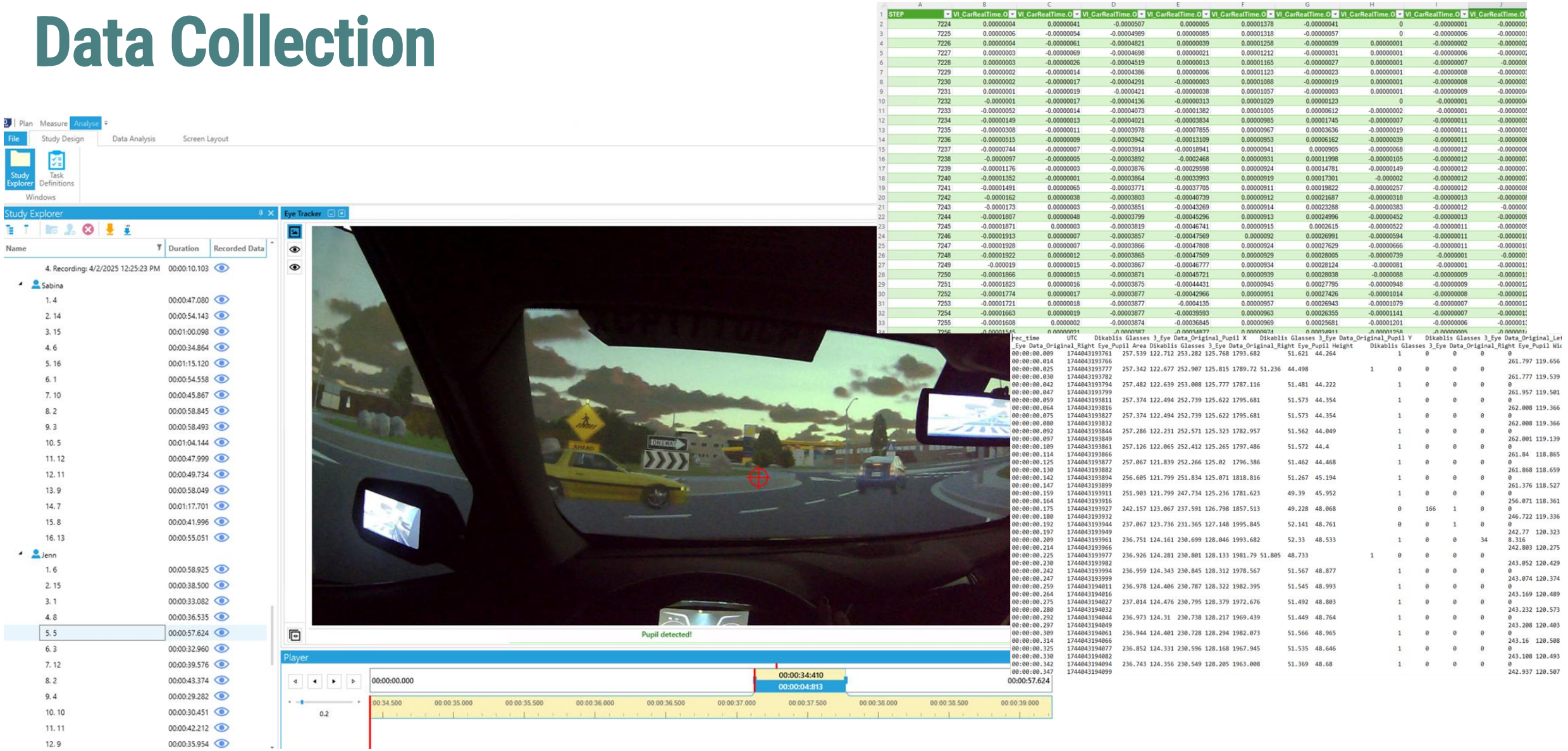
Blender





3. Driving Simulator (Results and Discussion)

Data Collection



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7245	-0.00001871	0.0000003	-0.00003819	-0.00046741	0.00000915	0.0002615	-0.00000522	-0.00000011	-0.00000009
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7251	-0.00001823	0.00000016	-0.00003875	-0.00044431	0.00000945	0.00027795	-0.00000948	-0.00000009	-0.00000012
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7253	-0.00001721	0.00000018	-0.00003877	-0.0004135	0.00000957	0.00026943	-0.00001079	-0.00000007	-0.00000012
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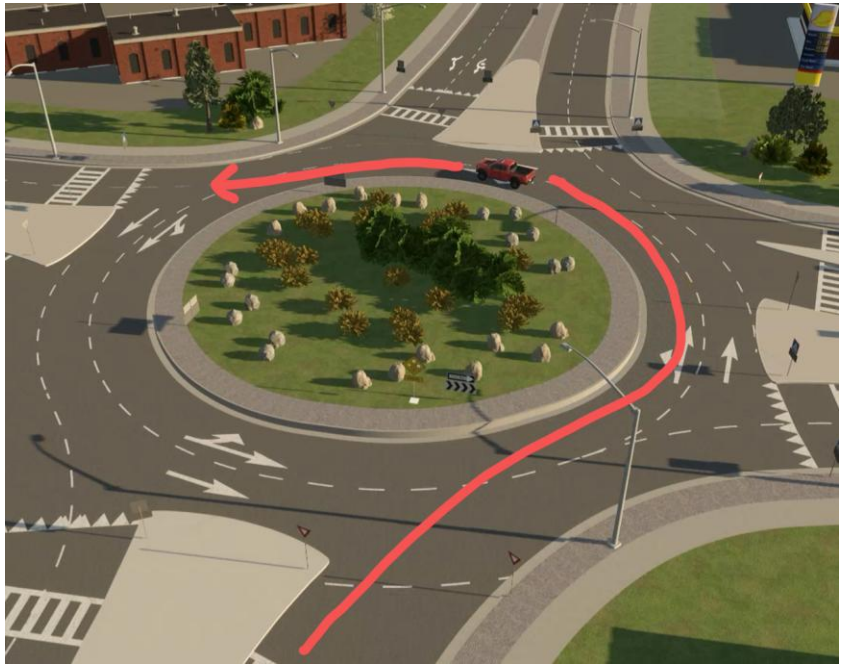
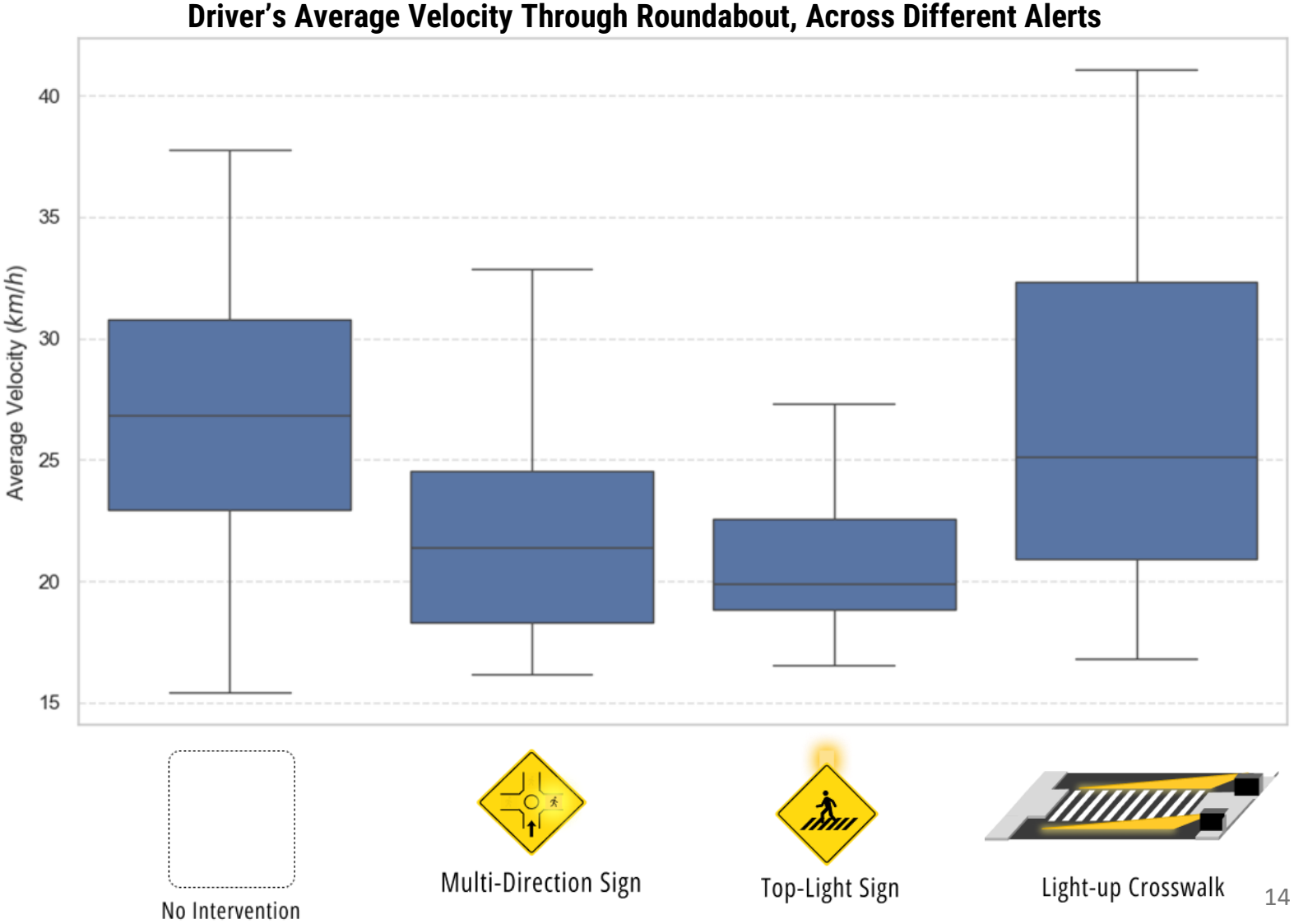
00:00:00.275	1744043194027	237.014 124.476 230.795 128.379 1972.676	51.492 48.803	1 0 0 0 0	0	243.169 120.489
00:00:00.280	1744043194032					
00:00:00.292	1744043194044	236.973 124.31 230.738 128.217 1969.439	51.449 48.764	1 0 0 0 0	0	243.208 120.403
00:00:00.297	1744043194049					
00:00:00.309	1744043194061	236.944 124.401 230.728 128.294 1982.073	51.566 48.965	1 0 0 0 0	0	243.16 120.508
00:00:00.314	1744043194066					
00:00:00.325	1744043194077	236.852 124.331 230.596 128.168 1967.945	51.535 48.646	1 0 0 0 0	0	243.108 120.493
00:00:00.330	1744043194082					
00:00:00.342	1744043194094	236.743 124.356 230.549 128.205 1963.008	51.369 48.68	1 0 0 0 0	0	242.937 120.507
00:00:00.347	1744043194099					

Driver's Average Velocity

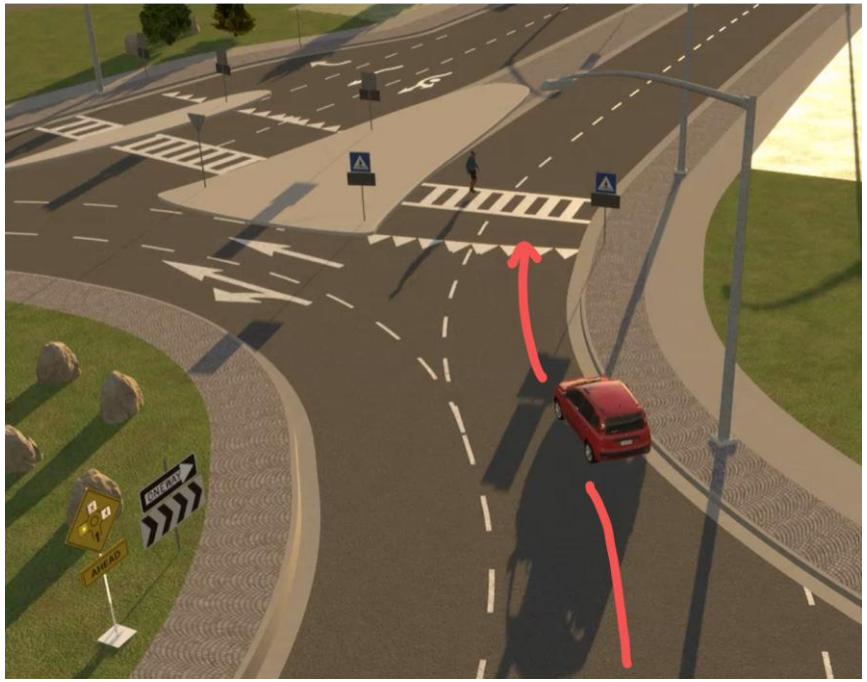


Repeated-Measures ANOVA:

$p = 0.002$

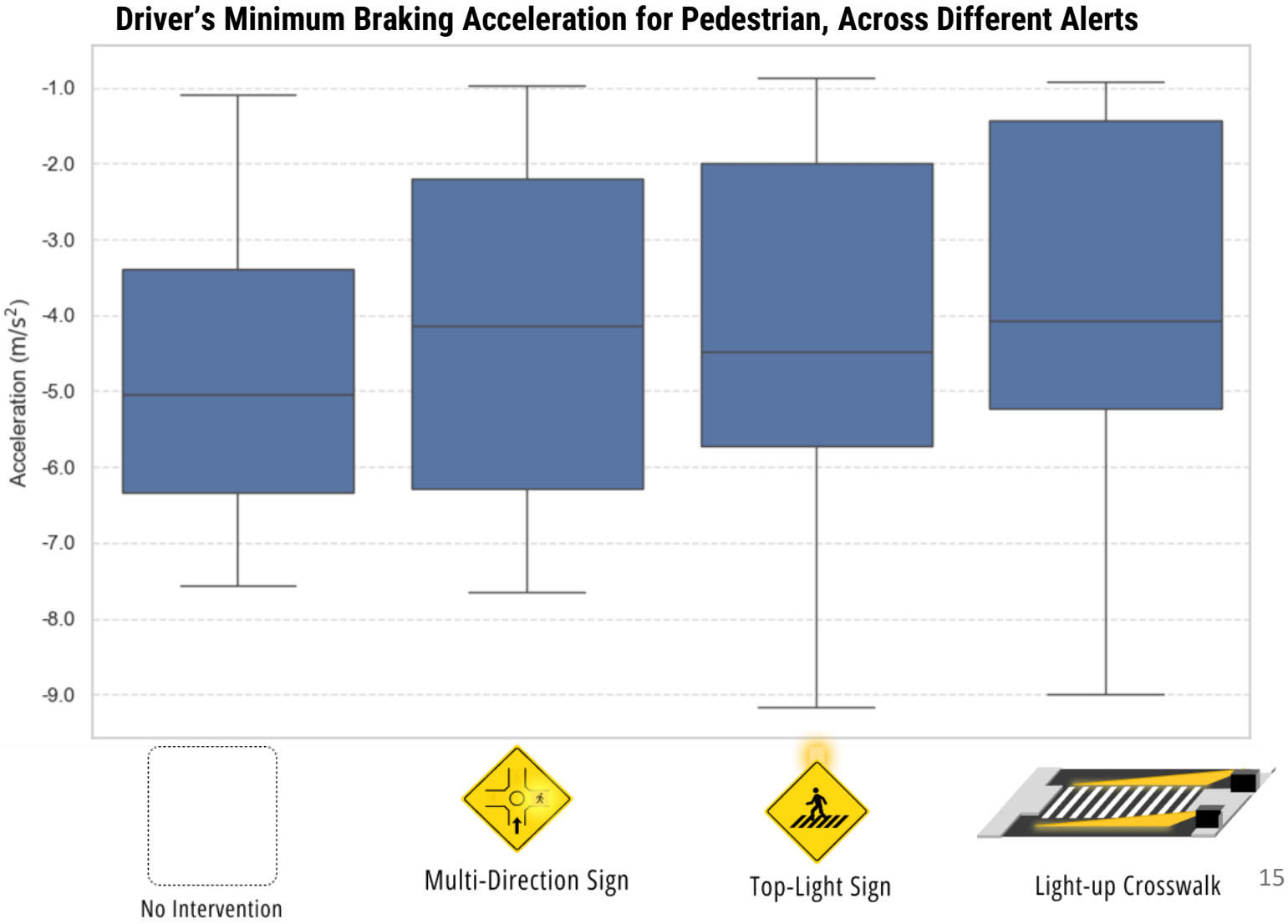


Driver's Minimum Acceleration ("Hardest Braking")



Repeated-Measures ANOVA:

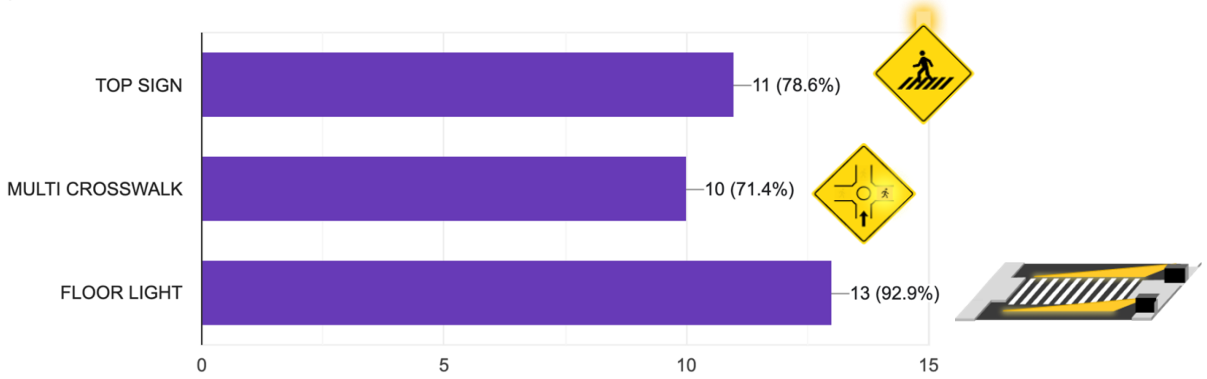
$p = 0.384$



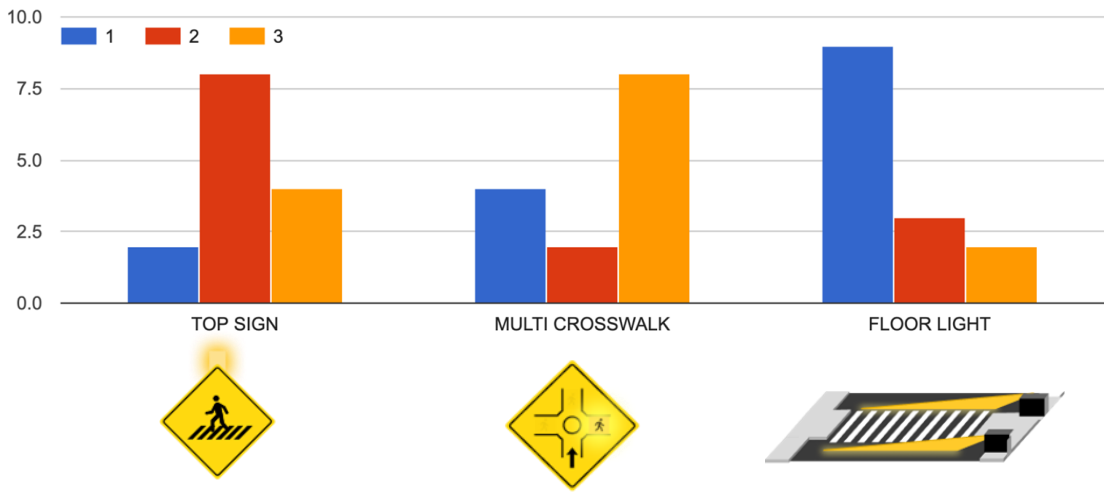
Exit Survey Results

Which signs did you see in the simulator?

14 responses



Please rank each sign/light by how fast you were able to understand the sign's meaning. 1 is understanding the sign/light the quickest, 3 is und...ng it slowest. Please only select each number once.

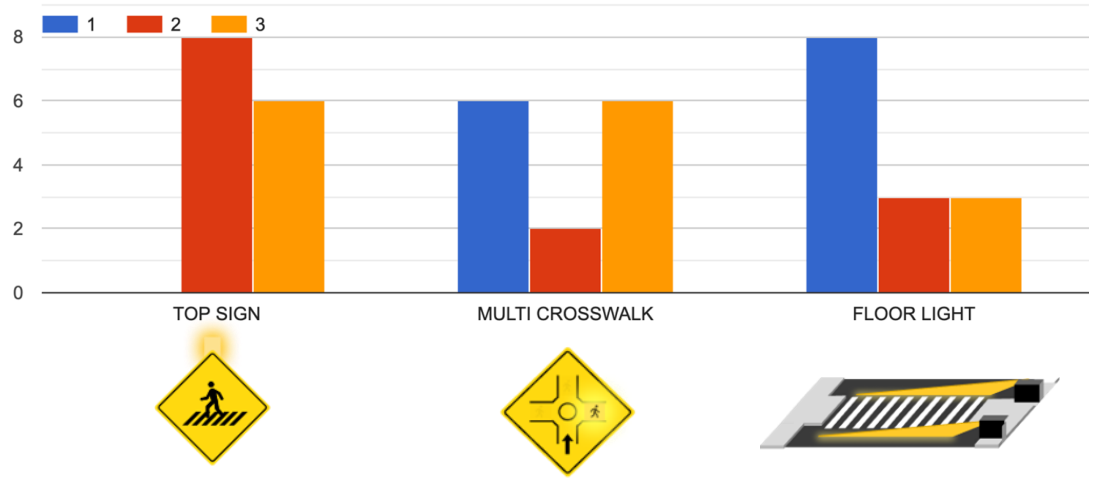


➔ People tend to ***confuse*** or ***forget details*** about the signs

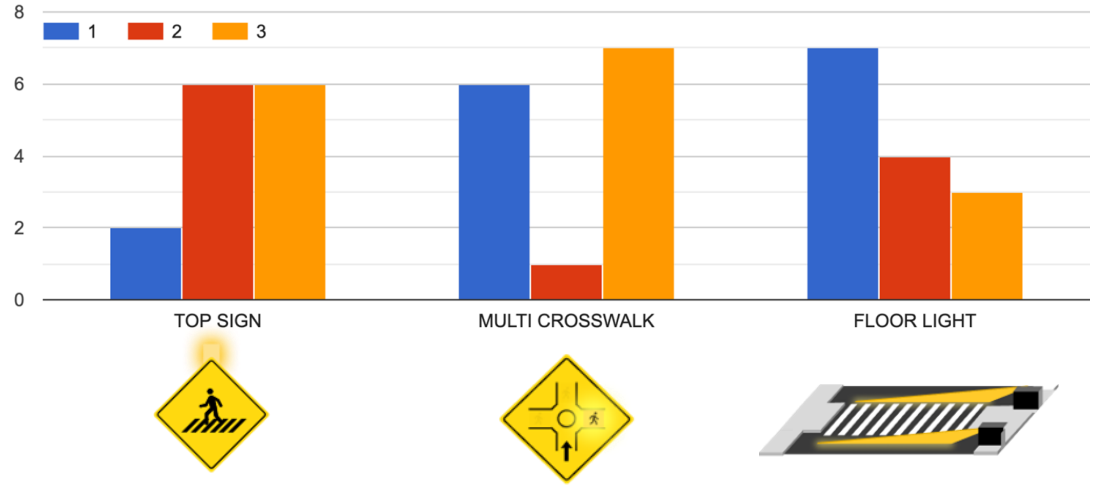
➔ ***Floor light*** was far more quickly understood

Exit Survey Results

Please rank each sign/light by how helpful you think it is. 1 is the most helpful, 3 is the least helpful. Please only select each number once.



Please rank each sign/light based on how much you would like to see it implemented in real life. 1 is the one you'd want the most, 3 is the one you'd want the least. Please only select each number once.



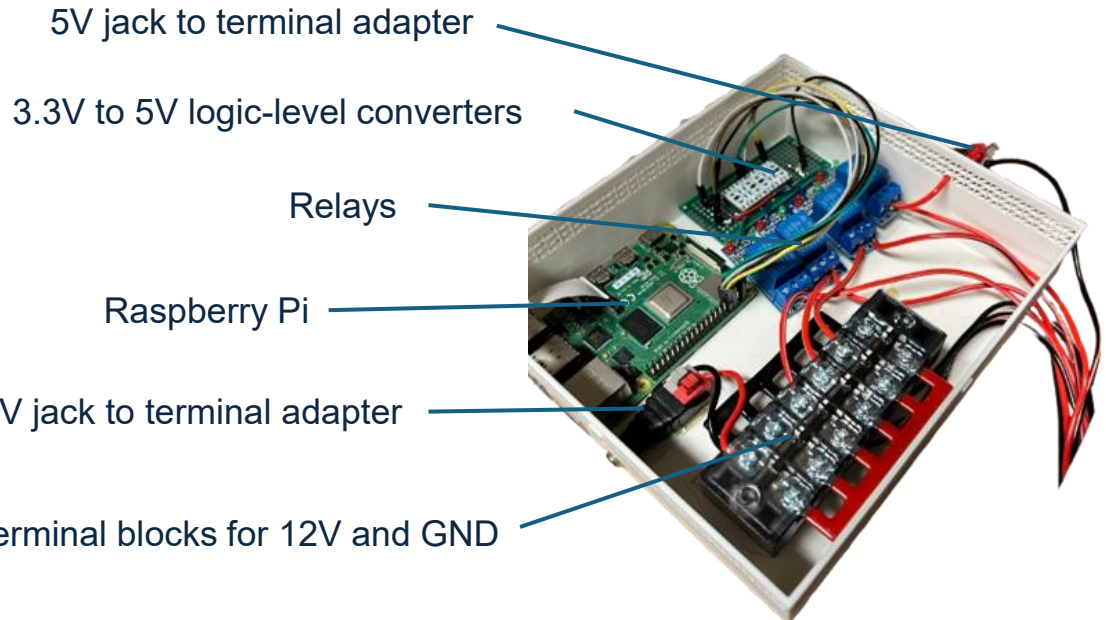
➔ ***Top sign*** was <u>not helpful</u>

➔ Participants wanted ***floor light*** implemented, divided on ***multi-crosswalk***

4. Engineering Solutions

Designed Solution - Multi-crosswalk Sign

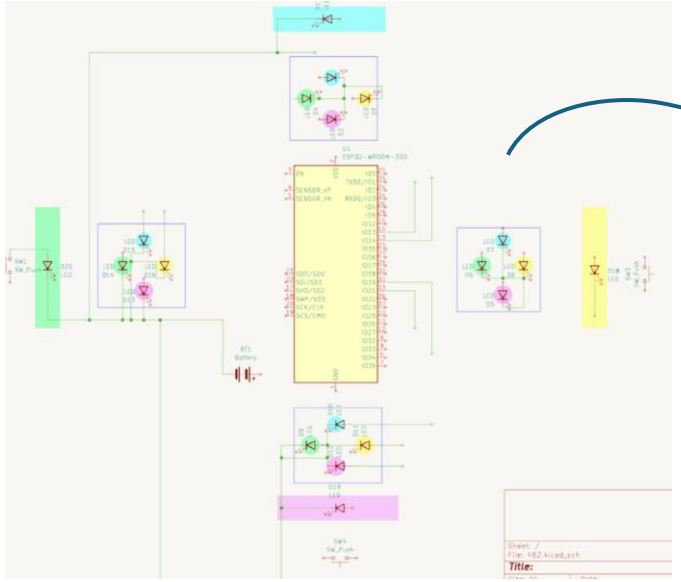
Electrical Housing



Sign

Designed Solution - Roundabout Diorama

Planned in KiCad

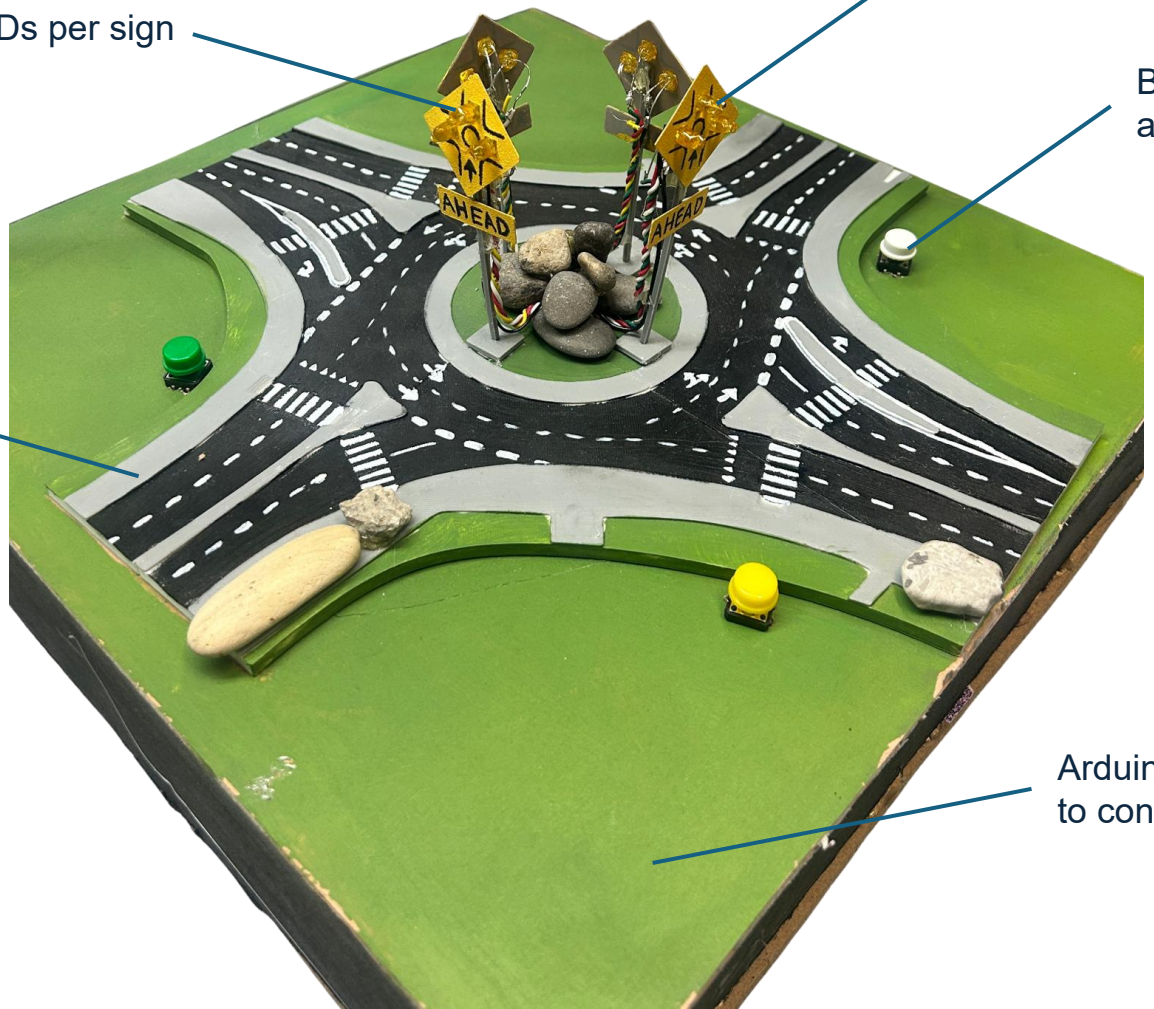


3D printed roundabout

3x LEDs per sign

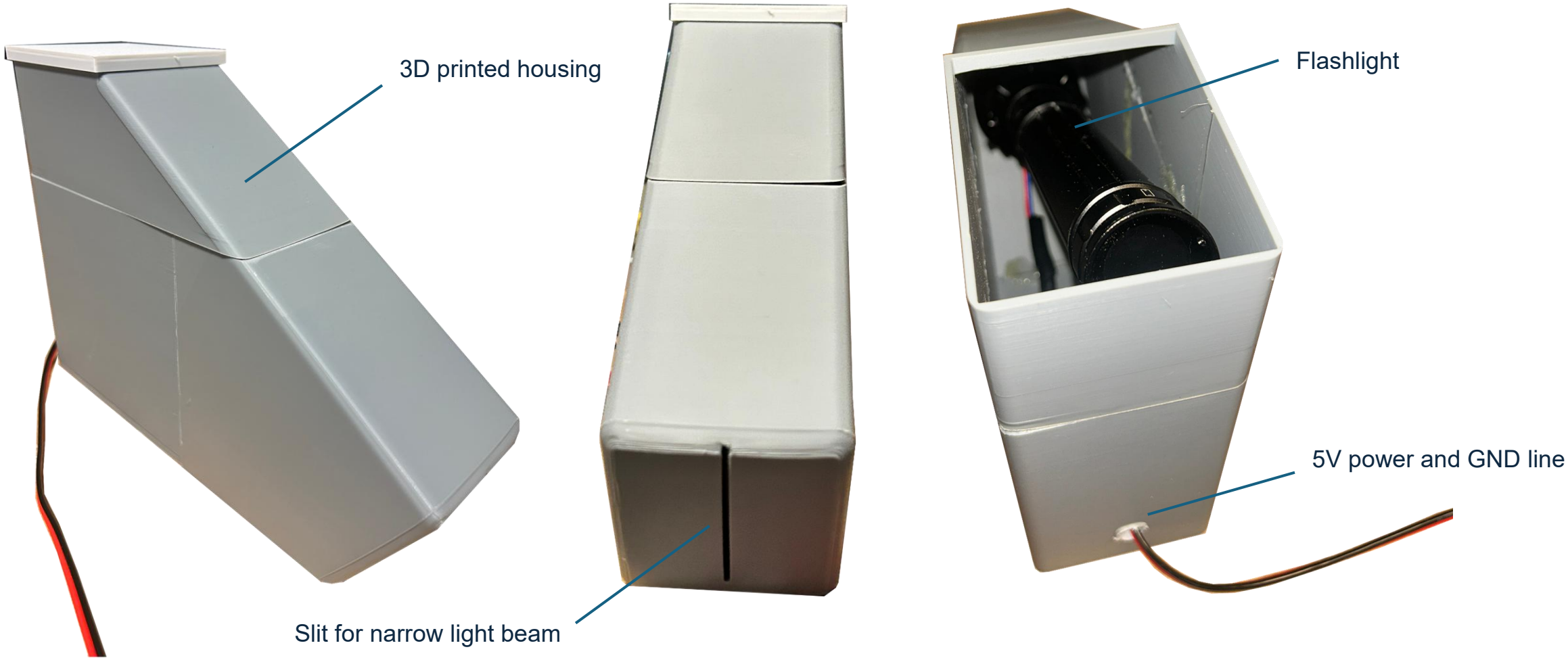
3D printed signs

Button to activate signs



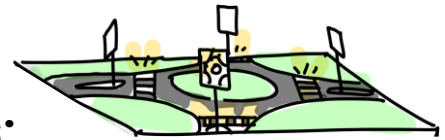
Arduino inside box to control signs

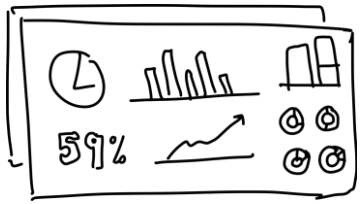
Designed Solution - Light-up Crosswalk

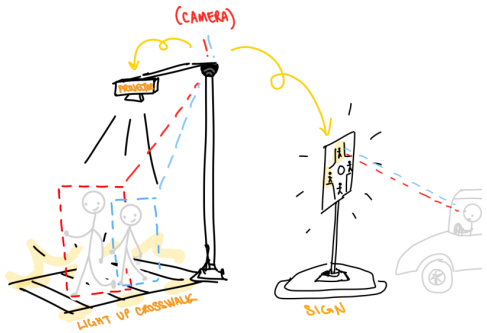


6. Conclusions and Recomendations

Conclusions







Original Objectives:

1. Design a research-backed novel pedestrian alerting system
2. Evaluate multiple design variants of this system in a high-fidelity driving simulator
3. Develop a physical proof-of-concept prototype

Learnings

- **Advance warning sign** at the roundabout entry effectively *reduced driver speeds*, aligning with the goal of minimizing collision risk.
- **Light-up sidewalk**, helped drivers notice pedestrians more easily.
- **Novel multi-crosswalk sign** held strong potential after users understood
- **A low-risk simulator environment** can be used as a method to overcome hesitancy and make progress in learning about roundabout safety for road users, at minimal cost and safety risk.
- **Communication** with the public is a key part of road infrastructure design (stakeholders, diorama etc).

Recommendations & Next Steps

- Promising results lead us to recommend the further exploration of dynamic signage in **high-traffic** two lane roundabouts as a solution that can increase pedestrian safety, *especially in regions with* ***vulnerable populations*** *(e.g. near senior homes)*
- **Use the AVRIL Simulator** to conduct more trials (95% confidence interval)
- **Improve computer vision detection system**, train in real world scenarios
- **Conduct field testing** at roundabouts, use the CV system to measure effectiveness

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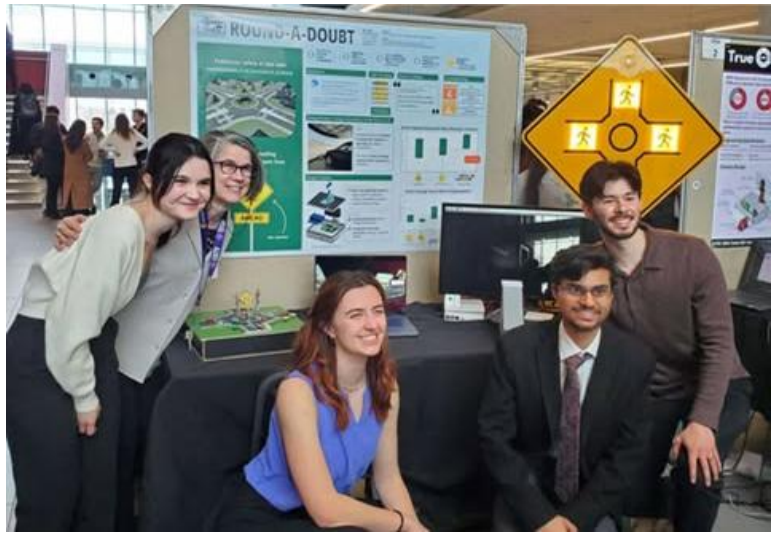
Acknowledgments



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Pedestrian Algorithm Validation

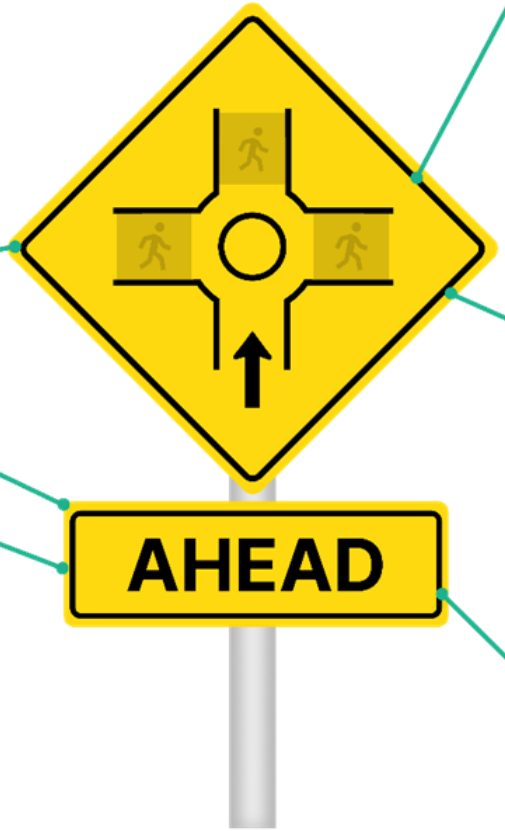
Metric	Value (%)
Precision	86.4
Recall	77.9
F1 Score	81.9
Pre-Tuning Avg. Precision	86.0

$$\text{Precision} = \frac{\text{True Positives}}{\text{True Positives + False Positives}}$$

$$\text{Recall} = \frac{\text{True Positives}}{\text{True Positives + False Negatives}}$$

Design Safety and Regulations - Physical

MTO standard for Sign Size:
- 60×60cm for diamond shape,
- 60×30cm for rectangular shape



(1) **Inner Border:** a continuous narrow strip the same colour as the legend, just inside the edge of the sign. This type of border improves the appearance of the sign. The width of the inner border should be approximately 1.5% to 3% of the smallest outer dimension of the sign. For a 60 cm x 60 cm sign, this translates to about 1 cm to 1.5 cm.

Warning for users in advance
MTO: "Signs are usually diamond-shaped and have a yellow background with black letters or symbols."

Highway Gothic Font, standard traffic sign font

The font type determines not only the appearance of the letters, but the ratio of letter height to letter width, stroke width of the letter relative to letter height, the kerning or space between letters and the spacing between words. Many of the standard fonts currently used for sign texts in the OTM are from the Highway Gothic series of fonts. Three series are commonly used for signs: Series C, D and E(modified) or E(M) (see Figure 1). (Note: For a

OTM:

Class	Sub-Class	Shape Code	Colour Code		
			Back-Ground	Message	Border
W Warning	Wc Intermittent Moving Hazards	◇	Yellow	Black	Black

Physical Materials meet MTO specifications :
- Using 3M Reflective Sheeting (to ensure night time visibility)
- UV resistant Inks and Vinyls stand up to the harsh Canadian weather.

Overall: fulfills the Professional Engineers Ontario Code of Ethics requirements for "fidelity to public needs" and "competence in performance."