Evaluation of Gainesville Pedestrian-Bicyclists Connected Vehicle Pilot

BED31-977-23

Final Report

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16. Abstract

The Florida Department of Transportation (FDOT) along with the University of Florida (UF) and the City of Gainesville (CoG) implemented an Accelerated Innovation Deployment (AID Grant, FL17) Demonstration Project [1]. The UF AID, or pedestrian-bicycle safety project, deployed and tested pedestrian and bicyclist safety applications at signalized intersections and midblock crossings using connected vehicle (CV) technologies. The project was conducted at the UF campus in Gainesville, Florida. The University of Florida Transportation Institute (UFTI) was retained to evaluate the “after” conditions, including the effectiveness of the system from various perspectives, such as hardware reliability and overall traveler satisfaction.
The technologies deployed in this project were passive pedestrian detection (PPD) systems, advance vehicle detection systems (AVDS), personal information devices (PID) (smartphones with an app), rectangular rapid flashing beacons (RRFB), road-side units (RSUs), on-board units (OBUs), and variable pedestrian phase recall applications. The research included a multifaceted evaluation of the installed hardware and software, as well as pedestrian, bicycle, and skateboarder perceptions and corridor-level operations. The following evaluations were conducted:
1. Software and hardware tools deployed around the study area, which aimed to minimize pedestrian-bicyclist crashes by proactively alerting motorists, pedestrians, and bicyclists of the impending danger. The system included intersection and midblock crossings, each equipped with warning and/or notification systems.
2. User perception of the smartphone application provided by the selected vendor and the effectiveness of PPD systems, RRFB, and other communication technologies to assist pedestrians and bicyclists when crossing.
3. Corridor-level safety and mobility performance.
It was concluded that the technology is not fully mature yet for statewide deployment. The research report provides detailed qualitative and quantitative assessments of various aspects of the system, along with recommendations for enhancements.
[1] https://www.fhwa.dot.gov/innovation/grants/projects/fl17.cfm

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Executive Summary

The Florida Department of Transportation (FDOT), in collaboration with the University of Florida and the City of Gainesville, conducted an evaluation of connected vehicle (CV) and pedestrian safety technologies along West University Avenue (WUA) in Gainesville, Florida. This corridor, adjacent to the University of Florida campus, experiences high pedestrian and bicycle activity, making it an ideal setting to assess how technologies such as passive pedestrian detection (PPD), rectangular rapid flashing beacons (RRFBs), roadside units (RSUs), on-board units (OBUs), and the TravelSafely smartphone application affect multimodal safety and traffic operations.

The evaluation examined system performance, user perceptions, safety outcomes, and corridor mobility. Regarding overall system performance, it was concluded that pedestrian detection accuracy varied widely (12.9%–95.2%), and weather and local roadside lighting conditions strongly influenced detection reliability. The communication system between OBUs and RSUs showed high reliability (96.3%), but maintenance issues and offline RSUs affected data completeness. The smartphone application reliability was high for cloud communications (99.1% of Personal Safety Messages (PSMs) received), but alert delivery was inconsistent, with delays observed when pedestrians were already in crosswalks.

The user perception was evaluated through focus groups, participant experiments, and surveys. The focus groups revealed moderate trust in the technology along with concerns about distraction and dependence on smartphone usage. Pedestrians and bicyclists that used the app and participated in the focus groups appreciated safety-focused alerts but expressed frustration with inconsistent or delayed notifications. Participants felt the app was more beneficial for drivers than for pedestrians or cyclists because drivers valued advance alerts while pedestrians often found notifications unnecessary or distracting. Users experienced false or missed alerts and noted that alerts differed across Apple and Android devices.

The user safety was assessed using historical crash data and video analysis, focusing on pedestrian and bicyclist incidents. Crash data analysis confirmed persistent pedestrian and bicyclist crash concerns, particularly along University Avenue. Near-miss data suggested reductions after deployment. There was a reduction in near-miss frequency from 48 incidents/hour in October 2022 to 31 incidents/hour in October 2024, a 35% decrease. Improvements were most visible at crosswalks and right-turn conflicts, though near-misses remain concentrated at busy turning locations. However, the safety improvements cannot be attributed solely to the system because there have been significant changes in the study network between the "before" and "after" periods of analysis, many of them to address safety concerns.

The mobility analysis evaluated level of service (LOS), delay, travel time, and average speed using probe data from the study corridor and three intersections after system implementation. Speed profiles indicated that evening peak speeds dropped below 15–20 mph, while morning peak speeds were higher. Sundays consistently showed the highest speeds in both directions. Although cameras, push buttons, and the app could all trigger pedestrian phases, the system did not differentiate the source of activations. As a result, it was not possible to quantify delay savings attributable to variable pedestrian recall. Vendors reported that push-button activations were not logged, and SPaT data only reflected active pedestrian phases, not the input source.

While added pedestrian phases slightly increased delays at some intersections, the overall impacts on mobility were minimal, and there were no major adverse effects on vehicle operations. The analysis indicated that traffic mobility efficiency was reduced, but this was offset by the intended benefits of safer crossings and more uniform traffic speeds.

The processes of data download, archiving and storage, analysis, access, and security were evaluated. The datasets analyzed included information from RRFB activations triggered by pedestrian information device (PIDs), pedestrian-phase calls from push buttons and PIDs, pedestrian location and direction, vehicle location, direction, speed, and classification, as well as the number of vehicle alerts and non-motorized transport (NMT) alerts. The project generated data from multiple sources, including OBUs, RSUs, TravelSafely app logs (alerts, route, visualizer), pedestrian detections from cameras, and RRFB activations. The project identified several data format inconsistencies: different components use incompatible formats. These differences required substantial post-processing and conversion to standard formats before analysis. Project data (OBU, RSU, app alerts, pedestrian detections, and safety logs) were successfully submitted to the USDOT ITS DataHub, making them accessible for third-party research and national CV pilot integration.

Based on the results of the analysis, several recommendations are provided to improve the pedestrian detection system, the communication system, and the smartphone application.

In conclusion, the Gainesville Connected Vehicle Pilot represents a significant step toward deploying innovative safety technologies for pedestrians and bicyclists. The findings underscore the importance of reliable detection, seamless communication, robust maintenance, and strong user engagement. By addressing the identified challenges and implementing the outlined recommendations, FDOT and its partners can enhance the effectiveness of CV deployments, ultimately contributing to safer, more efficient, and more resilient urban mobility systems.

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List of Acronyms

AI – Applied Information (Company)

AID – Accelerated Innovation Deployment

AVDS – Advance Vehicle Detection System

BSM – Basic Safety Message

CV – Connected Vehicle

CoG – City of Gainesville

EBL_lane4_egress1 – Eastbound Left, Lane 4, Egress to Lane 1

EBL_lane4_egress2 – Eastbound Left, Lane 4, Egress to Lane 2

EBR_lane1_egress1 – Eastbound Right, Lane 1, Egress to Lane 1

EBR_lane1_egress2 – Eastbound Right, Lane 1, Egress to Lane 2

EBT_lane2 – Eastbound Through, Lane 2

EBT_lane3 – Eastbound Through, Lane 3

FDOT – Florida Department of Transportation

FMU – Field Management Unit

fps – Frames per Second

FY – Fiscal Year

HCM – Highway Capacity Manual

HCS – Highway Capacity Software

LOS – Level of Service

MAP – Map Message

MP4 – MPEG-4 Video Format

MySQL – My Structured Query Language (Database)

NBL_lane3_egress1 – Northbound Left, Lane 3, Egress to Lane 1

NBL_lane3_egress2 – Northbound Left, Lane 3, Egress to Lane 2

NBR_lane1_egress1 – Northbound Right, Lane 1, Egress to Lane 1

NBT_lane1 – Northbound Through, Lane 1

NBT_lane2 – Northbound Through, Lane 2

OBU – OnBoard Unit

PID – Personal Information Device

PPD – Passive Pedestrian Detection

PSM – Personal Safety Message

Ped_EW_X – Pedestrian crossing East to West (X = Crosswalk ID)

Ped_NS_X – Pedestrian crossing North to South (X = Crosswalk ID)

Ped_SN_X – Pedestrian crossing South to North (X = Crosswalk ID)

Ped_WE_X – Pedestrian crossing West to East (X = Crosswalk ID)

RRFB – Rectangular Rapid Flashing Beacon

RSU – RoadSide Unit

SBL_lane3_egress1 – Southbound Left, Lane 3, Egress to Lane 1

SBL_lane3_egress2 – Southbound Left, Lane 3, Egress to Lane 2

SBR_lane1_egress1 – Southbound Right, Lane 1, Egress to Lane 1

SBR_lane1_egress2 – Southbound Right, Lane 1, Egress to Lane 2

SBT_lane1 – Southbound Through, Lane 1

SBT_lane2 – Southbound Through, Lane 2

SPaT – Signal Phase and Timing

SQL – Structured Query Language

SR – State Road

TIM – Traveler Information Message

TTC – Time-to-Collision

TTI – Travel Time Index

UF – University of Florida

UFTI – University of Florida Transportation Institute

US – United States Route

USDOT – United States Department of Transportation

WBL_lane3_egress1 – Westbound Left, Lane 3, Egress to Lane 1

WBL_lane3_egress2 – Westbound Left, Lane 3, Egress to Lane 2

WBR_lane1_egress1 – Westbound Right, Lane 1, Egress to Lane 1

WBT_lane1 – Westbound Through, Lane 1

WBT_lane2 – Westbound Through, Lane 2

WUA – West University Avenue

YOLO – You Only Look Once (object detection model)

1 Introduction

The UF AID Demonstration Project represents one of the first large-scale efforts in Florida to integrate connected vehicle and smart-infrastructure technologies into a university campus environment. The project was motivated by a clear safety problem: high pedestrian and bicycle activity around the UF campus combined with a history of crashes and frequent conflicts with vehicles. Addressing this issue required innovative approaches to improve multimodal safety in a complex urban setting.

The overall goal of the project was to assess the impact of new technologies applied to transportation by deploying and testing connected and automated safety applications in real-world conditions. To achieve this, the project identified three main objectives: (1) evaluate the performance and reliability of deployed hardware and software technologies, (2) assess traveler perceptions of the system and smartphone application, and (3) measure corridor-level safety and mobility outcomes through crash, near-miss, and operational data analyses. These objectives were addressed through a structured research approach that included system deployment, technical evaluation, user studies, and before-and-after comparisons of safety and mobility.

The deployment combined hardware installations, such as roadside pedestrian detection systems and flashing beacons, with software tools and a smartphone application designed to deliver real-time alerts to drivers, pedestrians, and bicyclists. By linking these technologies, the project created a test bed for evaluating how advanced systems perform under high pedestrian and bicycle demand and variable roadway conditions.

This report presents the complete evaluation of the project. It provides a detailed description of the problem, outlines the objectives and tasks undertaken to address it, and introduces the research approach used for the evaluation. The findings deliver lessons learned, essential modifications for system improvement, and recommendations for future applications of connected and automated safety technologies in Florida and beyond.

The next section of the report provides the project's background and details the study area and motivation, followed by a discussion of the project objectives. The fourth section describes the system and its components, while the fifth section describes the hardware and software evaluation. The sixth section discusses the analyses conducted to obtain traveler perspectives of the system obtained via focus groups and a survey. The report then summarizes the evaluation of corridor-level impacts related to usability, safety, and traffic operational performance and provides an overview of the data management. The last section provides conclusions and recommendations from all components of the study.

2 Project Background

The Florida Department of Transportation (FDOT) along with the University of Florida (UF), and the City of Gainesville (CoG) implemented an Accelerated Innovation Deployment (AID) Demonstration Project. The project was funded by an AID Grant for Fiscal Year (FY) 2017 through the United States Department of Transportation (USDOT). The UF AID, or pedestrian-bicycle safety project, deployed and tested pedestrian and bicyclist safety applications at signalized intersections and midblock crossings using Connected Vehicle (CV) and other innovative technologies. The UF AID system was deployed at the UF campus in Gainesville, Florida.

Under a previous FDOT project (Elefteriadou et al., 2023) the UFTI researchers completed the "before" analysis for the selected study area, which has extensive pedestrian, bicycle, transit, and vehicle activity. That study reported a total of 1110 vehicle crashes, 49 pedestrian crashes and 48 bicycle crashes within the study area between May 2014 and May 2019 (Elefteriadou et al., 2023). The study also found there was frequent jaywalking on West University Avenue and high pedestrian density around bus stops near the Reitz Student Union building.

The four project roadways are State Road (SR) 26 (University Avenue), US 441 (SW 13th Street), Museum Road, and Gale Lemerand Drive. The project instrumented thirteen (13) signalized intersections and five (5) unsignalized midblock crossings (with flashing beacons). These streets have high pedestrian and bicyclist traffic with transit stops. The technologies deployed in this project are Passive Pedestrian Detection (PPD) systems, Advance Vehicle Detection Systems (AVDS), Personal Information Devices (PID) (smartphones with an app), Rectangular Rapid Flashing Beacons (RRFB), Road-Side Units (RSUs), On-Board Units (OBUs), and variable pedestrian phase recall applications. The study area is shown in Figure 2-1. The four corridors contain several midblock crossings and signalized intersections. Midblock crossings are designated as C1, C2, …Cn; signalized intersections are labeled as S1, S2, …, Sn.

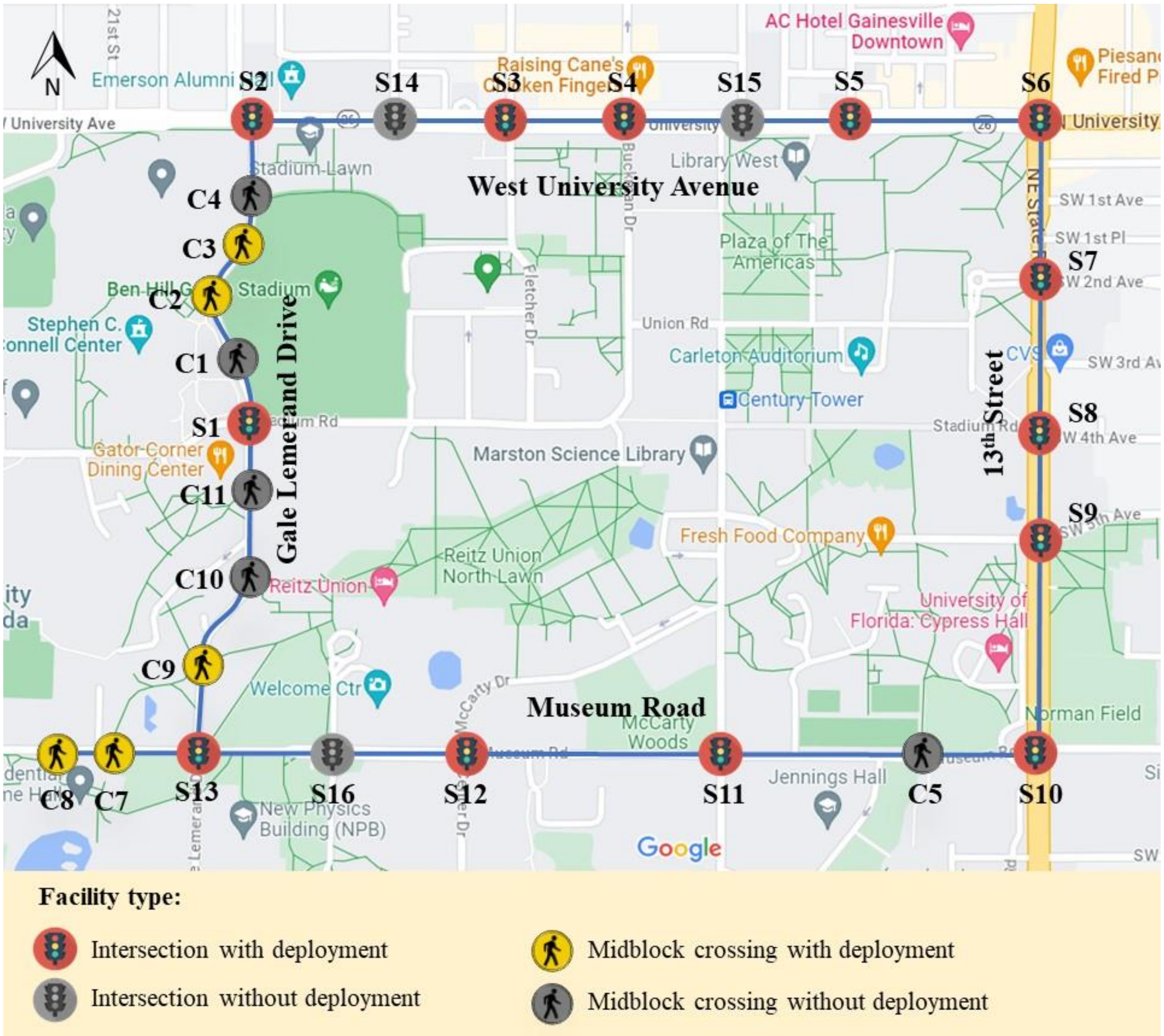


Figure 2-1 – Deployment area

Table 2–1 and Table 2–2 provide the list of intersections and midblock crossings in the study area at the time of the evaluation. Some of the crosswalks were not earmarked for deployment (shaded rows in Table 2-2) even though they are on the network. Some crosswalks were ruled out after considering right-of-way and power supply. Signals S14, S15 and S16 did not exist during the planning of the project: they were stop-controlled intersections that were converted to signals recently.

Table 2–1 - List of intersections

ID	Name
S1	Stadium Rd. @ Gale Lemerand Dr.
S2	W Univ. Ave. @ Gale Lemerand Dr.
S3	W Univ. Ave. @ 18th St.
S4	W Univ. Ave. @ 17th St.
S5	W Univ. Ave. @ 15th St.
S6	W Univ. Ave. @ 13th St.
S7	SW 2nd Ave. @ 13th St.
S8	SW 4th Ave. @ 13th St.
S9	SW 5th Ave. @ 13th St.
S10	SW 8th Ave. @ 13th St.
S11	Museum Rd. @ Newell Dr.
S12	Museum Rd. @ Center Dr.
S13	Museum Rd. @ Gale Lemerand Dr.
S14	W Univ. Ave. @ 19th St.
S15	W Univ. Ave. @ 16th St.
S16	Museum Rd. @ Sweetwater Drive

Table 2–2 - List of midblock crossings

ID	Between Signals
C1	S1 & S2
C2	S1 & S2
C3	S1 & S2
C4	S1 & S2
C5	S10 & S11
C7	West of S13 along Museum Rd.
C8	West of S13 along Museum Rd.
C9	S13 & S1
C10	S13 & S1
C11	S13 & S1

Note: Shaded rows are locations without technology deployment.

The research team evaluated the effectiveness of the system from various perspectives, including hardware reliability and overall traveler satisfaction. The following sections of the report first detail the study objectives, and then describe the UF AID system, provide an evaluation of several of its hardware and software components, summarize the traveler perception-related evaluations conducted, and provide a safety and mobility assessment of the network considering "before" and "after" conditions.

3 Project Objectives

This research project conducted a multifaceted evaluation of the installed hardware and software, as well as pedestrian, bicycle, and driver perceptions, and corridor-level operations. The project had the following objectives:

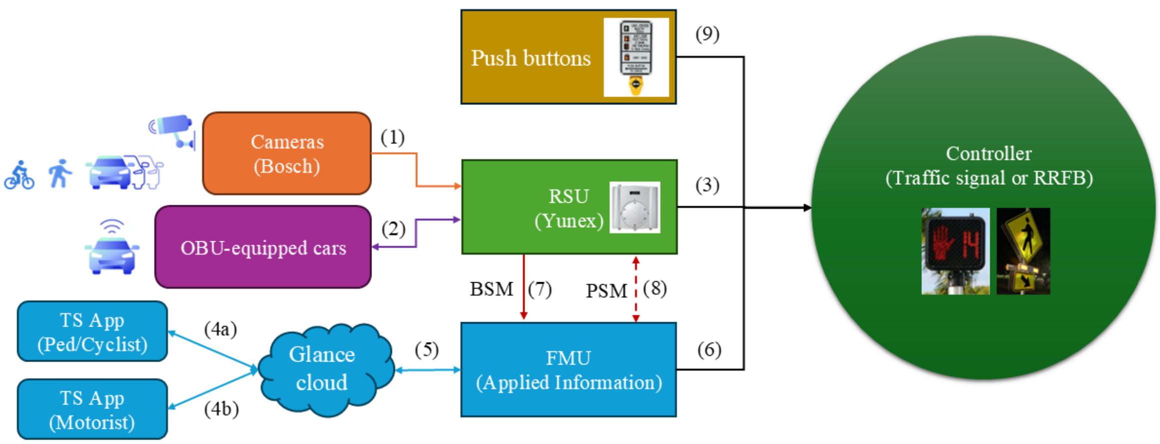
1. Evaluate the software and hardware tools deployed around the study area, which aimed to minimize pedestrian-bicyclist crashes by proactively alerting motorists, pedestrians, and bicyclists of the impending danger. The system evaluated included intersection and midblock crossings, each equipped with warning or notification systems to improve pedestrian-bicyclist access and safety at the subject locations.
2. Evaluate user perception of the smartphone application provided by the selected vendor, the effectiveness of PPD systems, RRFB and other communication technologies used to assist pedestrians and bicyclists with crossing busy streets.
3. Evaluate corridor-level performance in terms of safety and mobility.
4. Conduct quantitative and qualitative evaluations of the effectiveness of the systems deployed.

4 Description of the System

As indicated earlier, the technologies deployed in this project are PPD systems, AVDS, PID (smartphones with an app), RRFB, RSUs, OBUs, and variable pedestrian phase recall applications.

Yunex was the main vendor in the deployment of the system. They were supported by other vendors including Bosch (cameras), Denso (OBUs and field monitoring units (FMU)), and Applied Information (Travel Safely application, hereafter referred to as "the app"). Appendix A provides an overview of the equipment and system components of the deployment.

The architecture of the communication system between the RSUs, OBUs, cameras, FMUs, the app, and controllers is presented in Figure 4-1. The figure lists the communication paths within the system, which are discussed and evaluated in the next section of the report. The evaluation was performed in steps: the first step considered the first three items shown in Figure 4-1, the second step followed the path highlighted in orange, and the final step followed the path highlighted in blue.



- (9) Pedestrians using pushbuttons activate the pedestrian phase at traffic signals or RRFBs at the midblock crossing.
- (1>3) Cameras detecting pedestrians activate the pedestrian phase at traffic signals or RRFBs at midblock crossing.
- (1>2) Cameras detecting pedestrians send warnings to vehicles equipped with OBU.
- (4a>5>6) Pedestrians using the application activate the pedestrian phase at traffic signals or RRFBs at midblock crossing.
- (2>7>5>4a) Vehicles equipped with OBU send warnings to pedestrians with the application.
- (1>7>5>4a) Cameras detecting vehicles send warnings to pedestrians with the application.
- (4a>5>4b) Pedestrians using the application send warnings to vehicles using the application and vice versa.
- (4a>5>8>2) Pedestrians using the application send warnings to vehicles equipped with OBU.
- (1>8>5>4b) Cameras detecting pedestrians send warnings to vehicles using the application.

Figure 4-1 – Architecture of the communication system

5 Hardware and Software Evaluation

To evaluate the system hardware and software, the research team assessed the performance of various components and communication paths of the architecture shown in Figure 4-1. The first part of this section provides the results of the analysis related to the reliability of the pedestrian detection system, which estimated its accuracy under different demand, lighting, and weather conditions. The second part summarizes the qualitative and quantitative analysis of the evaluation of the communication system. The third part evaluates the smartphone application. The last part provides a summary and recommendations related to the system's hardware and software.

5.1 Evaluation of the pedestrian detection system

The reliability of the pedestrian detection system was evaluated using videos recorded from the system cameras and comparing the detections obtained from the embedded algorithms to manual counts.

Videos were recorded during different time periods and under varying demand, lighting (for example, morning, dusk, evening), and weather conditions (sunny, rainy). The reliability of each camera was measured in terms of the percentage of pedestrians detected over the total number of pedestrians present.

The following paragraphs detail the steps taken to complete this analysis:

1. Selection of representative locations
2. Evaluation of the operational status of the cameras
3. Development of video sampling methodology
4. Qualitative evaluation of the pedestrian detection system
5. Quantitative evaluation of the pedestrian detection system

5.1.1 Selection of study locations

Three signalized intersections (S2, S4 and S6) and one midblock crossing (C8) were selected for this study (Table 5–1). S2, S4, and S6 were chosen due to their inclusion in the previous study (BDV31-977-120). S6 represents a heavily travelled intersection characterized by high vehicular and pedestrian traffic. S4 is the only intersection where pedestrian heading direction is considered to activate the pedestrian crossing phase for the crosswalk parallel to the pedestrian's heading direction. The only available midblock crossing with an active camera at the time of this study was C8. Recording from multiple cameras concurrently requires a reliable and fast internet connection, as well as computational power, since the computers utilize GPUs to process the videos. Therefore, for each intersection we recorded video footage from two cameras concurrently. Each camera covers one crosswalk at the intersection.

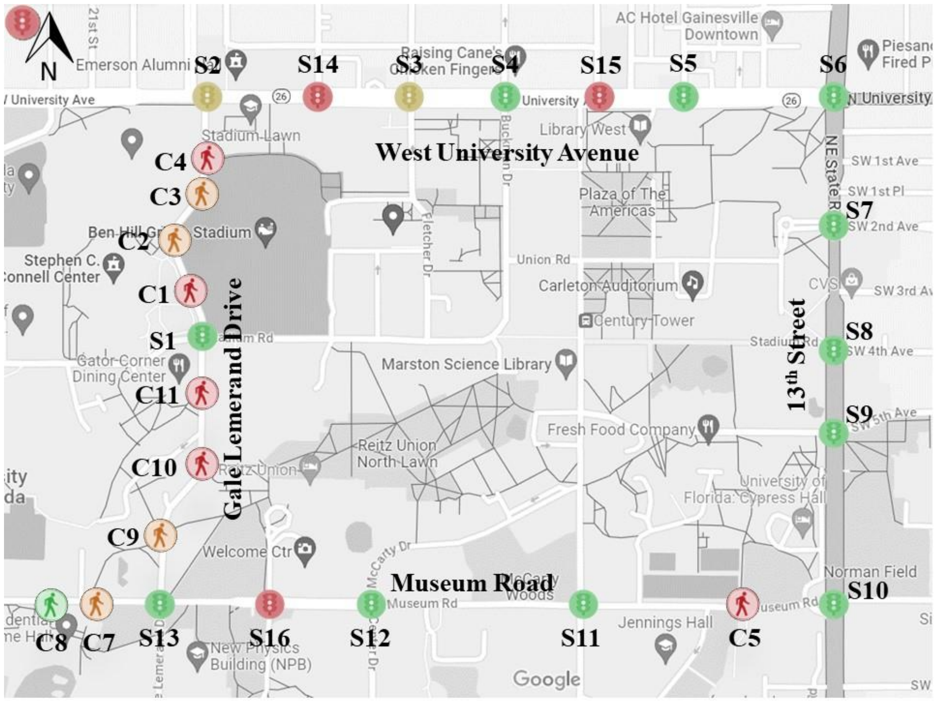
Table 5–1 – Study locations and selected cameras in each intersection

ID	Location	Camera view
S2	W Univ. Ave. @ Gale Lemerand Dr.	Two cameras- south and east Crosswalks
S4	W Univ. Ave. @ 17th St.	Two cameras- South and West Crosswalks
S6	W Univ. Ave. @ 13th St.	Two cameras- South and West Crosswalks
C8	West of S13 along Museum Rd.	One camera- midblock-crosswalk

5.1.2 Evaluation of the operational status of the cameras

Figure 5-1 depicts the availability and operational status of cameras within the study area. No cameras were installed at intersections S14, S15, and S16 since these were unsignalized during the contracting phase. Table 5–2 shows the camera operational status at these intersections during the time of the evaluation. The observations provided were recorded over the course of a month and the issues identified were not resolved during that time. “None” indicates the location had no active deployment.

The cameras at midblock crossings are powered by solar energy. Unfortunately, when solar panels are situated in shaded locations their battery reserves may deplete during overcast or rainy conditions. Additionally, internet (LTE/wireless) connectivity issues from the vendor deployment may render these cameras inaccessible. This was the case for the study locations in this project. Table 5–3 outlines the availability of midblock cameras and their detection capabilities during the time of the evaluation. “NA” indicates the location has no active deployment.



Map guide:

Color	Signs	Definition
Green		Cameras available and working.
Yellow		Cameras available but not all are working.
Orange		Cameras available but none are working.
Red		No cameras available.

Figure 5-1 – Study area camera operation

Table 5–2 – Camera operational status at the signalized intersections during the time of the evaluation

Intersection ID	**Available cameras**	**Working cameras**	**Comment**
S1	4	4	None
S2	3	2	Camera facing south has issues.
S3	4	2	Getting “unknown error”.
S4	4	4	None
S5	3	3	None
S6	4	4	None
S7	4	4	None
S8	4	4	None
S9	4	4	None
S10	4	4	None
S11	4	4	None
S12	4	4	None
S13	4	4	None

Table 5–3 – Midblock camera availability and detection status during the time of the evaluation

Midblock ID	Has camera	Detection	Camera name
C1	No	NA	NA
C2	Yes	No	Midblock 2
C3	Yes	Yes	Midblock 1
C4	Yes	NA	NA
C5	No	NA	NA
C7	Yes	No	Midblock 4
C8	Yes	No	Midblock 3
C9	Yes	Yes	Midblock 5
C10	No	NA	NA
C11	No	NA	NA

5.1.3 Development of video sampling methodology

Video was used to obtain the actual number of pedestrians during the testing. Guidelines from the FDOT standard specification 995-2.8 (Florida Department of Transportation, 2024) were followed in this evaluation. These specifications are for the detection of vehicles, therefore we have adapted them for pedestrian detection.

Based on the FDOT standard specification 995-2.8, video samples were recorded at three intersections (S2, S4, and S6) and one available midblock crossing (C8) under both sunny and rainy conditions. The amount of rainfall varied during the video recordings. The goal was to collect video samples for each intersection under different weather conditions within the same day. However, rainy weather posed challenges due to infrequency or camera accessibility issues. Samples were recorded on Tuesdays, Wednesdays, and Thursdays, excluding holidays and days with low pedestrian traffic.

The detection accuracy of each camera was calculated based on weighted accuracy of different periods. Table 5–4 lists the day periods, sample durations, and the weights necessary for calculating final weighted accuracy. These weights are recommended by the FDOT standard, and each unit of weight corresponds to 15 minutes of data; therefore, 24 hours in a day total up to 96 units. Each sample from a period represents other intervals in that period. Therefore, periods with longer durations have higher weights. The weighted accuracy is calculated as follows:

$$Weighted\ Accuracy = \frac{\sum Weight_{period} * Accuracy_{period}}{Total\ sum\ of\ weights} \quad (1)$$

Table 5–4 – Video data collection periods

Period	Representation	Duration	Weight
Early morning (predawn) [EM]	12:30 A.M.-6:30 A.M.	15 minutes	24
Dawn [DA]	6:30 A.M.-7:00 A.M.	30 minutes	2
AM peak [AMP]	7:00 A.M.-8:00 A.M.	15 minutes	4
Late AM off-peak [LAOP]	8:00 A.M.-12:00 P.M.	15 minutes	16
Noon [NO]	12:00 P.M.-1:00 P.M.	15 minutes	4
Afternoon off-peak [AOP]	1:00 P.M.-5:00 P.M.	15 minutes	16
PM peak [PMP]	5:00 P.M.-6:00 P.M.	15 minutes	4
Dusk [DU]	6:00 P.M.-6:30 P.M.	30 minutes	2
Night [NI]	6:30 P.M.-12:30 A.M.	15 minutes	24
Total sum of weights			96

Table 5–5 provides a summary of the recordings including sample availability for each period, location, and weather conditions. Recordings for S2 on sunny days are unavailable due to maintenance issues for the camera facing south. The camera for the midblock (C8) lacks pedestrian detection capability and a defined detection area, resulting in the absence of pedestrian data collection at this location.

Table 5–5 – Summary of video recordings

Location	Amount of time recorded	Comments
S2-WUA & GL	2 hours and 45 minutes /Rainy	The camera facing south is non-functional, resulting in a lack of data for sunny days.
S4-WUA & 17th St	2 hours and 45 minutes / Sunny 2 hours and 45 minutes / Rainy	These cameras consider the direction of the pedestrian movement.
S6-WUA & 13th	2 hours and 45 minutes / Sunny 2 hours and 45 minutes /Rainy	Heavy pedestrian and vehicular traffic.
C8-Midblock	2 hours and 45 minutes / Sunny 2 hours and 45 minutes / Rainy	Camera works but it is not detecting pedestrians as the "detection zone" is not defined.

5.1.4 Qualitative evaluation of the pedestrian detection system

The research team manually collected the pedestrian detection data by reviewing the recorded samples and monitoring the pedestrian zone activations. Additionally, for the only available midblock location (C8), there is no designated detection area for pedestrian detection: the camera works but it is not detecting pedestrians and consequently not activating the pedestrian crossing beacons at midblock crossings. Within each camera view, the system defines two zones, one in each corner of the intersection, to detect pedestrians as they approach. When a pedestrian is detected within the designated area, the detection area's color changes, and the boundary box around the pedestrian turns red. If the pedestrian has been detected but is outside of the detection area, the boundary box color is pink. Objects detected outside the detection zones are outlined in orange boundary boxes. The type of observed objects is indicated at the top of the boundary box, (person, bicycle, motorcycle, car, truck, or bus). Figure 5-2 depicts the boundary box colors for detected objects and the activation of pedestrian detection zones. Figure 5-3 to Figure 5-5 showcase images obtained from video samples at selected intersections, with each camera focused on a specific crosswalk that is horizontal (i.e., left to right) in the camera view.

The detection areas are activated simultaneously for each crosswalk, regardless of whether the pedestrian is detected on the right or left side of the crosswalk from the camera's perspective. However, the system considers pedestrian heading (i.e., the direction the pedestrian is moving) only at one location in the study area: S4-W Univ. Ave. @ 17th St. This location has defined directionality in cameras UA @17th Cam 1 EB, UA @17th Cam 2 WB, and UA @17th Cam 3 NB. In this case, each detection area operates independently and considers pedestrian heading to activate the detection area based on pedestrian intention. Pedestrian heading direction is considered to activate the pedestrian crossing phase for the crosswalk parallel to the pedestrian's heading direction. In some scenarios when the pedestrian walks in the detection area without any specified direction, the pedestrian phase is activated by mistake.

Figure 5-2 – Boundary box colors in different scenarios

Figure 5-3 – Image extracted from video at S6-W Univ. Ave. @ 13th St.

Figure 5-4 – Image extracted from video at S4-W Univ. Ave. @ 17th St.

Figure 5-5 – Image extracted from video at S2-W Univ. Ave. @ Gale Lemerand Dr.

The pedestrian detection system was found to have errors leading to decreased accuracy in certain situations. These errors are categorized into detection errors, activation errors, other observations, and software errors.

5.1.4.1 Detection errors

This type of error occurs when there is a problem with detecting objects. Figure 5-6 illustrates a detection error occurring at S2-W Univ. Ave. @ Gale Lemerand Dr., where the traffic signal pole shown on the right is mistakenly detected as a person, resulting in the activation of the pedestrian detection zone. This type of error is classified as a false positive in the evaluation process.

Figure 5-6 – Detection error at S2-W Univ. Ave. @ Gale Lemerand Dr.

5.1.4.2 Activation errors

This type of error occurs when the pedestrian detection area fails to activate when a pedestrian is present and crossing the crosswalk. This situation is classified as a false negative and was a common occurrence across all locations evaluated. Figure 5-7 shows an example when the system did not detect the pedestrian while they were crossing, and classified them as a vehicle instead.

Horizontal crosswalks (i.e., left to right) in camera view are the crosswalks that receive the green when pedestrians are detected. Sometimes, these pedestrians may activate the detection area for other crosswalks (i.e., those that are vertical in the camera view). These scenarios are classified as "true positives" for the intended direction of pedestrian travel because pedestrians are present and detected in the detection areas. However, they also generate an incorrect activation in the direction they did not travel. Figure 5-8 highlights this issue which occurred at S4-W Univ. Ave. @ 17th St. when the system incorrectly detected pedestrians waiting to cross the vertical crosswalk (i.e., top to bottom) in the camera view. This problem is not unique to this intersection and was observed in many other intersections as well. In such cases, both crosswalks (horizontal and vertical) activate their respective pedestrian phases.

To address such issues, it is essential to carefully define two components:

1. Pedestrian detection zones that are drawn using the camera software
2. Pedestrian heading, which considers the direction of the pedestrian movement within the detection area.

It is important that both these elements are defined correctly for the detection/activation to work. For example, at S4-W Univ. Ave. @ 17th St, the pedestrian heading is defined correctly. However, the pedestrian detection areas are drawn in a way that they overlap significantly between the two camera views, leading to incorrect activations.

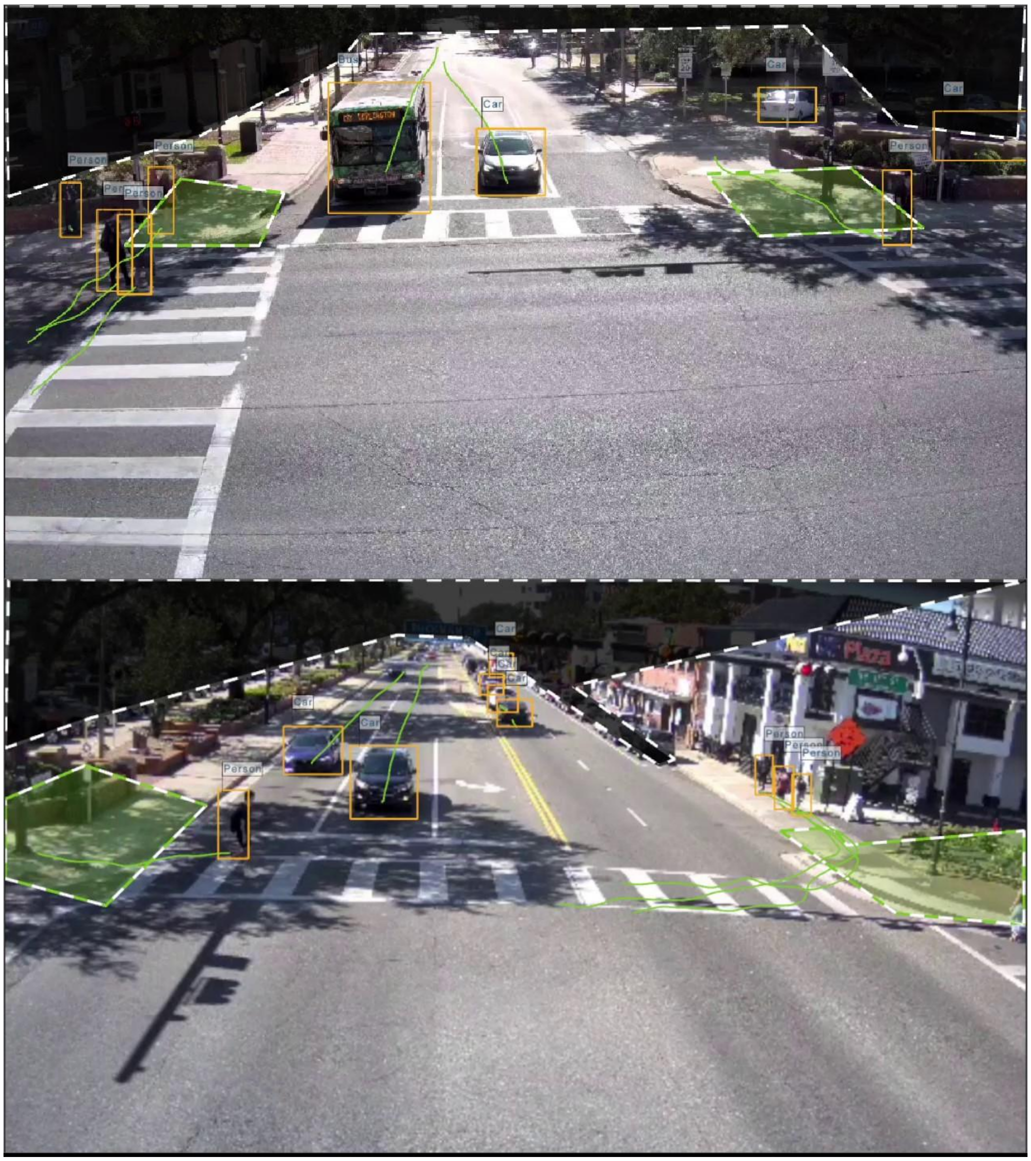


Figure 5-7 – Error in S4-W Univ. Ave. @ 17th St. resulted in failure to detect the pedestrian

Figure 5-8 – Error in S4-W Univ. Ave. @ 17th St. resulted in false activation

5.1.4.3 Other observations

It was observed that the system detects only a few pedestrians when they are within a larger crowd in the detection areas. When pedestrian density is high, the pedestrians are underestimated by the camera's software. However, since there is no difference in the zone activation, whether there is one pedestrian or a group of pedestrians, for evaluation purposes we considered this as the correct activation of the system. Figure 5-9 illustrates a scenario where a crowd of pedestrians is crossing together.

In the camera software, the object detection has "person" and "bicycle" classes. However, there is no "scooter" object class. Scooters have different speed than either of these classes. They are classified as “person” or “bicycle” by the camera’s software. When we inquired, the vendor did not provide a specific explanation or criteria for distinguishing between modes.

Figure 5-9 – Error in detecting the number of pedestrians at S6-W Univ. Ave. @ 13th St.

5.1.4.4 Software errors

The Bosch Configuration Manager was utilized to access the cameras deployed. However, several software errors were encountered during this process. When the camera is unavailable, or there are internet connectivity issues, we encountered errors such as "Unprocessable Entity," "RcppSDK: 'Response timeout'" or “Unknown error. Err. ID: 0x0001”, as depicted in Figure 5-10, Figure 5-11 and Figure 5-12. These issues were observed over the span of a month.

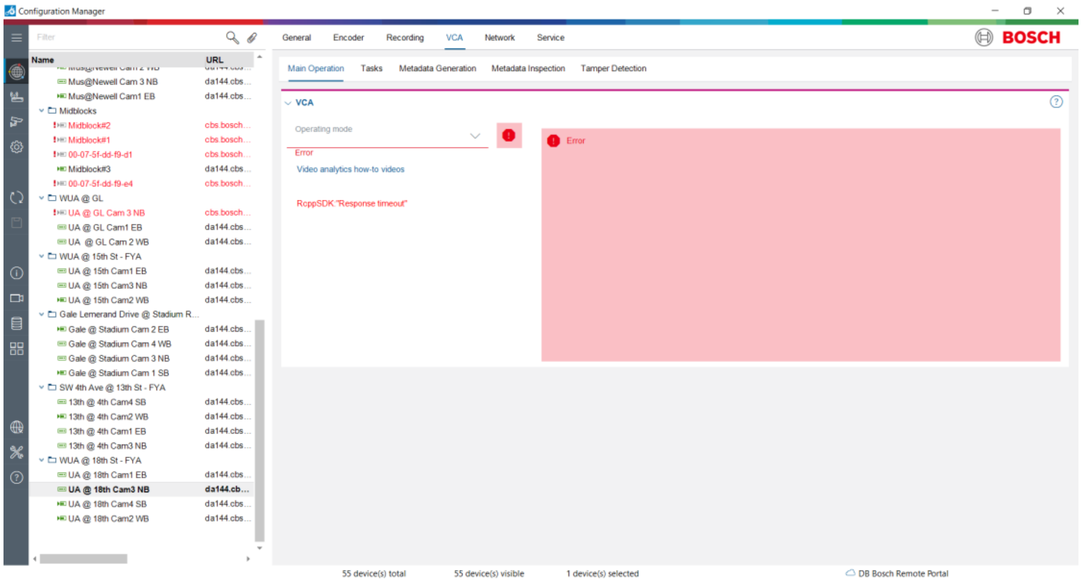


Figure 5-10 – RcppSDK: Response timeout error in Bosch Configuration Manager

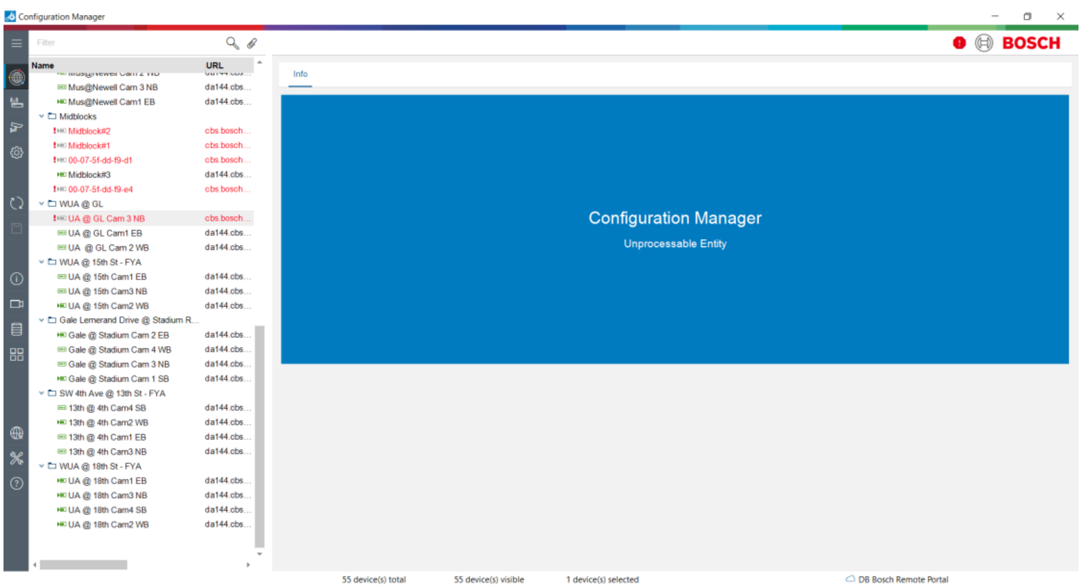


Figure 5-11 – Unprocessable Entity error in Bosch Configuration Manager

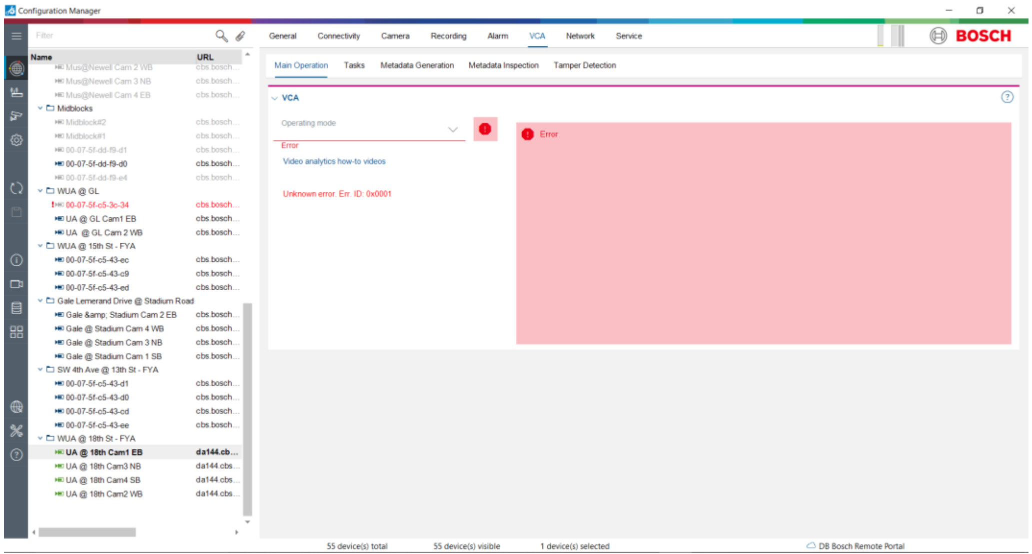


Figure 5-12 – Unknown error in Bosch Configuration Manager

5.1.5 Quantitative evaluation of the pedestrian detection system

We assessed the reliability of each device by obtaining the percentage of pedestrians detected over the total number of pedestrians present. Each camera corresponds to one crosswalk. For each crosswalk we collected the number of observations at different times of day, and constructed the confusion matrix shown in Table 5–6. The confusion matrix serves as a method to evaluate the performance of binary classification systems. It comprises actual and predicted classes, both of which are binary variables.

Table 5–6 – Confusion matrix

		Predicted class	
		Positive (1)	Negative (0)
Actual class	Positive (1)	True positive (TP)	False negative (FN)
	Negative (0)	False positive (FP)	True negative (TN)

The values in the confusion matrix are defined as:

- True positive (TP): The number of correctly predicted positive instances.
- True negative (TN): The number of correctly predicted negative instances.
- False positive (FP): The number of instances incorrectly predicted as positive when they are negative.

- False negative (FN): The number of instances incorrectly predicted as negative when they are positive.

In this evaluation, true positives represent cases where pedestrians are both observed and detected. False negatives occur when pedestrians are observed but not detected by the detection area. False positives arise when the detection zone is activated without the presence of observed pedestrians. Since we are solely interested in observed pedestrians, true negatives are not applicable. Therefore, the accuracy for each crosswalk at different times of the day is calculated as the ratio of true positives to the number of observations:

$$Accuracy = 100 * \frac{Number\ of\ Detected\ Observations\ (True\ Positives)}{Total\ Number\ of\ Observations} \quad (2)$$

During the data collection process for pedestrian crossings, several assumptions were made to ensure accurate and consistent analysis:

- Detection zone activations that last less than 1 second are disregarded to prevent false positives. This means that brief, momentary activations, such as those caused by passing pedestrians on sidewalks, will not trigger the system. Only sustained activations of 1 second or longer are recognized to ensure that the detection is accurate and corresponds to a legitimate pedestrian presence.
- Detection zone deactivations lasting less than 1 second are considered active. This means that if the detection zone briefly deactivates for less than a second, it will still be considered active. Adopting this approach helps to prevent interruptions in detection, thereby ensuring continuous monitoring and accurate pedestrian detection.
- When a crowd of pedestrians is waiting to cross, and one or some of them are detected, it is assumed that the system activated correctly, and we assume all pedestrians are true positives.
- The focus of analysis is solely on pedestrians crossing the crosswalk horizontally in the camera's field of view, as they are the crosswalks intended to be activated by the detection system.
- Pedestrians crossing but not detected by the detection zone (excluding crowd cases) are considered as undetected.
- Pedestrians are truly detected when they are present in the detection area and activating the pedestrian crossing phase.

Table 5–7 to Table 5–16 show the results of this evaluation for different locations, weather conditions, and crosswalks. Table 5–17 represents the overall weighted accuracy in the observations for each case (location, weather condition, and crosswalk).

Table 5–7 – S4-WUA & 17th St-Sunny-South crosswalk

Time of day	Number of observations	False positives	True negatives	True positives	False negatives	Accuracy (%)
EM (12:30 A.M.-6:30	4	0	0	2	2	50
DA (6:30 A.M.-7:00 A.M.)	3	0	0	2	1	66.7
AMP (7:00 A.M.-8:00	7	0	0	7	0	100
LAOP (8:00 A.M.-12:00	38	0	0	36	2	94.7
NO (12:00 P.M.-1:00 P.M.)	28	0	0	20	8	71.4
AOP (1:00 P.M.-5:00 P.M.)	28	0	0	26	2	92.9
PMP (5:00 P.M.-6:00 P.M.)	25	0	0	21	4	84
DU (6:00 P.M.-6:30 P.M.)	59	0	0	44	15	74.6
NI (6:30 P.M.-12:30 A.M.)	6	0	0	4	2	66.7

Table 5–8 – S4-WUA & 17th St-Sunny-West crosswalk

Time of day	Number of observations	False positives	True negatives	True positives	False negatives	Accuracy (%)
EM (12:30 A.M.-6:30	2	0	0	1	1	50
DA (6:30 A.M.-7:00 A.M.)	4	0	0	4	0	100
AMP (7:00 A.M.-8:00	8	0	0	6	2	75
LAOP (8:00 A.M.-12:00	31	0	0	24	7	77.4
NO (12:00 P.M.-1:00 P.M.)	43	0	0	33	10	76.7
AOP (1:00 P.M.-5:00 P.M.)	16	0	0	11	5	68.8
PMP (5:00 P.M.-6:00 P.M.)	21	0	0	16	5	76.2
DU (6:00 P.M.-6:30 P.M.)	40	1	0	30	9	75
NI (6:30 P.M.-12:30 A.M.)	20	0	0	13	7	65

Table 5–9 – S4-WUA & 17th St-Rainy-West crosswalk

Time of day	Number of observations	False positives	True negatives	True positives	False negatives	Accuracy (%)
EM (12:30 A.M.-6:30	0	NA	NA	NA	NA	NA
DA (6:30 A.M.-7:00 A.M.)	2	0	0	0	2	0
AMP (7:00 A.M.-8:00	3	0	0	3	0	100
LAOP (8:00 A.M.-12:00	23	0	0	16	7	69.6
NO (12:00 P.M.-1:00 P.M.)	32	0	0	18	14	56.3
AOP (1:00 P.M.-5:00 P.M.)	18	0	0	16	2	88.9
PMP (5:00 P.M.-6:00 P.M.)	2	0	0	2	0	100
DU (6:00 P.M.-6:30 P.M.)	3	0	0	1	2	33.3
NI (6:30 P.M.-12:30 A.M.)	42	0	0	40	2	95.2

Table 5–10 – S4-WUA & 17th St-Rainy-South crosswalk

Time of day	Number of observations	False positives	True negatives	True positives	False negatives	Accuracy (%)
EM (12:30 A.M.-6:30	0	NA	NA	NA	NA	NA
DA (6:30 A.M.-7:00 A.M.)	6	0	0	1	5	16.7
AMP (7:00 A.M.-8:00	7	0	0	5	2	71.4
LAOP (8:00 A.M.-12:00	17	0	0	16	1	94.1
NO (12:00 P.M.-1:00 P.M.)	90	0	0	71	19	78.9
AOP (1:00 P.M.-5:00 P.M.)	31	0	0	22	9	71
PMP (5:00 P.M.-6:00 P.M.)	4	0	0	3	1	75
DU (6:00 P.M.-6:30 P.M.)	4	0	0	2	2	50
NI (6:30 P.M.-12:30 A.M.)	20	0	0	19	1	95

Table 5–11 – S2-WUA & GL-Rainy-East crosswalk

Time of day	Number of observations	False positives	True negatives	True positives	False negatives	Accuracy (%)
EM (12:30 A.M.-6:30	2	1	0	0	1	0
DA (6:30 A.M.-7:00 A.M.)	8	6	0	1	1	12.5
AMP (7:00 A.M.-8:00	3	0	0	0	3	0
LAOP (8:00 A.M.-12:00	6	0	0	2	4	33.3
NO (12:00 P.M.-1:00 P.M.)	4	0	0	0	4	0
AOP (1:00 P.M.-5:00 P.M.)	3	0	0	1	2	33.3
PMP (5:00 P.M.-6:00 P.M.)	9	0	0	3	6	33.3
DU (6:00 P.M.-6:30 P.M.)	29	19	0	2	8	6.9
NI (6:30 P.M.-12:30 A.M.)	14	14	0	0	0	0

Table 5–12 – S2-WUA & GL-Rainy-South crosswalk

Time of day	Number of observations	False positives	True negatives	True positives	False negatives	Accuracy (%)
EM (12:30 A.M.-6:30	1	0	0	0	1	0
DA (6:30 A.M.-7:00 A.M.)	5	1	0	2	2	40
AMP (7:00 A.M.-8:00	6	0	0	2	4	33.3
LAOP (8:00 A.M.-12:00	12	0	0	2	10	16.7
NO (12:00 P.M.-1:00 P.M.)	7	0	0	3	4	42.9
AOP (1:00 P.M.-5:00 P.M.)	6	0	0	5	1	83.3
PMP (5:00 P.M.-6:00 P.M.)	20	0	0	11	9	55
DU (6:00 P.M.-6:30 P.M.)	49	0	0	29	20	59.2
NI (6:30 P.M.-12:30 A.M.)	5	0	0	0	5	0

Table 5–13 – S6-WUA & 13th St-Sunny-South crosswalk

Time of day	Number of observations	False positives	True negatives	True positives	False negatives	Accuracy (%)
EM (12:30 A.M.-6:30	1	0	0	0	1	0
DA (6:30 A.M.-7:00 A.M.)	21	0	0	14	7	66.7
AMP (7:00 A.M.-8:00	22	0	0	18	4	81.8
LAOP (8:00 A.M.-12:00	60	0	0	42	18	70
NO (12:00 P.M.-1:00 P.M.)	143	0	0	135	8	94.4
AOP (1:00 P.M.-5:00 P.M.)	75	0	0	75	0	100
PMP (5:00 P.M.-6:00 P.M.)	80	0	0	79	1	98.8
DU (6:00 P.M.-6:30 P.M.)	147	0	0	144	3	98
NI (6:30 P.M.-12:30 A.M.)	24	0	0	17	7	70.8

Table 5–14 – S6-WUA & 13th St-Sunny-West crosswalk

Time of day	Number of observations	False positives	True negatives	True positives	False negatives	Accuracy (%)
EM (12:30 A.M.-6:30	2	0	0	1	1	50
DA (6:30 A.M.-7:00 A.M.)	12	0	0	7	5	58.3
AMP (7:00 A.M.-8:00	23	0	0	14	9	60.9
LAOP (8:00 A.M.-12:00	71	0	0	68	3	95.8
NO (12:00 P.M.-1:00 P.M.)	104	0	0	93	11	89.4
AOP (1:00 P.M.-5:00 P.M.)	84	0	0	80	4	95.2
PMP (5:00 P.M.-6:00 P.M.)	125	0	0	119	6	95.2
DU (6:00 P.M.-6:30 P.M.)	194	0	0	174	20	89.7
NI (6:30 P.M.-12:30 A.M.)	32	0	0	25	7	78.1

Table 5–15 – S6-WUA & 13th St-Rainy-South crosswalk

Time of day	Number of observations	False positives	True negatives	True positives	False negatives	Accuracy (%)
EM (12:30 A.M.-6:30 A.M.)	2	0	0	2	0	100
DA (6:30 A.M.-7:00 A.M.)	5	0	0	4	1	80
AMP (7:00 A.M.-8:00 A.M.)	28	0	0	28	0	100
LAOP (8:00 A.M.-12:00	239	0	0	239	0	100
NO (12:00 P.M.-1:00 P.M.)	134	0	0	129	5	96.3
AOP (1:00 P.M.-5:00 P.M.)	159	0	0	154	5	96.9
PMP (5:00 P.M.-6:00 P.M.)	5	0	0	3	2	60
DU (6:00 P.M.-6:30 P.M.)	254	0	0	252	2	99.2
NI (6:30 P.M.-12:30 A.M.)	88	0	0	81	7	92.1

Table 5–16 – S6-WUA & 13th St-Rainy-West crosswalk

Time of day	Number of observations	False positives	True negatives	True positives	False negatives	Accuracy (%)
EM (12:30 A.M.-6:30 A.M.)	6	0	0	0	6	0
DA (6:30 A.M.-7:00 A.M.)	11	0	0	9	2	81.8
AMP (7:00 A.M.-8:00 A.M.)	20	0	0	16	4	80
LAOP (8:00 A.M.-12:00	322	0	0	322	0	100
NO (12:00 P.M.-1:00 P.M.)	105	0	0	101	4	96.2
AOP (1:00 P.M.-5:00 P.M.)	149	0	0	146	3	98
PMP (5:00 P.M.-6:00 P.M.)	20	0	0	19	1	95
DU (6:00 P.M.-6:30 P.M.)	263	0	0	255	8	97
NI (6:30 P.M.-12:30 A.M.)	62	0	0	53	9	85.5

Table 5–17 – Overall weighted accuracy

ID-Location-Weather-Crosswalk	Weighted accuracy %	Number of observations	Comment
S6-WUA & 13th St-Sunny-South crosswalk	60.9	573	Some VRUs are not detected while crossing.
S6-WUA & 13th St-Sunny-West crosswalk	77.2	647	Some VRUs are not detected while crossing.
S6-WUA & 13th St-Rainy-South crosswalk	95.2	914	Pedestrians in a crowd are considered as detected (true positive).
S6-WUA & 13th St-Rainy-West crosswalk	69.4	958	Some VRUs are not detected while crossing.
S4-WUA & 17th St-Sunny-West crosswalk	66.3	198	Some VRUs are not detected while crossing.
S4-WUA & 17th St-Sunny-South crosswalk	74	185	Some VRUs are not detected while crossing.
S4-WUA & 17th St-Rainy-West crosswalk	82.1	125	Some VRUs are not detected while crossing.
S4-WUA & 17th St-Rainy-South crosswalk	82.7	179	Some VRUs are not detected while crossing.
S2-WUA & GL-Rainy-East crosswalk	12.9	78	The camera mistakenly detects a traffic pole as a person, resulting in the activation of the pedestrian detection area.
S2-WUA & GL-Rainy-South crosswalk	24.2	111	Poorly defined “detection areas” in the camera software are causing numerous instances where pedestrians are not detected while crossing.

Table 5–18 and Table 5–19 provide the average accuracy by location and weather condition. Figure 5-13 displays the average accuracy by time of the day. The findings reveal that the average accuracy for S4 and S6 is approximately 76%. Because of the error discussed earlier for S2 (detecting traffic signal pole as a pedestrian, refer to detection error), it has low accuracy.

The system performs better during sunny days (69.6 %) than during rainy days (61.1 %). The accuracy of detection is lower at dawn (31.3 %), significantly increases at mid-day (82.8 %), and then decreases again during dusk (64.8 %). The average peak performance for all cameras occurs in the afternoon off-peak period (AOP) (1:00 P.M. to 5:00 P.M.) with 82.8 % accuracy.

Table 5–18 – Average detection accuracy by location

Location	Average accuracy %
S6-WUA & 13th St	75.7
S4-WUA & 17th St	76.3
S2-WUA & GL	18.6

Table 5–19 – Average detection accuracy by weather condition

Weather Condition	Average accuracy %
Sunny	69.6
Rainy	61.1

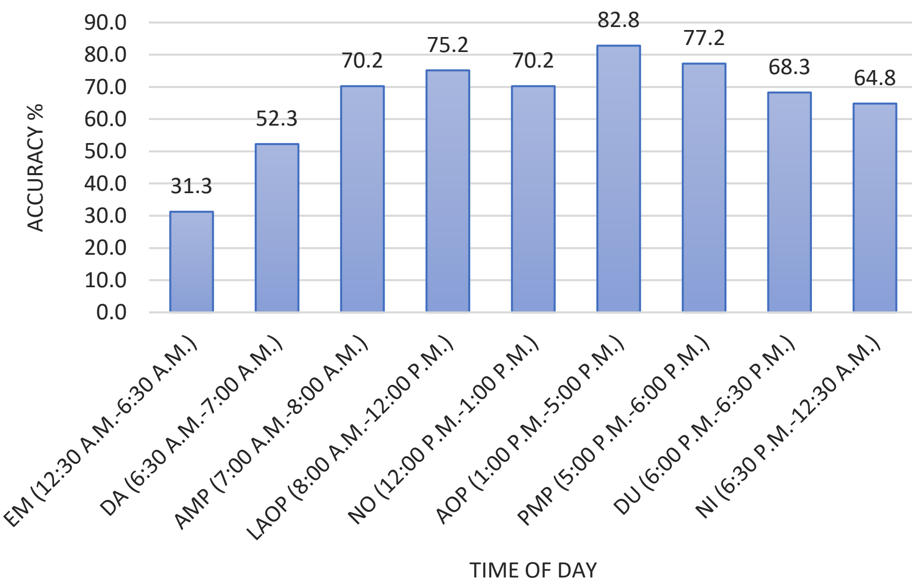


Figure 5-13 – Average detection accuracy by time of day (%)

5.2 Evaluation of the communication between the OBUs and RSUs

In this part of the research, we evaluated the ability of the RSUs to disseminate appropriate warnings and information to OBUs and the signal controllers. The reliability of the devices is defined as the percentage of messages received over the total number of messages sent under various scenarios.

The research team conducted field observations to assess how OBUs receive messages and alerts from RSUs. Three test runs were conducted, in both the clockwise and counterclockwise direction along the four highways in the perimeter of the UF campus. Since the assessment of communication reliability is not dependent on traffic patterns and day of the week, test runs were collected during weekends. Test run 1 took place on Saturday night, while test runs 2 and 3 were held on Friday afternoons. Test run 2 occurred on a sunny day, whereas test run 3 took place on a rainy day. Denso OBUs with heads-up displays were utilized for all the test runs.

The first subsection discusses the qualitative analysis, and the second subsection presents the results of the quantitative analysis.

5.2.1 Qualitative analysis

During the test runs, three types of messages were obtained. Figure 5-14 illustrates the speed limit message, which is displayed when the vehicle exceeds the posted speed limit. Figure 5-15 depicts the signal timing at intersections, showing a countdown during green and red light phases. Figure 5-16 indicates a pedestrian crossing warning message.

Figure 5-14 – Speed limit message received by OBU

Figure 5-15 – Count down to the beginning of red on the OBU

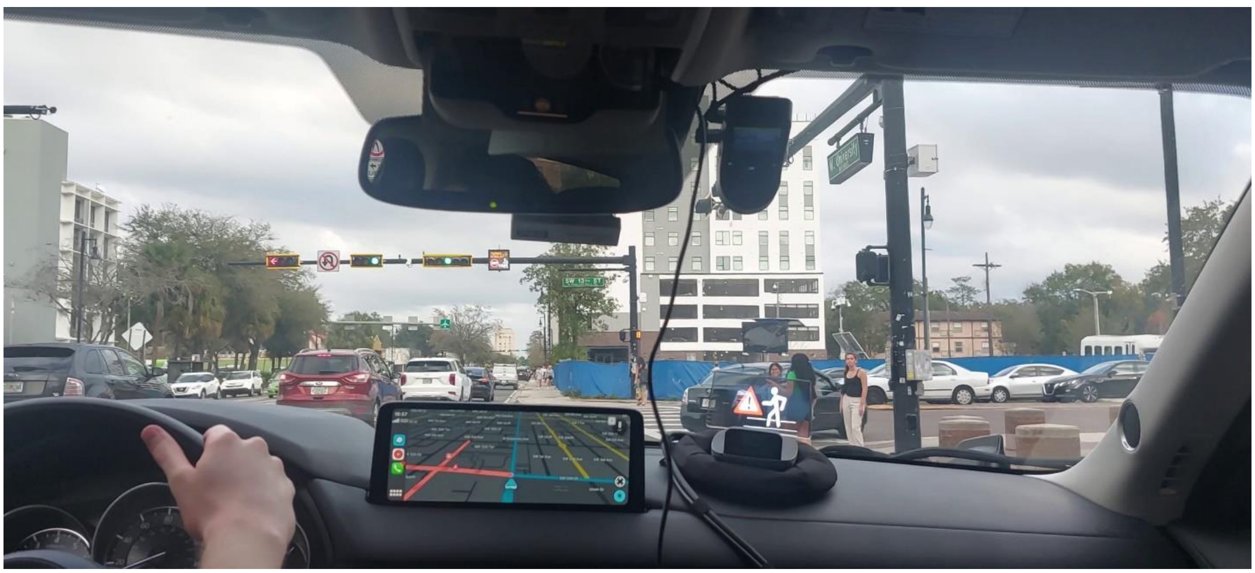


Figure 5-16 – Pedestrian crossing warning received by OBU.

Table 5–20 presents a summary of qualitative observations regarding the OBU messages received. According to our observations, pedestrian crossing warnings were received when pedestrians were detected at corners of intersections. Occasionally, messages were received even when no pedestrians were present, but the pedestrian phase was active at the intersection (i.e., false alerts). Pedestrian crossing warnings were sometimes observed after the pedestrian entering or immediately after the pedestrian passing the intersection.

Speed limit messages were evaluated when received, typically indicating a speed higher than the posted speed limit. Signal timing messages were usually received near intersections. In counterclockwise test runs of the study area, the left turn lane traffic signal was accurately detected. However, sometimes the countdown sequence remained constant on a number or fluctuated, possibly due to semi-actuated signal control or connection issues. The number of observations for signal timing is 13, as we evaluated 13 intersections with instrumentation.

Table 5–21 provides the overall accuracy of the OBU alerts received. In this table, false alerts represent situations when there was no pedestrian at the intersection, but we were receiving pedestrian crossing alerts. There were no false alerts for the 2nd and 3rd runs. The number of observations indicate the pedestrian presence at the intersections, and true alerts show the number of alerts received while pedestrians were present.

Even though pedestrians were observed on most test runs, the OBU did not display an alert regarding pedestrian crossings. Some of the issues based on our discussion with the vendors were:

- Detection issues at intersections are due to poor design of detection areas, occlusion, and low performance in dark periods.
- Cameras and RSUs were offline, or there was a network issue connecting them, and they needed maintenance (S2 and S10).
- Midblock crossings are powered by solar panels and batteries. However, issues such as miswiring, insufficient battery charge, and the placement of solar panels in shaded areas prevent them from functioning properly.

Table 5–20 – Summary of qualitative observations of received OBU messages

Test run	Measures	Speed limit	Signal timing	Pedestrian warning
Test run 1 2023-10-14	Observations	7	26	7
	True alerts	7	13	2
	False alerts	NA	NA	3
	Percentage alert received	100	50	28.5
Test run 2 2024-01-26	Observations	2	26	23
	True alerts	2	16	7
	Percentage alert received	100	61.5	30.4
Test run 3 2024-02-23	Observations	13	26	23
	True alerts	13	18	8
	Percentage alert received	100	69.2	34.8

Table 5–21 – Overall accuracy of the OBU alerts received

Overall accuracy	Speed limit	Signal timing	Pedestrian warning
Alert received	22	47	17
Field observation	22	78	53
Percentage alert received	100%	60%	32%

5.2.2 Quantitative analysis

To evaluate the performance of the devices (OBUs and RSUs), the research team defined their reliability as the ratio of received basic safety messages (BSMs) by RSUs to the total number of BSMs sent by OBUs:

$$Reliability = 100 * \frac{Number\ of\ received\ BSMs\ by\ RSUs}{Total\ number\ of\ BSMs\ sent\ by\ OBU} \tag{3}$$

OBUs transmit BSMs every 0.1 seconds, following the message structure outlined in the SAE J2735_2016 standard (SAE International, 2016).

Table 5–22 provides details on the types and number of messages received by OBUs in field observations within the study area. There are four types of messages received by OBUs: Map, Signal Phase and Timing (SPaT), Personal Safety Message (PSM), and Traveler Information Message (TIM). SPaT messages are the most common messages received by OBUs. MAP messages have the lowest count, while the number of TIM and PSM messages are similar.

In our last two test runs, we directly connected a laptop to the OBU to collect data logs sent and received by the OBU and obtained data from RSUs to evaluate device reliability in sending messages to RSUs (equation (3)). Table 5–23 provides the total number of BSMs sent, as well as details regarding received and not-received BSMs by RSUs within the study area. Based on these observations, the calculated reliability is 96.3%. Figure 5-17 displays a heatmap indicating locations where BSMs were received in the last test run, while Figure 5-18 shows points where BSMs were not received by RSUs during the last test run.

RSUs at S6-WUA & 13th Street and S9-13th Street & Inner road-SW 5th Street were not sending any messages during the last test run, resulting in a lack of data for these locations. Upon enquiry, the vendor reported the equipment was not functioning due to maintenance.

Table 5–22 – Types and number of messages received by OBU

	Test Date 1/26/2024	**Test Date 2/23/2024**
Test duration (min)	52	45
SPaT	51722	53081
TIM	16290	14045
PSM	14505	15303
MAP	6267	5172

Table 5–23 – BSMs sent by OBU

Total Number of BSMs sent by the OBU	25739
BSMs received by the RSUs	24784
BSMs not received by the RSUs	955

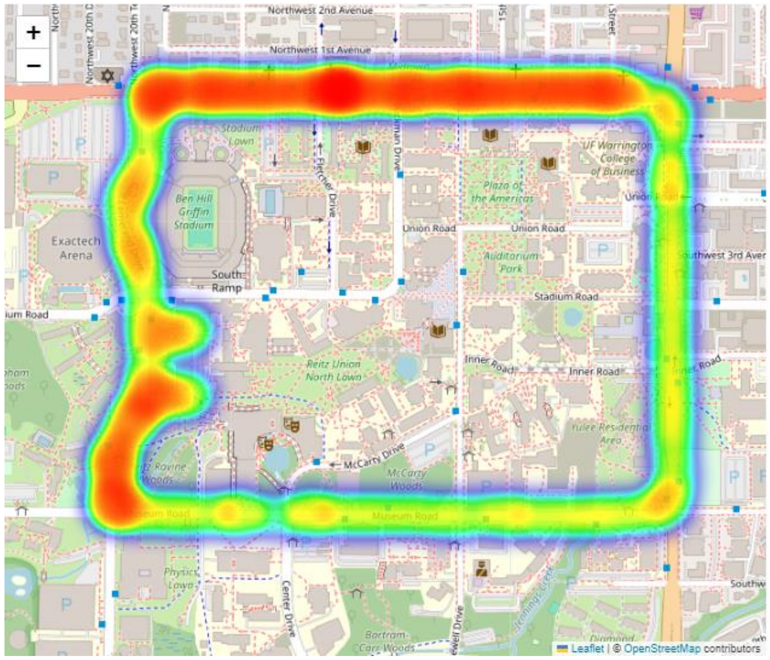


Figure 5-17 – BSMs received by RSUs in the study area

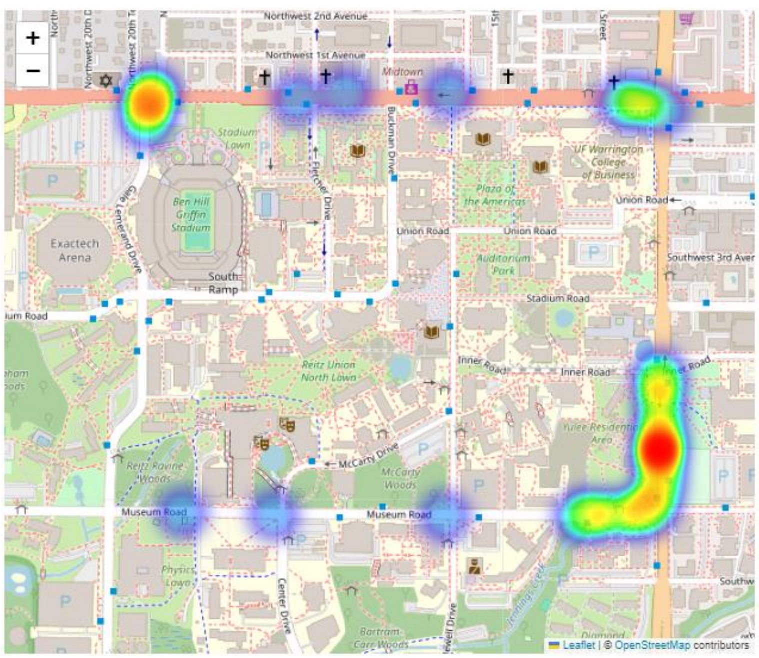


Figure 5-18 – BSMs not received by RSUs in the study area

5.3 Evaluation of the smartphone application

Next, the research team evaluated the smartphone application and its ability to communicate with pedestrians and vehicles in a timely fashion. The FDOT-procured system includes the Glance

Travel Safely (TS) application, which is provided by Applied Information. The app sends information (location, speed, etc.) about the user (motorist, pedestrian, or cyclist) to the Glance Cloud, which forwards this information to the FMUs deployed as hardware in the study area. The FMU is installed in the signal controller cabinet and uses an onboard cellular modem to transmit and receive data from the devices inside the cabinet.

This subsection first discusses the communication system architecture shown in Figure 4-1 and then describes the operation of FMUs and their evaluation. The third subsection introduces the smartphone application and its functionality. The fourth subsection provides the evaluation of the reliability of the communication between pedestrians and vehicles. The fifth subsection describes the evaluation of the reliability of the communication between pedestrians and infrastructure. The last part summarizes the findings and recommendations for improving the effectiveness of the app.

5.3.1 Communication system architecture

In the architecture of the communication system (Figure 4-1), first, information received from pedestrians informs the infrastructure. FMUs receive PSMs from pedestrians using the app through the Glance Cloud via cell connection (4a>5 in Figure 4-1). At intersections, the safety messages received by pedestrians using the app activate the pedestrian pushbutton inputs (through the FMUs, 4a>5>6); similarly, at midblock crossings they activate the flashing beacons.

Second, information received by vehicles and the infrastructure inform pedestrians. At both types of locations, the FMUs forward any BSMs they receive from cameras and vehicles to the Glance Cloud, which alerts app users regarding rapidly approaching vehicles (2>7>5>4a and 1>7>5>4a).

Third, information received by the infrastructure (and indirectly from pedestrians) informs vehicles (from pedestrians to the OBU 4a>5>8>2, from pedestrians to the motorist app 4a>5>4b, and cameras through 1>2). As shown, vehicles may receive pedestrian presence-related warnings either through the OBU or through the app.

The specifics of activating the pedestrian phase at signalized intersections, and activating RRFB at midblock crossings are discussed below:

- **Pedestrian phase activations at intersections:** At intersections, pedestrians can activate the pedestrian phase to let them cross the street in three ways. First, they can press a pushbutton (Figure 4-1, link 9), which uses a direct hardwired signal to physically activate the pedestrian phase. Second, passive pedestrian detection via cameras can detect pedestrians and send this information through V2X to the RSU, which then communicates with the controller to activate the pedestrian phase (1>3 in Figure 4-1). Third, pedestrians using the app can leverage pedestrian-to-infrastructure (P2I) communication through a cloud platform, requiring cellular data service, to send a message to the Glance Cloud. This message instructs another device (FMU) to communicate with the controller and activate the pedestrian phase (4a>5>6 in Figure 4-1).

- **RRFB activation at midblock crossings:** At midblock crossings, pedestrians can activate RRFBs to let them cross the street in three ways. First, they can press a pushbutton (9 in Figure 4-1), which physically signals the system to activate the RRFB. Second, cameras can detect pedestrians and send a message to an RSU, which then communicates with the IO (Input/Output) module to activate the RRFB (1>3 in Figure 4-1). Third, pedestrians with the app can send a message to the Glance Cloud, which tells another device (FMU) to communicate with the controller and activate the RRFB (4a>5>6 in).

5.3.2 Description and evaluation of the FMU operations

FMUs are installed at each location in the study area. FMUs directly connect and trigger pedestrian phases at intersections or activate the RRFBs at midblock crossings. FMUs receive the information regarding pedestrian or cyclist presence from the Glance Cloud. Figure 5-19 provides an image of an FMU used in the study area.

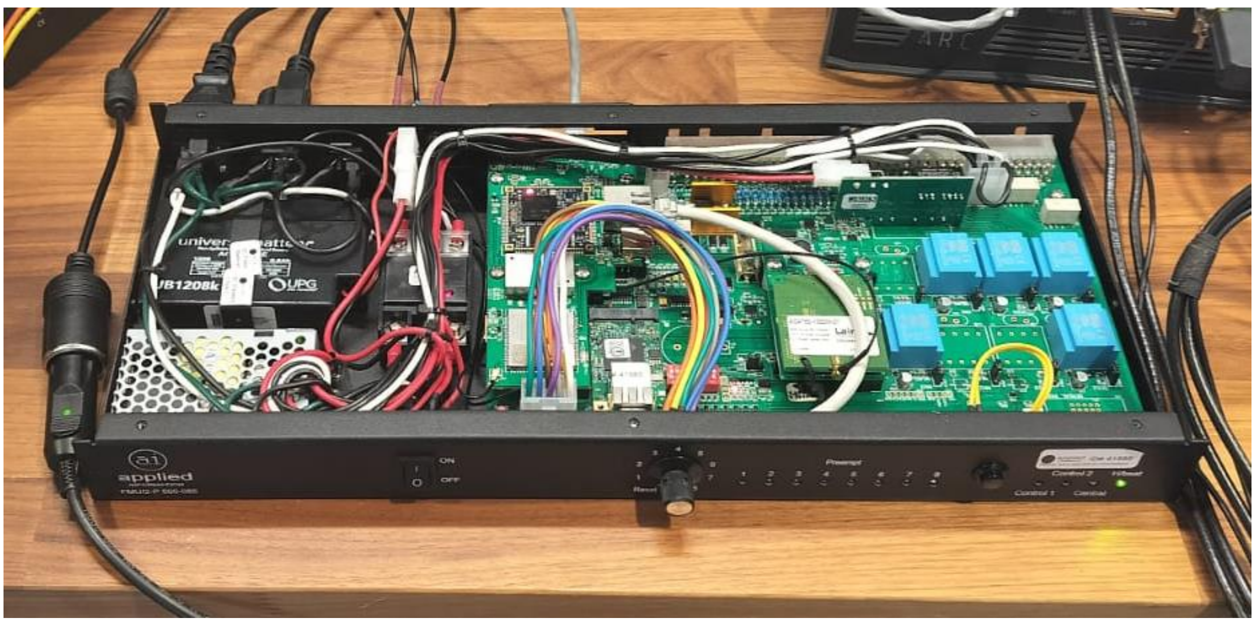


Figure 5-19 – A field-monitoring unit (FMU) used in the study area

The research team evaluated the operational status of FMUs in the study area to ensure they function properly. The Glance portal, which is provided by Applied Information, was used to monitor the operational status of each FMU. Figure 5-20 presents the main page of the Glance portal with the list of intersections and midblock crossings shown on the left side of the screen, and a map of the deployed units on the right side. The portal provides information on the status, alarms, power status, time since last contact, cabinet temperature, battery, humidity, network status, etc., of each FMU. Figure 5-21 illustrates an example of an FMU with offline status and Figure 5-22 shows an example of an FMU with online status. Figure 5-23 provides a screenshot of the log page, which includes communication, diagnostic, and device logs.

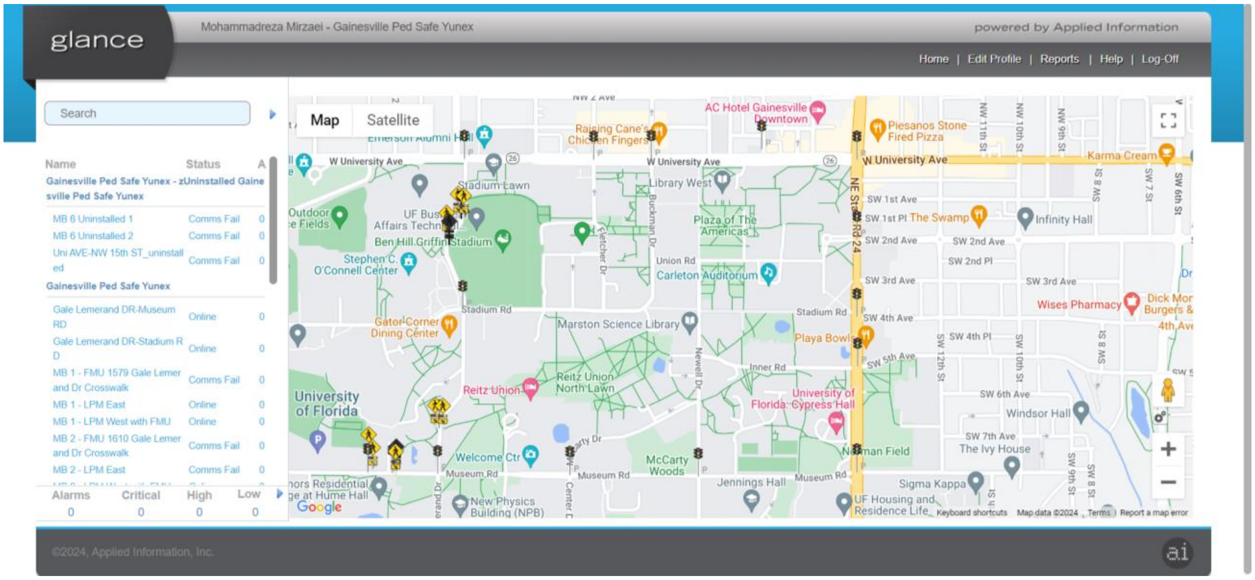


Figure 5-20 – Applied Information Glance portal view and deployment area

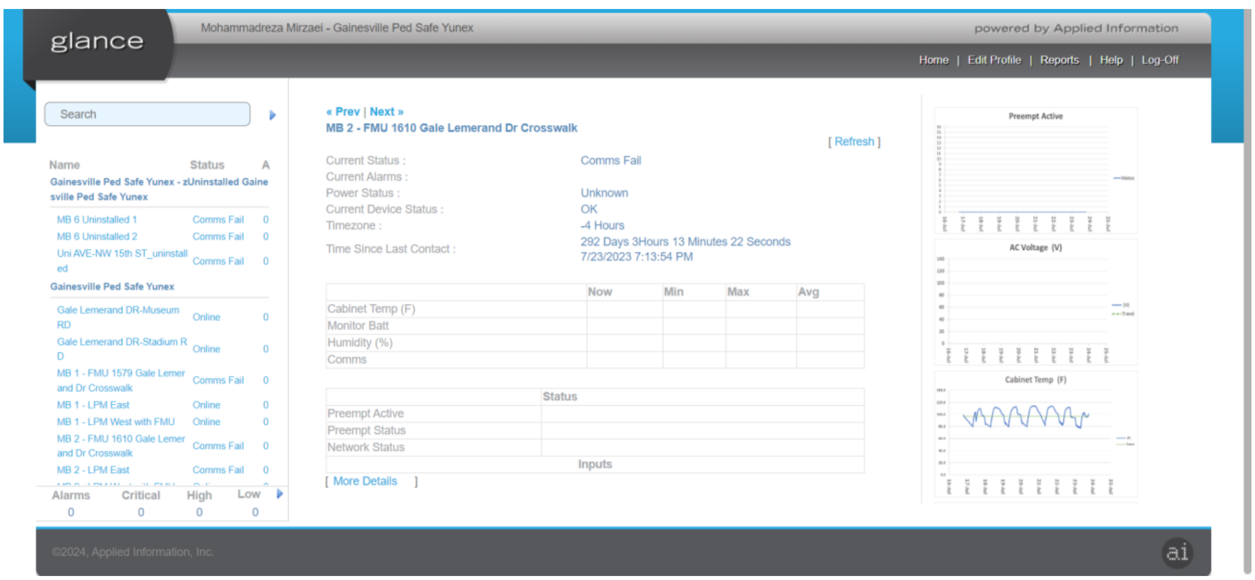


Figure 5-21 – FMU with offline status

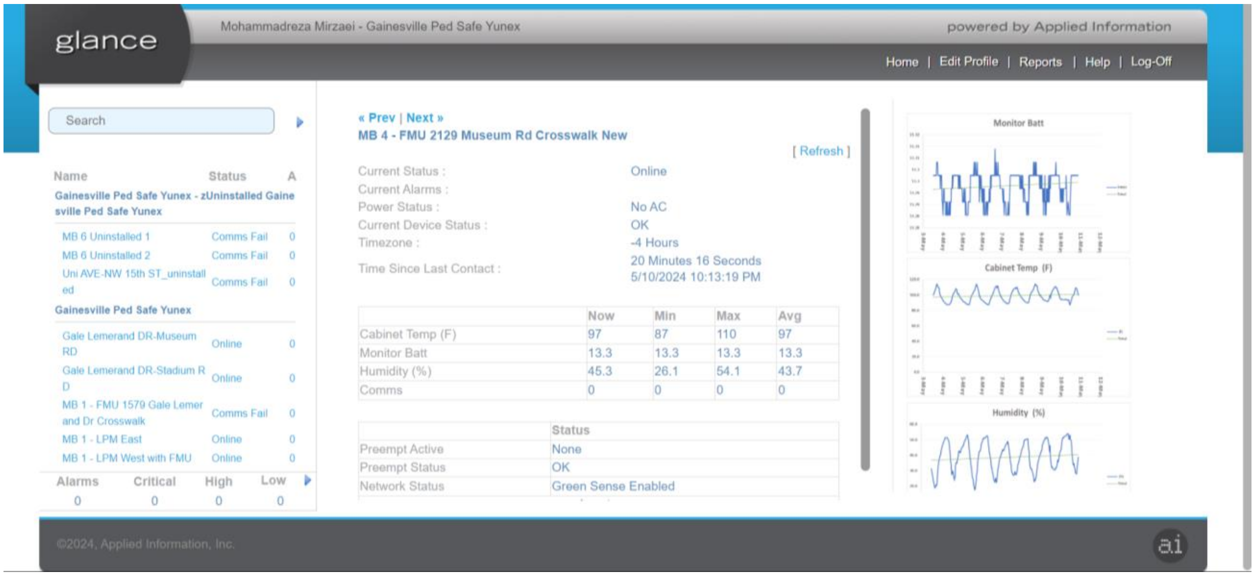


Figure 5-22 – FMU with online status

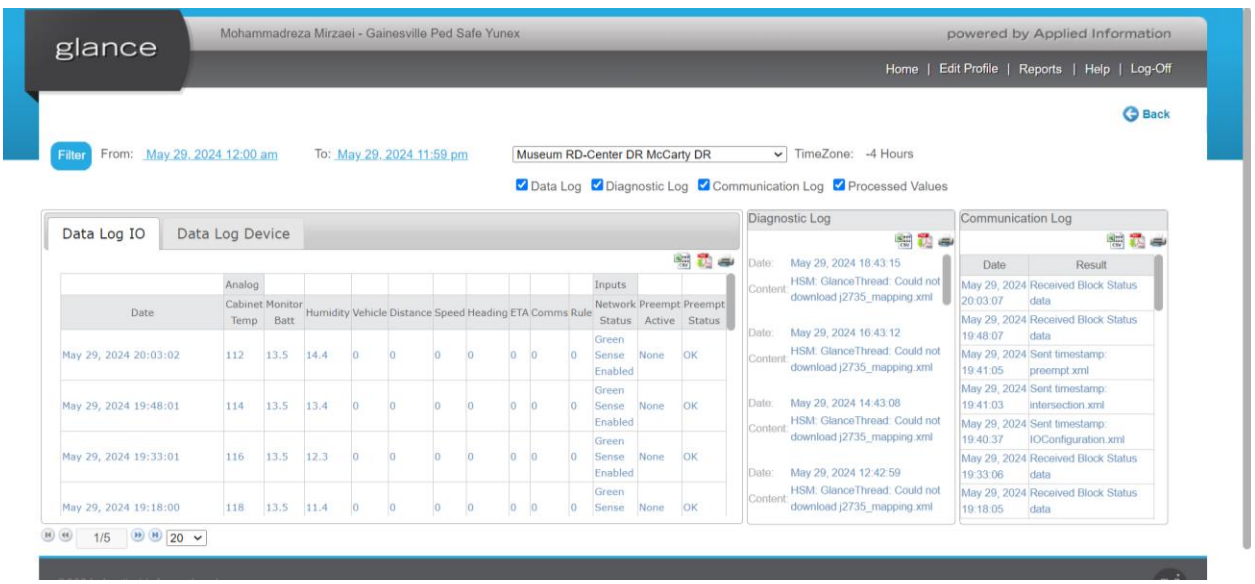


Figure 5-23 – Screenshot of an FMU log page

The operational status of FMUs as obtained from the Glance portal on several days between May 14-29, 2024 (May 14, 16, 20, 23, 29) and July 30th, is presented in Table 5–24 for intersections and Table 5–25 for midblock crossings. The operational status of each device is presented as being in online or offline status. As shown, most of the intersection devices are online (12 out of 13), while most midblock crossing devices are offline (4 out of 5).

Table 5–24 – Operational status of FMUs at intersections in the deployment area

Location	**Operational status-May 29th**	**Operational status-July 30th**
Gale Lemerand Drive @ Stadium Road (S1)	Online	Online
University Avenue @ Gale Lemerand Drive (S2)	Online	Online
University Avenue @ NW 18th Street/Fletcher Drive (S3)	Online	Online
University Avenue @ Buckman Drive/17th Street (S4)	Online	Offline Time Since Last Contact: 7/5/2024 11:37:07 AM
University Avenue @ NW 15th Street (S5)	RMA Stock 40778: Online Uni AVE-NW 15th ST_uninstalled: Offline Time since last contact: 3/2/2024 10:26:22 AM	NW 15th - W University Ave 40778: Online
University Avenue @ SW 13th Street (S6)	Online	Online
SW 13th Street @ Union Road/SW 2nd Avenue (S7)	Online	Online
SW 13th Street @ Stadium Road/SW 4th Avenue (S8)	Online	Online
SW 13th Street @ Inner Road/SW 5th Street (S9)	Online	Online
SW 13th Street @ Museum Road (S10)	Online	Online
Museum Road @ Newell Drive (S11)	Online	Online
Museum Road @ Center Drive McCarty drive (S12)	Online	Online
Gale Lemerand Drive @ Museum Road (S13)	Online	Online

Table 5–25 – Operational status of FMUs at midblock crossings in the deployment area

Location	Operational status-May 29th	Operational status-July 30th
Midblock 1 (C3)	FMU: Offline LPM East & LPM West with FMU: Online Time since last contact: 5/9/2024 8:24:22 AM	FMU: Online LPM East & LPM West with FMU: Online
Midblock 2 (C2)	LPM West with FMU Online FMU & LPM East: Offline Time since last contact: 7/23/2023 7:13:54 PM	FMU: Offline LPM East & LPM West with FMU Online Time since last contact: 7/23/2023 7:13:54 PM
Midblock 3 (C8)	Online	FMU: Offline LPM North & LPM South with FMU: Online Time Since Last Contact : 7/29/2024 2:01:59 PM
Midblock 4 (C7)	FMU & LPM South: Online LPM North with FMU: Offline Time since last contact: 3/17/2024 3:24:16 AM	FMU: Online LPM South & LPM North with FMU: Online
Midblock 5 (C9)	May 16, 2024: Online May 29, 2024: FMU offline LPM East & LPM West with FMU: Online Time since last contact: 5/18/2024 5:20:11 AM	FMU: Offline LPM East & LPM West with FMU: Online Time since last contact: 5/18/2024 5:20:11 AM
Midblock 6 (C5) (Not installed)	Uninstalled-Offline Time since last contact: 10/10/2022 8:21:54 AM	Uninstalled-Offline Time since last contact: 10/10/2022 8:21:54 AM

To address these issues, the research team has been communicating with the vendors. In summary, the following issues have been found to result in offline status:

- FMUs are not supplied with power in some of the midblock crossings but they operate with solar panels (C2, C3, C7, and C8). Their placement in shaded areas with tree coverage prevents them from functioning properly. For example, C3 is usually out of power after midnight and starts working after 8:45 AM in typical weather conditions.
- Some FMUs are under maintenance, and vendors are planning to swap them (C3, and C9)

- The Applied Information team indicated there may be miswiring by Yunex at C2, and C7. Also, the camera at C7 is not configured with the correct information regarding its own longitude and latitude, therefore it does not trigger pedestrian alerts
- Some batteries are not working, and some have insufficient battery charge (C2, and C7)

5.3.3 Description of the smartphone application

The app can be used in three modes: motorist, pedestrian, and cyclist. The user can select the mode manually, or the application can determine it automatically. The research team did not test whether this determination is accurate, as the potential number of scenarios for such an evaluation is extremely large and depends on exact location, speed, surrounding environment, position of the device, etc. Users can enable or disable many options in the app settings while using the application. Users can disable display or audible alerts, and they can record their route while using the application. Additionally, the application has some specialized features, such as a colorblind mode option. Visually impaired people, crossing guards, and construction workers can enable the vulnerable road user option in the application, which sends specific alerts to other users. Furthermore, pedestrians can receive alerts from speeding cars, approaching buses, and emergency vehicles. Motorists have the option to receive alerts regarding pedestrians and cyclists ahead. They may also receive alerts such as approaching red lights, school zones, work zones, etc. Figure 5-24 provides screen shots of the main page and the app settings.

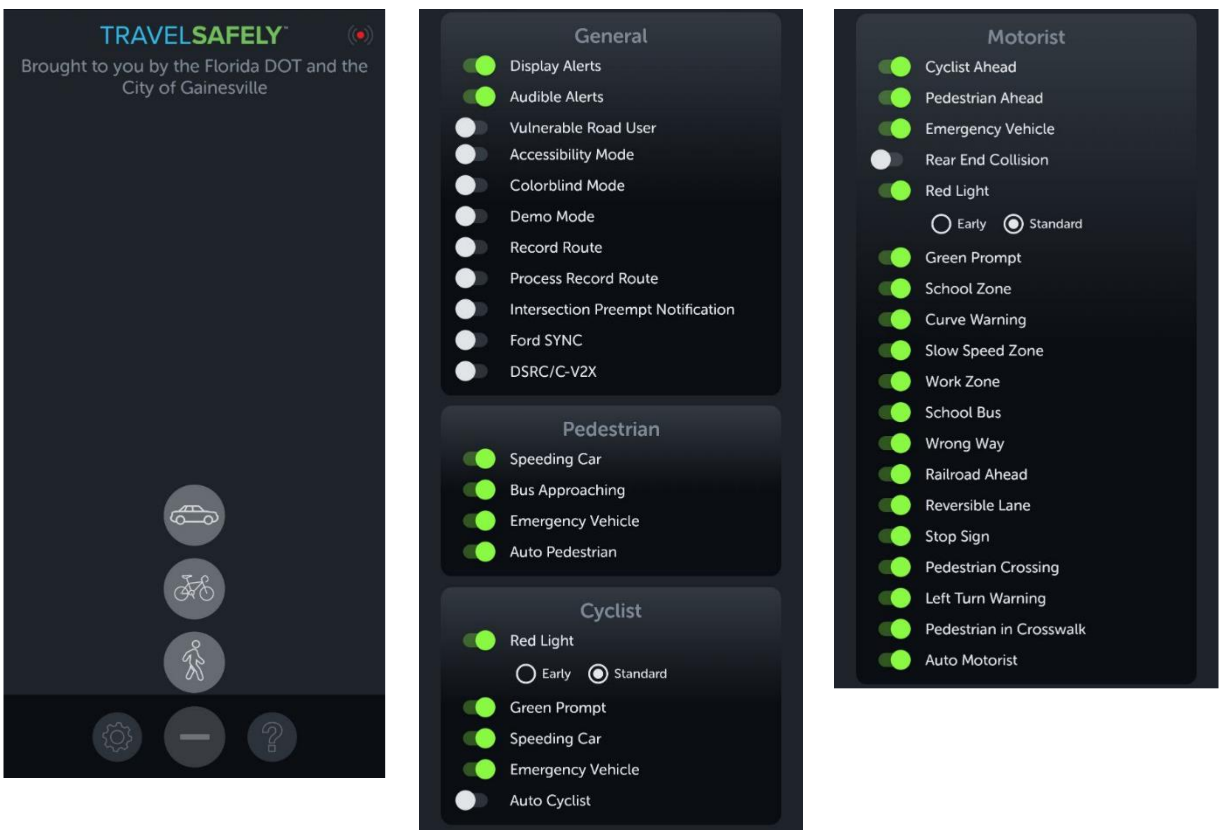


Figure 5-24 - Travel Safely application main page (left) and settings (center and right)

The app sends information about the user activity (latitude, longitude, speed, and heading, etc.) to the Glance Cloud. This information is obtained using the data visualizer. Figure 5-25 shows the data visualizer and messages received in the Glance Cloud.

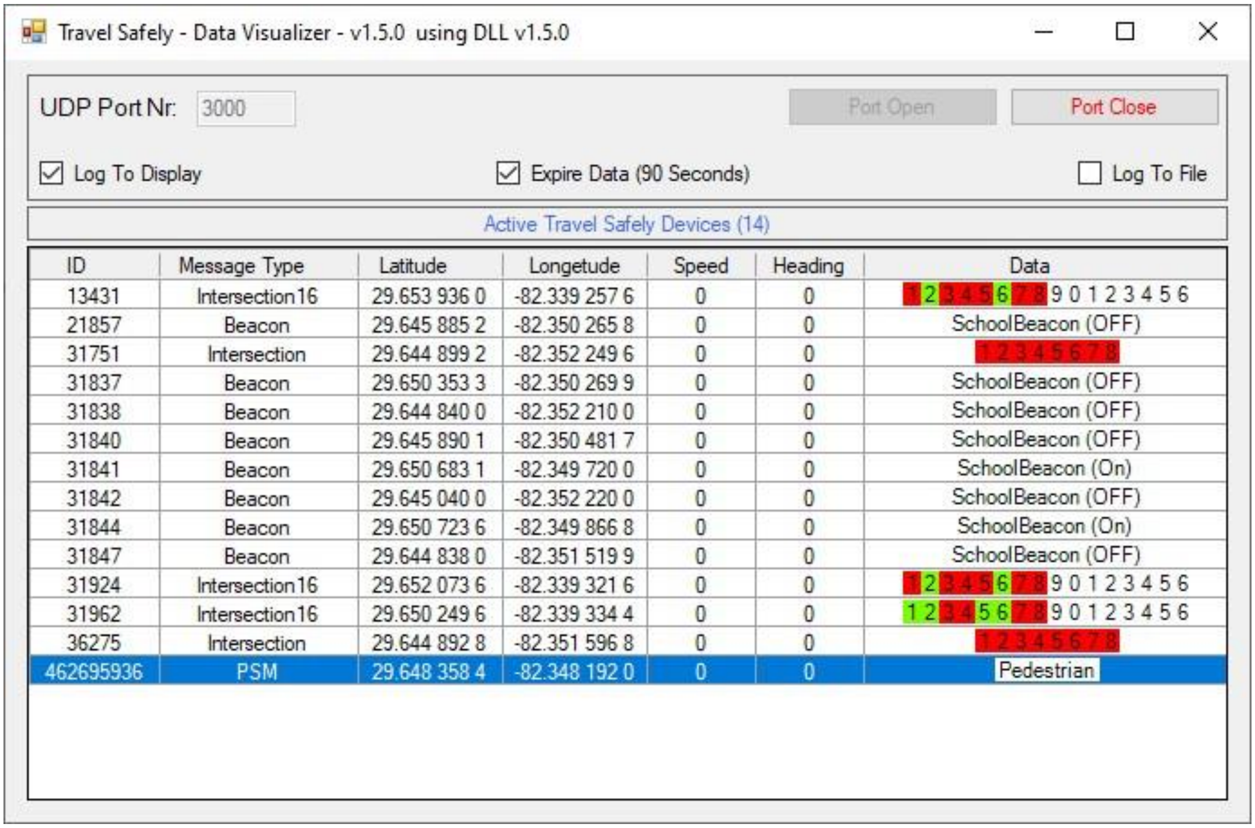


Figure 5-25 – Travel Safely data visualizer in the Glance Cloud

Each message has an ID, message type (intersection, beacon, PSM, vehicle, etc.), latitude, longitude, speed, heading, and additional data based on each message type. For the intersection message type, the data column shows the SPaT information and active green phase. For the beacon message type, the data column shows the status of the RRFB (on, or off). The PSM message type includes pedestrian or cyclist types in the data column. The vehicle message type indicates whether the vehicle is a privately owned vehicle or an emergency vehicle. Table 5–26 shows the message types and their related data types.

Table 5–26 – Received message types and related data types

Message type	Data type
Intersection, Intersection16	'enSPaTMessage'
PSM	'Pedestrian', 'Cyclist'
Beacon	'SchoolBeacon (On)', 'SchoolBeacon (OFF)'
Vehicle	'Neutral', 'Emergency'

The following types of alerts are available in driver, pedestrian, or cyclist mode:

<u>Motorist mode</u>

1. **Signal phasing and timing (SPaT):** Location, traffic light, and time to change in the color of a traffic light are shown in this type of alert (Figure 5-26, left)
2. **Get ready for green:** The app displays a countdown at the red light and verbally notifies the app user approximately five seconds before the light turns green (Figure 5-26, center)
3. **Red light warning:** If the motorist speeds towards a red light, the app will alert them that they are approaching the intersection too fast (Figure 5-26, right). Two settings can be selected in the settings screen for this alarm: the standard mode and the early mode. The early mode provides this warning at a speed lower than that of the standard mode. The speed threshold for standard mode is 48 mph, whereas the speed threshold for early mode is 32 mph. Users selecting the standard mode receive fewer red light alarms than early mode users. The app documentation does not provide specifics regarding the threshold distance from the stop bar, and Applied Information did not provide additional information to the research team regarding this.
4. **Cyclist ahead:** For motorists, the app provides a warning if there is a cyclist on the road ahead. The bicyclist mode is mostly used to activate the bicycle phase in signalized intersections when a group of cyclists approach the intersection. A cyclist receives an alert if they ride along with the vehicle towards it, and a collision is projected (Figure 5-27).
5. **Warnings related to pedestrian presence:** The app provides four types of warnings related to pedestrian presence, depending on the speed of the vehicle and on where the information regarding the pedestrian presence originates.
    a. **Pedestrian ahead:** This warning is provided to motorists when they are traveling at a relatively lower speed (less than 20 mph), if the system projects the vehicle may not be able to stop in time. This warning originates from the infrastructure (Figure 5-28, left)
    b. **Stop (for) pedestrian:** This warning is provided to motorists when they are traveling at a relatively higher speed (above 20 mph) if the system projects the vehicle may not be able to stop. Similarly to the previous warning, this warning originates from the infrastructure (Figure 5-28, right)
    c. **Pedestrian (in yellow):** This type of message originates from pedestrians using the app when the motorist is traveling at a relatively lower speed. This yellow-colored message is provided to motorists as a pedestrian-to-vehicle (P2V)

message, showing that the pedestrian is present near the motorist (Figure 5-29, left)

d. **Pedestrian (in red):** This type of message originates from pedestrians using the app. Similarly to the previous message, it is provided to motorists as a pedestrian-to-vehicle (P2V) message, showing that the pedestrian is present near the motorist when the motorist is approaching the pedestrian at a relatively higher speed (Figure 5-29, right)

Pedestrian and cyclist mode

1. **High-speed vehicle caution:** A yellow alert is received when the vehicle approaches at a fairly high speed a pedestrian with the application, and is likely collide within a few seconds (Figure 5-30, left)
2. **High-speed vehicle:** A red alert is received when the vehicle's speed is exceedingly high and the stopping distance is short, which can cause a collision with the pedestrian (right Figure 5-30, right)

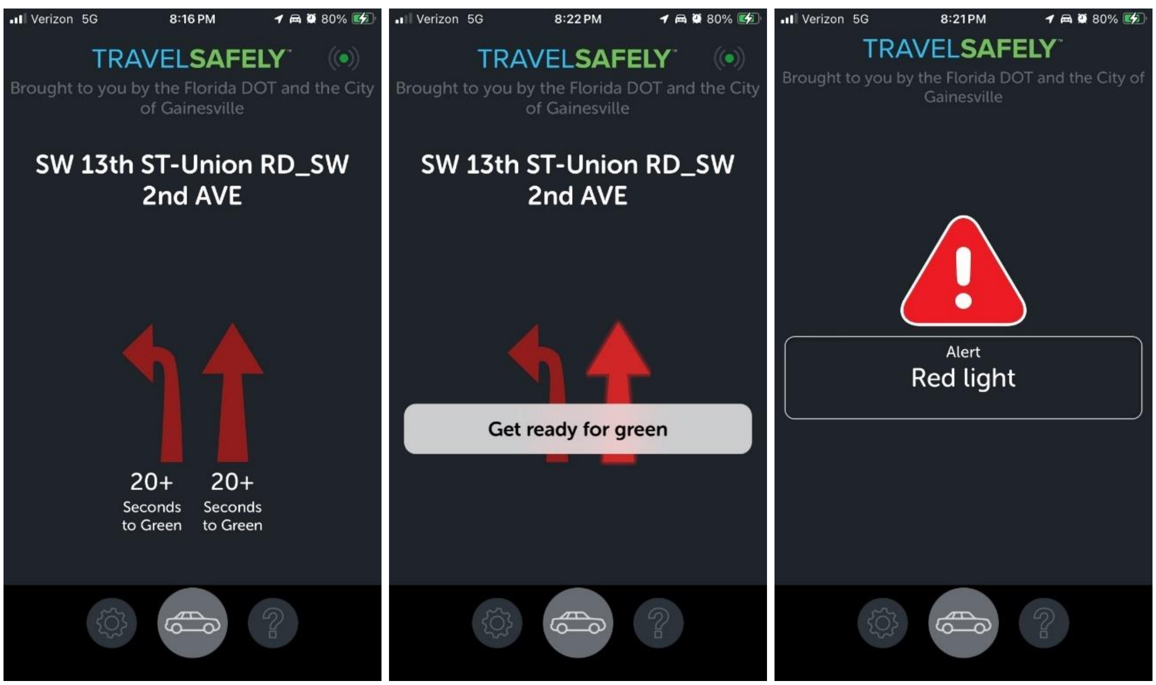


Figure 5-26 – SPaT message (left); Get ready for green (center); Red-light alert (right) in motorist mode

Figure 5-27 – Cyclist alert in motorist mode

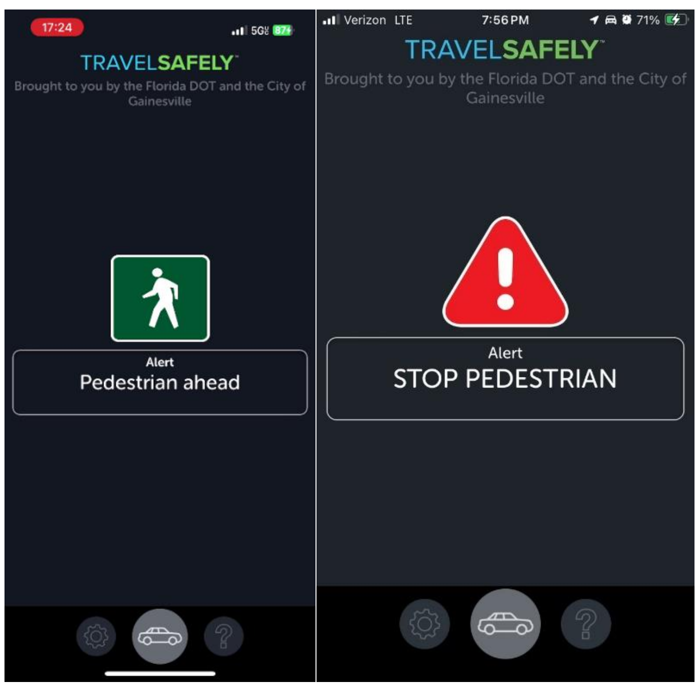


Figure 5-28 – Pedestrian ahead alert (left); Stop pedestrian alert (right) in motorist mode

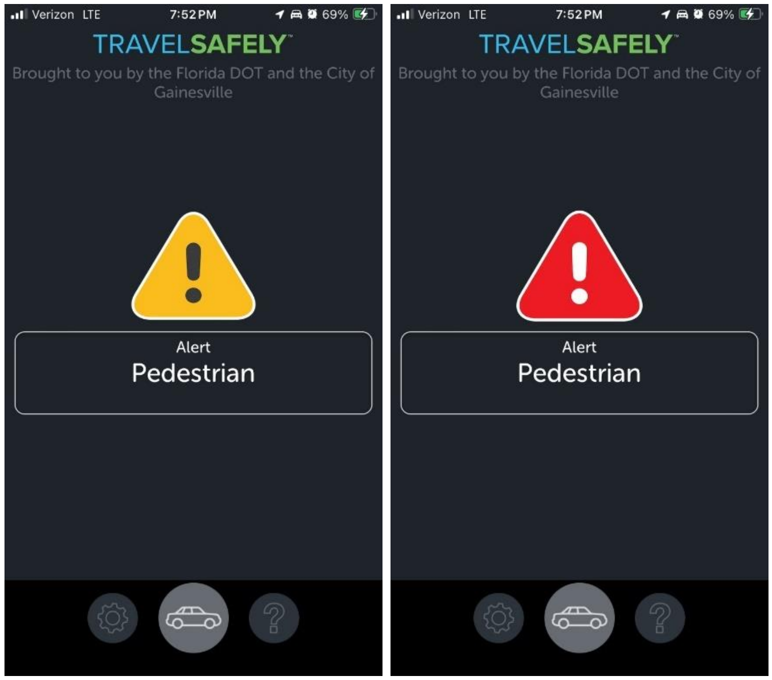


Figure 5-29 – Pedestrian alert in yellow (for lower vehicle speeds, left); and in red (for higher vehicle speeds, right) in motorist mode

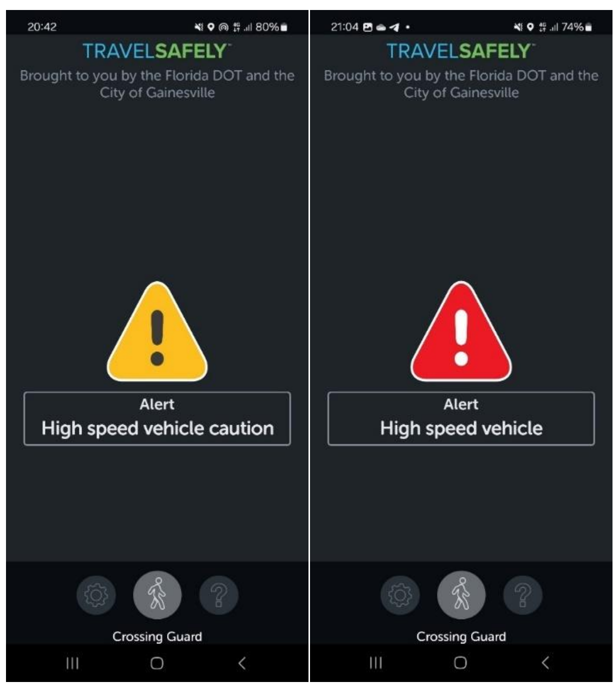


Figure 5-30 – Vehicle alert for lower speeds (left) and higher speeds (right) for both pedestrian and cyclist modes

5.3.4 Evaluation of the communication between pedestrians and vehicles

This subsection summarizes the evaluation of the communication between pedestrians and vehicles with the application. It evaluates the following paths shown in Figure 4-1 and highlighted at the bottom of that figure in light blue:

1. 4a>5>4b: Pedestrians using the application send warnings to vehicles using the application and vice versa.
2. 1>7>5>4a: Cameras detecting vehicles send warnings to pedestrians with the application.
3. 1>8>5>4b: Cameras detecting pedestrians send warnings to vehicles using the application.
4. 2>7>5>4a: Vehicles equipped with OBU send warnings to pedestrians with the application.
5. 4a>5>8>2: Pedestrians using the application send warnings to vehicles equipped with OBU.

For this evaluation the research team conducted several test runs with a vehicle equipped with an OBU and the app, and a researcher/pedestrian present in the field. A researcher/ pedestrian using the app was positioned at an intersection or midblock crossing, while a researcher/vehicle equipped with an OBU and the app drove towards that intersection or midblock crossing.

The app data were obtained through the Glance Cloud using Applied Information's data visualizer (as described in Section 5.3.3). The vendor made these data available to the research team on April 30, 2024. The team also obtained RSU and OBU data during the test runs. During the testing (Spring 2024) Applied Information was not supporting an option to record the received messages in the app. Therefore, the data were only available through the Glance Cloud. In future evaluations, the message transmission reliability between the application and the Glance Cloud can be evaluated faster by developing this option in the app.

The research team conducted four test runs and obtained field observations in the following locations: S4 (University Avenue @ Buckman Drive/17th Street), S7 (SW 13th Street @ Union Road/SW 2nd Avenue), S12 (Museum Road @ Center Drive McCarty drive), and C8 (Midblock 3). The paragraphs below describe each of the tests and our findings for each one. As shown, not all components of the system work as expected, therefore the research team collected data only for the paths working properly at the time of the test.

During the first test run (April 24, 2024), the research team aimed to examine all available paths discussed above (4a>5>4b, 1>7>5>4a, 1>8>5>4b, 2>7>5>4a, and 4a>5>8>2). However, there was no BSM forwarding from RSUs to FMUs (link 7 in Figure 4-1) enabled at any of the locations. To conduct the testing, the UF team requested from the vendor to enable this function. It is not clear why this functionality was not initially enabled and whether this may be an issue under full deployment. In addition, during this first test run, the Glance Cloud data were not available. Therefore, the research team was only able to observe the types of alerts received in the app in both motorist and pedestrian modes (4a>5>4b). The research team determined that SPaT (Signal Phase and Timing) messages were received only at S7 (13th Street and 2nd Avenue-Union Road). SPaT messages in other locations were not being received because the The Applied Information team was not able to translate messages with the SAE J2735 standard (SAE International, 2016) at other locations (the Applied Information system was not compliant with the SAE J2735 standard at these other locations). This incompatibility prevented the application from displaying SPaT information. Note that since then, Applied Information has addressed this issue. Because of these two issues the research team was not able to obtain any quantitative data during the first test.

In the second test run (May 1, 2024), the BSM forwarding was enabled at four locations (S4, S7, S12, and C8), and the Applied Information Glance Cloud data were available. During this test, the research team aimed to examine the same paths as in the previous test run (4a>5>4b, 1>7>5>4a, 1>8>5>4b, 2>7>5>4a, and 4a>5>8>2). However, we observed that the researcher-pedestrian received numerous consecutive “High-speed vehicle” alerts. These can be distracting and result in turning off the app. The research team determined that these alerts were received even when the pedestrian was on the sidewalk, the crosswalk was empty, and vehicles were stopped. The research team speculates that this may result if cameras have trouble accurately detecting vehicles near the stop bars at intersections or if there are delays in sending these alerts. Due to this malfunction, the research team was not able to obtain quantitative results during this second test run.

In the third test run (May 23, 2024), the research team aimed to examine the remaining paths with communication functionality (4a>5>4b and 4a>5>8>2). To test these paths, we first tried to isolate link 8. The research team asked the Yunex team to turn off receiving PSMs from other sources (push buttons and cameras, i.e., links 1 and 3) except those from the Glance Cloud (link 8). In this case, RSUs did not receive any pedestrian presence messages, and no PSMs were recorded in the data, which confirmed that only link 8 was isolated for testing. However, the research team determined that link 8 was not working and vehicles with OBUs could not receive alerts from pedestrians using the application. Despite follow-ups by the research team, this problem was not resolved during the evaluation period.

Therefore, we focused our efforts on the remaining path (4a>5>4b in Figure 4-1). These data were collected during the third and fourth test runs (May 23, 2024 and June 28, 2024, respectively). Table 5–27 summarizes the data collected during these last two test runs. The first column provides the test location, while the second column indicates how many alerts should have been received. The last two columns indicate how many alerts were actually received for the two modes tested. The research team speculates that alerts not received in motorist (100% - 86% = 14%) and pedestrian mode (100% - 79.1% = 20.9%) may be due to the low speed of the vehicle or communication issues, between vehicle and pedestrian apps.

Table 5–27 – Alerts received in the communication between vehicles and pedestrians

Location	Total tests conducted	Alerts received in motorist mode	Alerts received in pedestrian mode
Museum road @ Center Drive (S12)	10	9 (90 %)	7 (70 %)
13th street @ 2nd Ave (S7)	14	13 (92.9 %)	12 (85.7 %)
University Ave @ 17th street (S4)	13	10 (76.9 %)	11 (84.6 %)
Total (Intersections)	**37**	**32 (86.5 %)**	**30 (81.1 %)**
Midblock 3 (C8)	**6**	**5 (83.3 %)**	**4 (66.7 %)**
Total (Intersections and Midblock)	**43**	**37 (86 %)**	**34 (79.1 %)**

5.3.5 Evaluation of the communications between pedestrians and infrastructure

This section discusses the evaluation of the communications from the pedestrians to the traffic signals and midblock crossing RRFBs (through 4a> 5> 6 in Figure 4-1). This feature should send location, speed, and direction alerts to the signal controllers regarding pedestrian activity at signalized intersections and to warning devices at midblock crossings. To accomplish this, the research team would have to obtain the hardware activations (link 6). However, Yunex indicated they were not able to provide us with this number.

Therefore, for this task, the research team only tested the messages sent from pedestrians to Glance Cloud (4a). During the evaluation period (Spring 2024), Applied Information was not recording the sent messages from the app to the Glance Cloud, and only the Glance Cloud data were available. In the future, logging these messages on both sides would allow for a better comparison and evaluation.

The research team collected field data on June 10, 2024, from 8:23 A.M. to 10:00 A.M. A researcher walked from S1 (Gale Lemerand Drive @ Stadium Road) in a clockwise pattern in the study area and then obtained the data (PSMs) recorded in the Glance Cloud during this time. Data from the Glance Cloud include datetime, ID, message type, latitude, longitude, speed, heading, data type (Table 5–26).

Figure 5-31 presents the heatmap of the received PSMs in the study area as obtained from the Glance Cloud. The figure shows that the Glance Cloud captures the presence of the researcher/pedestrian in numerous locations indicating that the application can send information to the Glance Cloud throughout the study area. The app uses a cell connection to communicate with the Glance Cloud and receives signals from the app as long as the cell network is working well. A total number of 4114 PSMs were received during this data collection period.

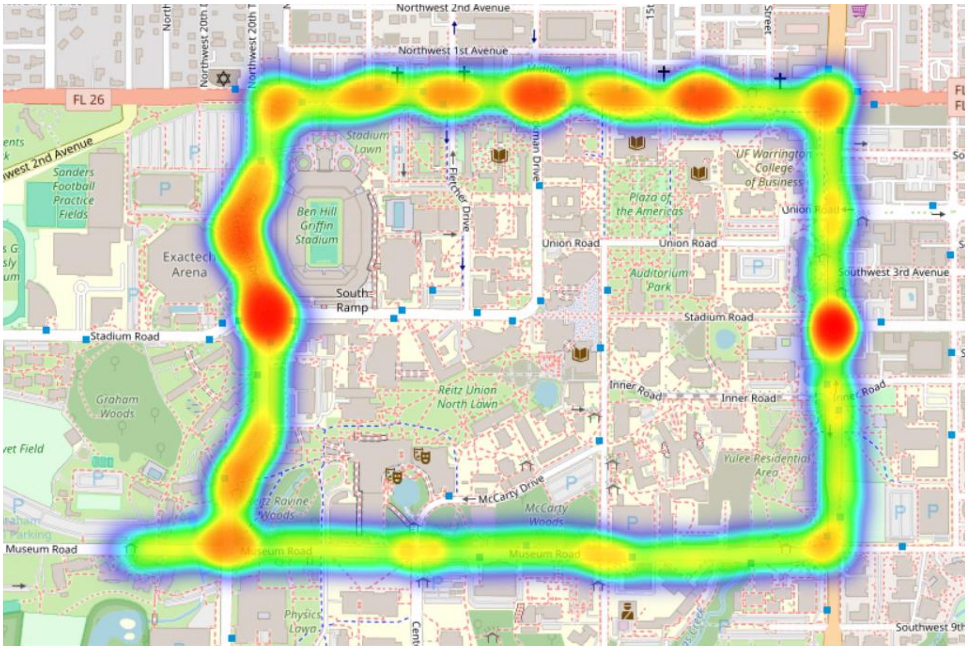


Figure 5-31 – PSMs received within the study area and recorded in the Glance Cloud (June 10, 2024)

During this field observation, the sole user of the application was the researcher as a pedestrian. To confirm that the only data recorded were those of the researcher/pedestrian, and to confirm they were received in the vicinity of the subject location, the research team cross-referenced the timestamps and locations corresponding to the pedestrian's presence at the site at each time interval. To achieve this, we obtained the number of PSMs received <u>during the specific time</u> when the researcher was located within 300 ft of each intersection center point location. We also obtained the total number of messages received within this same time interval anywhere else within the study area, excluding the subject location. The ratio of the two represents the reliability of communication for the location.

The time interval during which the researcher/pedestrian was present at each location, the number of PSMs within this time interval, the total number of PSMs within 300 ft of the location in the time interval, and the reliability of communication for each location are provided in Table 7. As shown, the overall reliability of communications was found to be 99.1 %, with 100 % measured for most locations, confirming that the only user of the application was the researcher/pedestrian. These minor discrepancies could be due to human error in recording times and distances when entering each location in the field.

Figure 5-32 shows graphically the PSMs received at each location. The location markers in the graph are shown in colors corresponding to the device location each message refers to, with each location assigned a random color. Locations shown in white indicate that no messages were received during the time interval when the researcher was present at that location.

Table 5–28 – Times of each location on the map (June 10, 2024)

Location	Researcher/ pedestrian was present from time (AM):	Researcher/ pedestrian was present to time (AM):	Total number of PSMs received	Number of PSMs received within 300 ft	Accuracy %
S1	08:23	08:30	340	340	100
C1	08:31	08:31	50	50	100
C2	08:32	08:33	97	97	100
C3	08:34	08:34	46	46	100
C4	08:35	08:35	47	47	100
S2	08:36	08:39	173	173	100
S14	08:41	08:42	90	90	100
S3	08:43	08:47	209	209	100
S4	08:48	08:52	219	219	100
S15	08:54	08:55	97	97	100
S5	08:56	08:58	115	115	100
S6	09:00	09:05	251	235	93.6
S7	09:07	09:12	246	238	96.7
S8	09:13	09:18	243	243	100
S9	09:18	09:21	139	139	100
S10	09:24	09:27	165	165	100
S11	09:31	09:34	164	164	100
S12	09:38	09:41	168	168	100
S16	09:43	09:43	40	40	100
S13	09:45	09:47	126	121	96.0
C7 & C8	09:48	09:52	211	211	100
C9	09:55	09:55	37	37	100
C10	09:57	09:57	47	47	100
C11	09:58	10:00	81	81	100
Total number of PSMs at intersections and midblock crossings			**3401**	**3372**	**99.1**

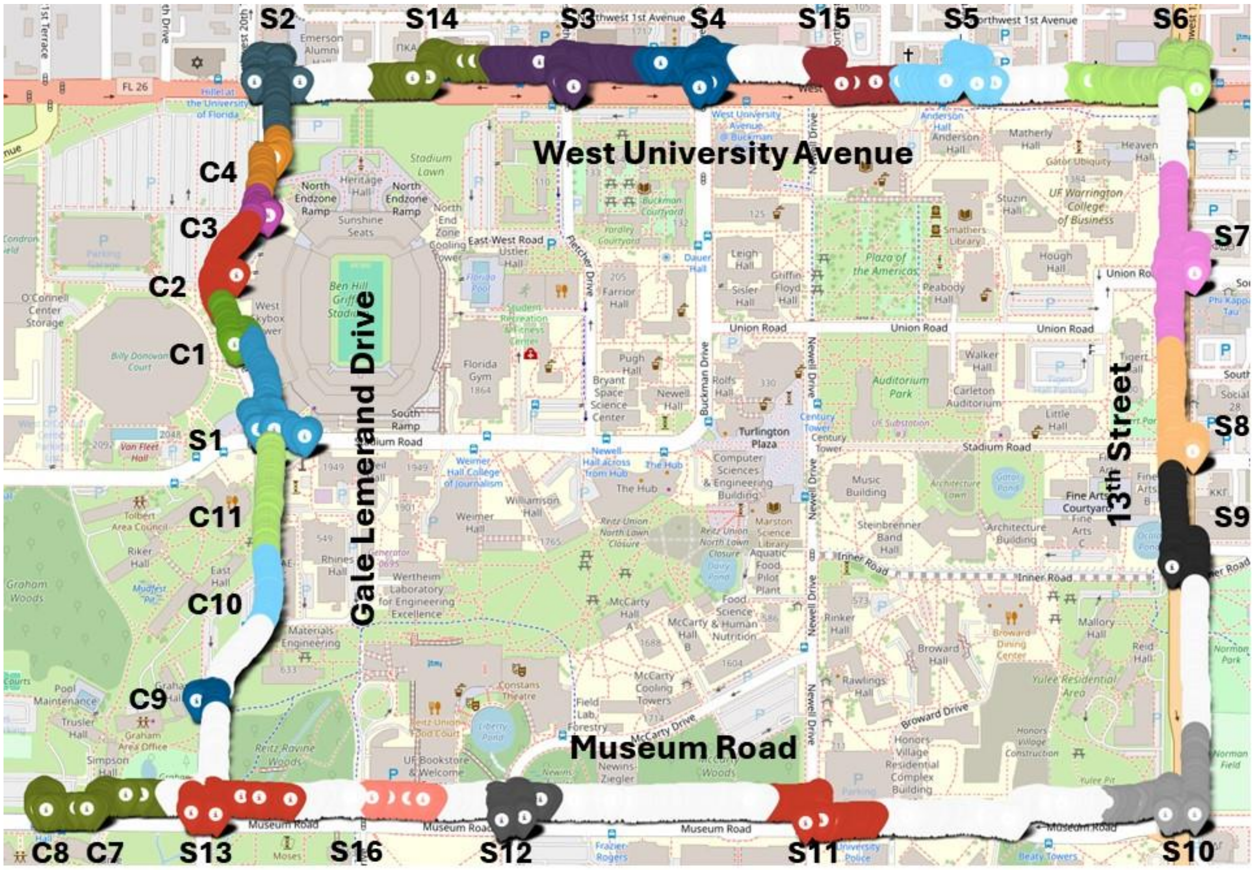


Figure 5-32 – PSMs received at each location and time (June 10, 2024)

5.4 Conclusions and recommendations

5.4.1 Pedestrian detection system

This task evaluated the accuracy of pedestrian detection by calculating the accuracy of each camera under various conditions. The results indicate that the accuracy of pedestrian detection varies widely, ranging from 12.9 to 95.2 percent. The results indicate that S4 and S6 have an average accuracy of approximately 76%, while S2 has 18.6 % accuracy. The cameras perform better on sunny days compared to rainy days. Detection accuracy rises from dawn to mid-day but declines toward dusk. The peak performance was observed between 1 P.M. and 5 P.M., with an accuracy of 82.7%. The pedestrian detection accuracy results highlight several issues that need to be addressed to improve the overall system accuracy. Below are some recommendations and issues identified:

1. The occurrence of numerous false negatives suggests that the pedestrian crossing system is failing to activate the detection zone effectively due to the poor design of detection

areas. This issue could be improved by changing the design of the detection zone to encompass all pedestrians.

2. Considering pedestrian heading direction in detection zone activation could reduce false activations during pedestrian crossings.
3. Rapid movement can sometimes lead to undetected instances. Considering the speed variability in pedestrians, scooters, and bicyclists, the occurrence of false negatives may decrease in detection. Including scooters as a distinct category in detection types is recommended due to their unique behavior compared to pedestrians or cyclists.
4. Many false positives occur during dark periods when the cameras incorrectly identify traffic poles or other objects as pedestrians. Enhancing detection models and algorithms in these scenarios would help address this issue.
5. In addition to detecting pedestrians at corners of intersections, detecting pedestrians on crosswalks and sending warning messages to both drivers and pedestrians should be addressed.

5.4.2 Communication system

The evaluation of message transmission between OBUs and RSUs involved both qualitative and quantitative analyses. The research team found a message transmission reliability of 96.3% within the study area. There was lack of data from two RSUs under maintenance in the third test run (as explained in 5.2.2). Addressing the maintenance issues can further enhance the reliability of the communication system.

Qualitative analysis revealed the percentage of pedestrian alerts received is low when compared to the actual observations when pedestrians were present. Solving detection issues (poor design of detection areas, occlusion, and low performance in dark periods), connection with RSUs and cameras (operation status and maintenance), and issues in midblock crossings such as miswiring, insufficient battery charge, and the placement of solar panels in shaded areas can improve the performance of pedestrian detection and communication systems.

In many cases, the drivers received the pedestrian alerts when the pedestrians were already in the crosswalk or when they were about to leave. This is an important issue that needs to be addressed to improve user perception of the system. The issue may be alleviated by detecting pedestrians on both corners and crosswalks, which may offer a more accurate method for sending warnings to CVs.

Speed limit alerts were received with high accuracy (100 %). To enhance the reliability of signal phasing and timing messages, monitoring the system operational status of equipment, and maintaining them may be beneficial strategies. This approach could potentially alleviate transmission inconsistencies and improve overall message reliability.

5.4.3 Smartphone application

The evaluation of the communication between pedestrians and vehicles and between pedestrians and infrastructure was significantly affected by issues related to installation and maintenance. Given the importance of these issues, we provide first a summary and conclusions related to these topics, and then we provide our conclusions related to system performance. The last part of the subsection provides recommendations regarding maintenance of such a system to increase its reliability.

Conclusions related to installation and maintenance

- The detection zones for the cameras used in the system were not properly defined.
- The FMUs often become non-functional and need frequent maintenance.
- The PSMs are not sent by RSU to FMU directly to enable the driver application to receive pedestrian alerts at the signals as this was not included in the scope of the installation project and the vendors did not activate it. However, the vendors indicated that the FMUs can receive this information indirectly through the signal controller when the pedestrian recall is activated. This may contribute to the delay in the messages being received. Similarly, the PSMs are not sent by FMU to RSU to enable the OBU to receive alerts when pedestrians use the application. Again, the vendors indicated that the RSUs can receive this information indirectly through the signal controller when the pedestrian recall is activated.
- The OBUs display pedestrian alerts with a significant delay (1.3 seconds before the crosswalk on an average of 7 total tests); for example, the alerts appear only after the vehicle has already reached or passed the crosswalk (4 tests from 7 total tests). Alerts should be received at least a few seconds before reaching the crosswalk to avoid collisions.
- Initially, the OBUs did not receive SPaT messages at some locations (S1- Stadium Rd. @ Gale Lemerand Dr.; S6 - W Univ. Ave. @ 13th St.; S8 - SW 4th Ave. @ 13th St.; and S9- SW 5th Ave. @ 13th St.). The vendor addressed this issue, and all the locations became functional for the later part of the evaluation.
- Initially, SPaT messages were not received in the driver application during Task 2 testing. However, the vendor addressed this issue, and all the locations became functional toward the later part of the evaluation.
- There is significant latency (4.4 seconds on average) in the messages received by the drivers using the application. In addition to the equipment issues mentioned above, there are delays due to the time taken for the transmission of GPS and the communication with the Glance Cloud. In addition, GPS updates every second and, according to the vendors, the server being pinged can change (for example Atlanta, Cape Town, and other locations).
- As shown by the operational status of FMUs, even though most intersections are online (12 out of 13), most midblock crossings are offline (4 out of 5). These occur mostly due to insufficient battery charge, solar panels located in shaded areas, incorrect wiring, and the removal of FMUs for repair or exchange. These issues may create significant problems with overall system reliability in future installations and would adversely affect wider deployments of such systems.
- Only a few locations had BSM forwarding (from RSU to FMU) initially enabled; it is not clear why that is the case and whether this may be an issue in future deployments.
- During the evaluation period, vehicles equipped with an OBU could not receive alerts from pedestrians using the app; OBUs received pedestrian presence messages only from camera detections or pushbutton pedestrian phase activations.

- A very high number of alerts were being received in the pedestrian mode at some locations. The research team speculates that the main issue is low accuracy in vehicle detection by cameras.

Conclusions related to system performance

- The evaluation of the communication system between pedestrians and vehicles shows that during a total of 43 tests, the researcher/pedestrian using the app received alerts in 79.1 % of the tests, and the researcher/driver received alerts in 86 % of the tests. The missed alerts may be due to errors in detecting the vehicle and/or the pedestrian or communication delays between vehicle and pedestrian apps.
- The evaluation of the communication system from pedestrians to infrastructure indicates that the Glance Cloud receives messages from researchers/pedestrians across all study locations, as expected. The analysis showed that the overall reliability in communication is 99.1 % when considering all locations within the study area. For some locations, reliability was found to be 100%. We believe that the inaccuracies observed were primarily due to human errors in time recording and estimating distances on-site.
- We were not able to evaluate the following:
    - The reliability of communication between vehicles equipped with OBU and pedestrians using the application (path 2>7>5>4a in Figure 4-1). Since the BSMs from different sources (OBUs and cameras detecting vehicles generating BSMs) were not separated, the alert sources were not evident to the research team when conducting this evaluation.
    - The message transmission reliability between Glance Cloud and FMUs since this data is not logged by the FMUs. (link 5 in Figure 4-1)
    - The communication between FMU and the signal controller (link 6 in Figure 4-1). The source of the pedestrian call was not available to the research team.
    - The reliability of the communication system from infrastructure to pedestrians (path 1>7>5>4a in Figure 4-1). Due to the offline status of FMUs in some locations and the unavailability of data logs from the FMUs , the research team could not conduct this evaluation.
- Overall, the system in its present form has significant drawbacks, and many issues need to be resolved before the system is ready for wider deployment.

In summary we recommend the following to increase system effectiveness:

Recommendations related to installation and maintenance

- Installation of all components should be checked carefully to ensure all components are charged properly.
- Calibration and testing of all cameras should be conducted to ensure they detect vehicles and pedestrians properly.
- Each of the communication components should be tested separately before installation is considered complete. This will help avoid issues with BSM forwarding, and other related system errors.

- Given the complexity of the system and the number of components, regular maintenance and testing is essential to maximize its effectiveness.

Other recommendations

- To facilitate testing, BSMs forwarded from OBUs should be handled distinctly from those forwarded by cameras. Separating messages from different sources (cameras and OBUs) would allow for evaluation of each device (cameras and OBUs).
- The reliability of message transmission between the app and the Glance Cloud can be better evaluated by logging the messages that are sent/received in the smartphone application. Comparing message logs from the smartphone application and the Glance Cloud would provide a better understanding of the reliability of this connection.
- During this evaluation the data logs available through Glance Cloud were not in the SAE J2735 format (SAE International, 2016). To evaluate the reliability of message transmission between the Glance Cloud, FMUs, and RSUs, the research team recommends logging data in the Glance Cloud with the same standard used in RSUs (the SAE J2735). This feature would facilitates matching messages between RSUs and the Glance Cloud or FMUs for future evaluations.

6 User Perception of The System

The primary goal of this evaluation was to assess user perceptions of the Travel Safely app and the overall system. This evaluation focused on the usability, effectiveness, and user acceptance of the technology across different driver populations categorized by age, ability, and preferred mode of travel. The research team assessed the perception and usage of the app using three approaches:

1. **Focus groups**: During the focus groups, the research team presented the app and technologies deployed in the study area and collected participant feedback. This subtask provided the research team with valuable insights to guide subsequent evaluation tasks.
2. **Participant experiments**: In this subtask, the research team recruited participants to test the app on the UF campus. The research team trained the participants in the use of the app, asked them to use it for a minimum of two weeks, and solicited their feedback through a survey and small group meetings. This evaluation examined usability, conformance, unsafe behaviors such as jaywalking, and the overall satisfaction of participants with the app.
3. **Survey**: The research team published a survey and obtained feedback by additional participants from FDOT to further examine the usability of the system.

The following subsections discuss the procedures and results from these three efforts.

6.1 Focus groups

Three focus groups were conducted, with each focus group consisting of seven participants selected to represent diverse demographics and travel preferences. Through these meetings, the research team employed a qualitative approach to gather in-depth insights into user experiences and perceptions.

The following paragraphs describe the participant recruitment process, followed by an overview of the focus group sessions. The third part summarizes the discussions from each session and provides the insights gathered from the focus group sessions.

6.1.1 Focus group recruitment

Participants were recruited using various channels, including advertising through the University of Florida Transportation Institute (UFTI), social media platforms (such as LinkedIn and Facebook groups), and flyers distributed across the UF campus. Researchers conducted initial screening by asking participants a series of questions to assess their eligibility and availability (available in Appendix B). To qualify, participants needed to meet the following requirements and eligibility criteria:

- ✓ Must be 18 years or older
- ✓ Must be a US citizen (due to payment process via UF research participant payment)
- ✓ Have a smartphone
- ✓ Drive, walk, or bike regularly on the UF campus

Participants received a $50 gift card in appreciation for their two-hour involvement.

6.1.2 Focus group sessions

The focus groups followed a four-part agenda:

1. Introduction to the study and the objectives of the focus group meetings (5 min).
2. Participants' experiences on campus (20 min).
3. Description of the app and video presentation of the app in action (15 min).
4. Feedback from participants regarding the app. (40 min).

The detailed agenda can be found in Appendix C

Three focus group sessions were conducted (October 28, 29, and 31, 2024). Each session consisted of seven participants, selected to represent diverse demographics and travel preferences. The research team aimed to include a diverse participant pool by ensuring representation across various demographics, commuting behaviors, and gender. The detailed demographic information for the participants is presented in Table 6–1 to Table 6–3.

Table 6–1 – Demographic information of participants in the focus group held on October 28, 2024

Age	Gender	How often do you drive, walk, or bike in an average week on the UF campus? (days)			How often do you drive, walk, or bike in an average week outside of the UF campus (off-campus)? (days)			Driver's license
		Drive	Walk	Bike	Drive	Walk	Bike	
36-45	Female	4-5	0	1-3	4-5	4-5	1-3	Yes
18-25	Male	0	4-5	6-7	1-3	6-7	6-7	Yes
26-35	Male	4-5	4-5	0	6-7	6-7	0	Yes
26-35	Female	0	4-5	0	6-7	6-7	0	Yes
18-25	Female	0	6-7	0	0	6-7	0	No
18-25	Male	1-3	4-5	4-5	6-7	4-5	1-3	Yes
18-25	Female	0	4-5	0	0	6-7	0	No

Table 6–2 – Demographic information of participants in the focus group held on October 29, 2024

Age	Gender	How often do you drive, walk, or bike in an average week **on the UF campus**? (days)			How often do you drive, walk, or bike in an average week outside of the UF campus **(off-campus)**? (days)			Driver's license
		Drive	**Walk**	**Bike**	**Drive**	**Walk**	**Bike**	
26-35	Female	0	1-3	1-3	1-3	1-3	4-5	Yes
18-25	Female	0	6-7	0	0	6-7	0	No
36-45	Male	1-3	1-3	1-3	4-5	4-5	4-5	Yes
26-35	Female	0	0	4-5	4-5	1-3	1-3	Yes
18-25	Male	1-3	4-5	1-3	6-7	4-5	1-3	Yes
18-25	Female	0	6-7	0	0	1-3	0	Yes
18-25	Male	0	6-7	0	1-3	1-3	0	Yes

Table 6–3 – Demographic information of participants in the focus group held on October 31, 2024

Age	Gender	How often do you drive, walk, or bike in an average week **on the UF campus**? (days)			How often do you drive, walk, or bike in an average week outside of the UF campus **(off-campus)**? (days)			Driver's license
		Drive	**Walk**	**Bike**	**Drive**	**Walk**	**Bike**	
18-25	Female	0	1-3	6-7	0	0	1-3	Yes
26-35	Female	1-3	1-3	0	6-7	6-7	0	Yes
18-25	Male	0	6-7	0	1-3	1-3	0	Yes
18-25	Male	1-3	6-7	0	4-5	1-3	0	Yes
18-25	Female	0	6-7	0	0	6-7	0	No
26-35	Male	1-3	4-5	4-5	4-5	6-7	4-5	Yes
18-25	Male	0	4-5	0	0	4-5	0	Yes

6.1.3 Focus group insights

Participants were initially asked about their experiences walking, cycling, driving, and using bus services both on-campus and off-campus. After presenting the app, their perceptions of the motorist and pedestrian alerts were gathered. The effectiveness of the app in addressing jaywalking was also discussed. Participants were asked about apps similar to Travel Safely and provided feedback on the app's design, layout, helpful features, and any confusing aspects, along with suggestions for improvement. The focus group questions are described in Appendix D. Finally, the participants offered their opinions on advantages and disadvantages of the app compared to traditional traffic signals and flashing beacons. A summary of the participant feedback, based on the focus group questions (described in Appendix E), is provided below.

Walking experience

- Walking on campus feels safer compared to off-campus areas.
- Sidewalks are disrupted by construction zones and often end abruptly.
- Drivers often do not yield to pedestrians, especially when turning right, raising safety concerns. Drivers yield to pedestrians better on campus than off campus.
- High-speed and quiet scooters using sidewalks pose risks to pedestrians.
- Lack of separate bike lanes and sidewalks leads to conflicts between pedestrians, bikes, and scooters.
- Scooters and bikes frequently block pedestrian pathways, causing inconvenience.
- Hot weather, especially in summer, poses challenges for walking.
- Uphill areas are inconvenient and difficult to walk.
- The 15-minute gap between classes creates stress for students trying to get to class on time.
- Assigned parking spaces are located far from destinations, adding to travel time.

Cycling experience

- Cycling feels safer on campus compared to off-campus areas.
- Vehicles frequently drive or park in bike lanes and sidewalks, obstructing cyclists.
- Drivers turning right often overlook scooters and bikes, failing to yield the right-of-way.
- Cyclists prefer riding on sidewalks when bike lanes are unavailable due to safety concerns from vehicle traffic.
- Many cyclists do not wear helmets, raising safety concerns.
- Some bike lanes are not continuous and merge into regular traffic lanes, creating hazards.
- Frequent jaywalking by pedestrians poses additional challenges for cyclists.

Driving experience

- Participants feel safe driving on campus when adhering to the speed limit.
- Some participants avoid driving on campus due to high pedestrian and bicyclist traffic during specific times.
- Drivers are concerned about jaywalking and the unexpected entry of pedestrians into crosswalks.
- Parking availability significantly influences the decision to use a car.

Public transportation experience

- Public transportation (bus) is not reliable on weekends and unpredictable on regular weekdays.
- Buses are frequently overcrowded.
- Some participants prefer walking or biking instead of taking the bus.
- The official “GNV RTS” app is not reliable; the third-party “Navigator” app is more reliable and provides better arrival estimates.
- Participants find it inconvenient to change bus routes to reach their destinations and feel there are not enough routes available.
- There is a lack of crosswalks near some bus stops, posing safety concerns.

Perception of motorist alerts

- Participants believe the app can be distracting.
- The app is seen as beneficial for people visiting unfamiliar areas.
- Integration with navigation apps such as Google Maps is suggested for improved usability.
- Participants expressed the need for a phone mount in cars or on bikes but are concerned it could still be distracting.
- The app could be useful for identifying unmarked crosswalks.
- Signal phasing and timing information could be helpful, though participants noted it might encourage speeding to beat signals.

Perception of pedestrian alerts

- Participants believe pedestrians are unlikely to download the app.
- Vibrations from the app could be misinterpreted and may be distracting.
- The app could be useful in audio mode, especially for individuals with accessibility needs.
- Many participants prefer not to use the app due to potentially annoying notifications.
- GPS accuracy is considered critical for the app's effectiveness.
- Participants mentioned that pedestrians may rely on the app warnings instead of paying attention to the approaching vehicles.

Jaywalking

- Participants believe the app will not effectively reduce jaywalking behavior.
- The higher density of crosswalks on campus makes it easier to cross safely, whereas people are more likely to jaywalk in areas with fewer crosswalks.
- Participants perceive jaywalking to be more common off-campus due to lower traffic volumes. On-campus, high levels of vehicle, pedestrian, and cyclist traffic are believed to discourage jaywalking.
- Overreliance on the app may create safety risks and lead to dangerous behavior.
- People tend to follow others when jaywalking.

Similar applications to Travel Safely

- Geico DriveEasy: Focuses on driver behavior, including monitoring hard stops and phone usage, primarily for insurance purposes.
- Tesla Safety Features: Provides in-vehicle safety alerts and notifications to enhance driver awareness and safety.

App’s design and layout

- The app’s user interface is user-friendly compared to other similar applications.
- It is easy to navigate and use.

- Participants suggested integrating the app with navigation tools such as Google Maps and Waze and displaying tools such as Android Auto and Apple CarPlay or bus service apps to display stops.
- The app should include both light and dark mode options.
- The app could be more accessible as a widget or a floating screen on the main display of phone.

Helpful or confusing features of the app

- The app could be especially helpful at night or at blind spots when it's difficult to see pedestrians.
- The app reduces the need to press pedestrian push buttons, improving convenience.
- The use of "motorist" instead of "driver mode" in the app is confusing when paired with a car icon.
- Alerts change too quickly, making it hard for users to process the information, as participants prefer focusing on their surroundings.
- Participants feel it would be overwhelming to receive that much information at once, and suddenly.

Suggestions to improve the app

- Participants suggested the app could be useful at animal crossings by sending alerts to drivers, helping reduce crash risks.
- The app could display information about accidents, crosswalks, and work zones for improved awareness.
- The app should work on the phone's "Do Not Distract Mode".

Advantages and disadvantages of the app compared to traffic signals and flashing beacons

- Advanced warnings would be more useful, rather than the imminent alerts that the app currently provides.

6.1.4 Focus groups summary and recommendations

This section provides lessons learned and promising aspects from the insights gathered during the focus group sessions. It also provides a list of suggested improvements for vendors to improve the app and the deployed sensors.

Lessons learned

- The app could be more beneficial off campus than on campus. Walking and cycling on campus feels safer than off campus for participants in our focus groups. Driving on campus requires significant attention due to high pedestrian traffic and limited parking. Our participants indicated that the app may be more of a distraction in this case.
- Driver behavior, as well as scooters and bicycles were seen as safety hazards.
- Participants found public transportation and the official bus app unreliable and cited a third-party app as preferred.

- Jaywalking remains a concern, and participants suggested that the app is unlikely to reduce the behavior. Furthermore, pedestrians could rely on the app warnings instead of looking for approaching vehicles.
- Participants find the app could be distracting if it is sending too much information.

Promising aspects

- Participants find the app could be useful, especially for people with disabilities. Additionally, the app could help with visibility at night or at blind spots.
- The app could enhance convenience by eliminating the need to press pedestrian push buttons.
- Providing signal phasing and timing information could be beneficial for drivers, but participants expressed concerns that it might encourage speeding to beat signals.

Suggested improvements and modifications for vendors

- Simplifying and pacing the alerts could enhance usability, as participants find it difficult to process rapidly changing alerts and feel overwhelmed by sudden, excessive information. This approach would allow users to focus more effectively on their surroundings.
- The term "motorist" in the app can be confusing when paired with a car icon; using "driver mode" instead would provide more clarity.
- Vibrations from the app might be misinterpreted or become distracting for users.
- Participants suggested integrating the app with navigation tools such as Google Maps and Waze and displaying tools such as Android Auto and Apple CarPlay, or bus service apps to display bus stops.
- Providing advanced warnings could enhance usability, as the app currently only delivers immediate alerts.
- The app could display information about accidents, crosswalks, and work zones to enhance driver awareness.
- The app could be used to send warnings to drivers regarding animals crossing the road.
- The app should offer both light and dark mode options for user preference.
- Adding functionality as a widget or a floating screen on the main phone display could improve accessibility and ease of use.

6.2 Participant experiments

During this subtask, the research team recruited participants to test the app at the UF campus and solicited their feedback after using the app for at least two weeks. This evaluation considered usability, conformance, unsafe behaviors such as jay-walking, and overall satisfaction of the participants with the app.

The first part discusses the recruitment process, while the second part provides an overview of the sessions conducted. The third part summarizes the results from the participant questionnaires and app usage reports. The last part provides insights gathered from the participant feedback sessions along with recommendations for vendors.

6.2.1 Participant experiments recruitment

To recruit participants for this subtask, researchers reached out to individuals who had previously expressed interest in joining the focus group sessions. A total of 60 individuals expressed willingness to take part in this phase of the study.

Participants were asked to complete the following steps:

- Attend an orientation session and download the app (1 hour, in-person)
- Use the app for two weeks
- Respond to an online questionnaire (30 minutes)
- Attend a feedback session and collect the gift card (1 hour, in-person)

During the participant experiment study, six orientation sessions and five feedback sessions were held. Out of the 60 people invited, 45 attended the orientation session and completed all steps of the study. In appreciation for their 2.5 hours of involvement, participants received a $75 gift card. Table 6–4 shows the list of orientation and feedback sessions including the number of participants in each session. The feedback sessions questions are provided in Appendix E.

Table 6–4 – Orientation and feedback sessions

Session	Date and time	Number of participants
Orientation 1	Wednesday, November 6, 9:30 AM - 10:30 AM	9
Orientation 2	Thursday, November 7, 1:30 PM - 2:30 PM	9
Orientation 3	Thursday, November 7, 4:30 PM - 5:30 PM	15
Orientation 4	Tuesday, November 19, 4:30 PM - 5:30 PM	5
Orientation 5	Thursday, November 21, 4:30 PM - 5:30 PM	3
Orientation 6	Friday, November 22, 12:00 PM - 1:00 PM	4
Feedback 1	Monday, December 2, 2:30 PM - 3:30 PM	12
Feedback 2	Tuesday, December 3, 12:00 PM - 1:00 PM	13
Feedback 3	Wednesday, December 4, 1:00 PM - 2:00 PM	7
Feedback 4	Thursday, December 5, 12:30 PM - 1:30 PM	11
Feedback 5	Thursday, December 12, 12:00 PM - 1:00 PM	2

6.2.2 Participant experiments sessions

The participant experiment consisted of four parts:

- Part 1: Orientation session (1 hour, in-person)

The session began with an introduction to the purpose of the study and the technology being evaluated.

  - Discussed confidentiality and obtained consent.
  - Participants were asked to mark the intersections and midblock crossings they most frequently use within the study area.
  - Introduced the research team and the purpose of the participant experiments.
  - Explained the participant experiment process and the importance of participant feedback.
  - Researchers presented the app, demonstrating its features and functionality.
  - Q&A
  - Participants installed the app, created an account, and verified the default settings of the app.
  - Participants were prepared for field observations using the app. They were divided into two groups: one acting as pedestrians and the other as drivers (passengers in a car).
- Part 2: Using the app for two weeks
  - Participants were asked to use the app in their desired mode of transportation (drive, bike, walk) for a two-week period after orientation sessions.
- Part 3: Responding to an online questionnaire, shown in Appendix F
  - An online questionnaire was prepared and shared with participants after using the app for two weeks. Participants filled out the questionnaire before joining the feedback sessions.
- Part 4: Attending a feedback session and collecting the gift card (1 hour, in-person)
  - Feedback sessions were conducted to obtain more detailed feedback on using the app.

6.2.3 Participant experiments questionnaire results

This section presents the results from the participant experiment questionnaire (shown in Appendix G), which aimed to gather feedback on the user experience with the app after the testing period. This online questionnaire focused on various aspects, including usability, user satisfaction, safety concerns, and overall impressions.

The results of the participant questionnaire provide insights into the app's impact on user behavior, safety perceptions, and overall experience. While the app showed promise in certain areas, such as increasing safety awareness and providing timely alerts, the feedback highlights several key insights and challenges:

Usage Patterns: Participants’ responses showed varied usage with the app, with some using it consistently over the two-week period while others’ use was limited. The frequency of received alerts was generally low, with most participants receiving between 1 and 5 alerts.

Effectiveness: Participants perceived the app as serving drivers more effectively than pedestrians and cyclists. They regarded RRFBs as the most effective traffic safety technology, while they gave mixed reviews to the app.

Safety perceptions: Although most users perceived that midblock crosswalks with flashing beacons improved safety, they had mixed opinions on whether the app reduced unsafe behaviors, such as jaywalking or failing to yield. Many participants remained neutral or disagreed with the app's effectiveness in this regard.

Compliance: The participants indicated that the app had minimal influence on improving their compliance with walk/don't walk signals, with 80% of respondents reporting no change in their compliance levels.

Distraction: Nearly half of the participants (44.4%) found the app distracting, citing issues such as app malfunctions, inaccurate alerts, and the need to troubleshoot while in motion, which raised safety concerns.

Satisfaction: User satisfaction with the app was mixed. While 40% were somewhat satisfied, a significant portion reported dissatisfaction or remained neutral.

Advantages and disadvantages: Participants noted benefits such as increased safety and timely alerts, but also highlighted technical issues, inaccurate alerts, and battery consumption as drawbacks.

Detailed responses gathered from participants are provided in Appendix G.

6.2.4 App usage during the test period

The research team tracked the usage of the pedestrian and bicycle app during the participant experiment (Task 3.2) using weekly reports provided by the vendor. Figure 6-1 and Figure 6-2 show a sample of the app usage weekly report from November 25, 2024, to December 2, 2024.

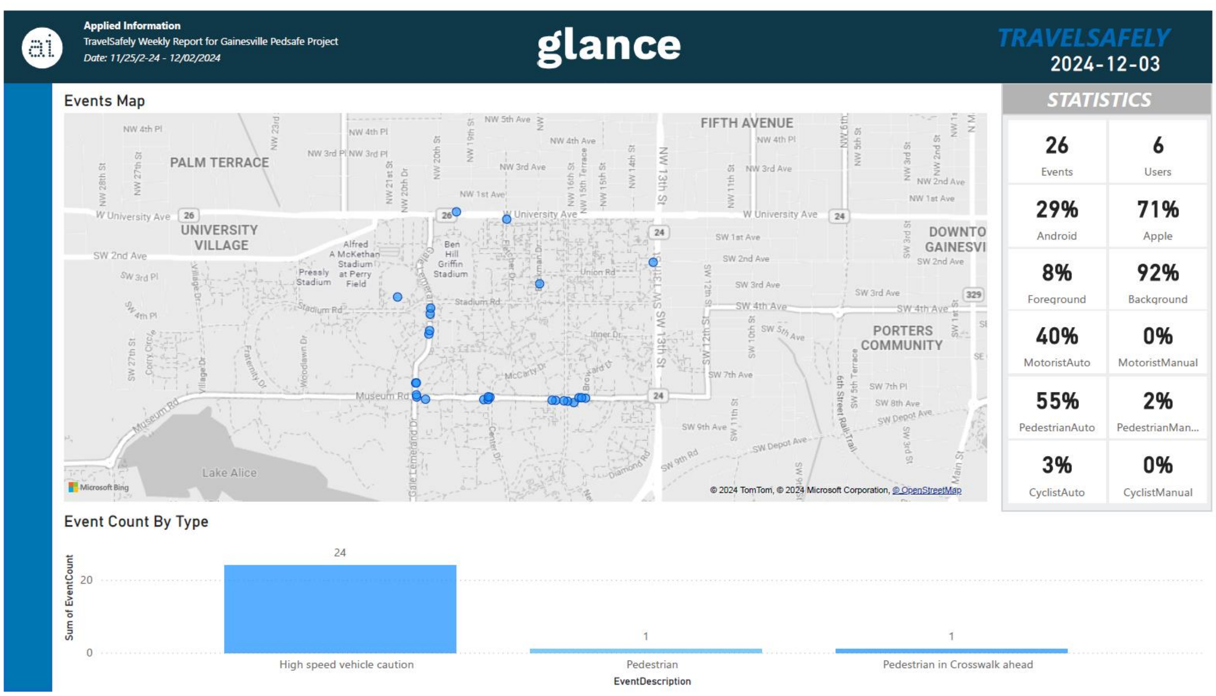


Figure 6-1 – The app usage weekly report view (statistics and map)

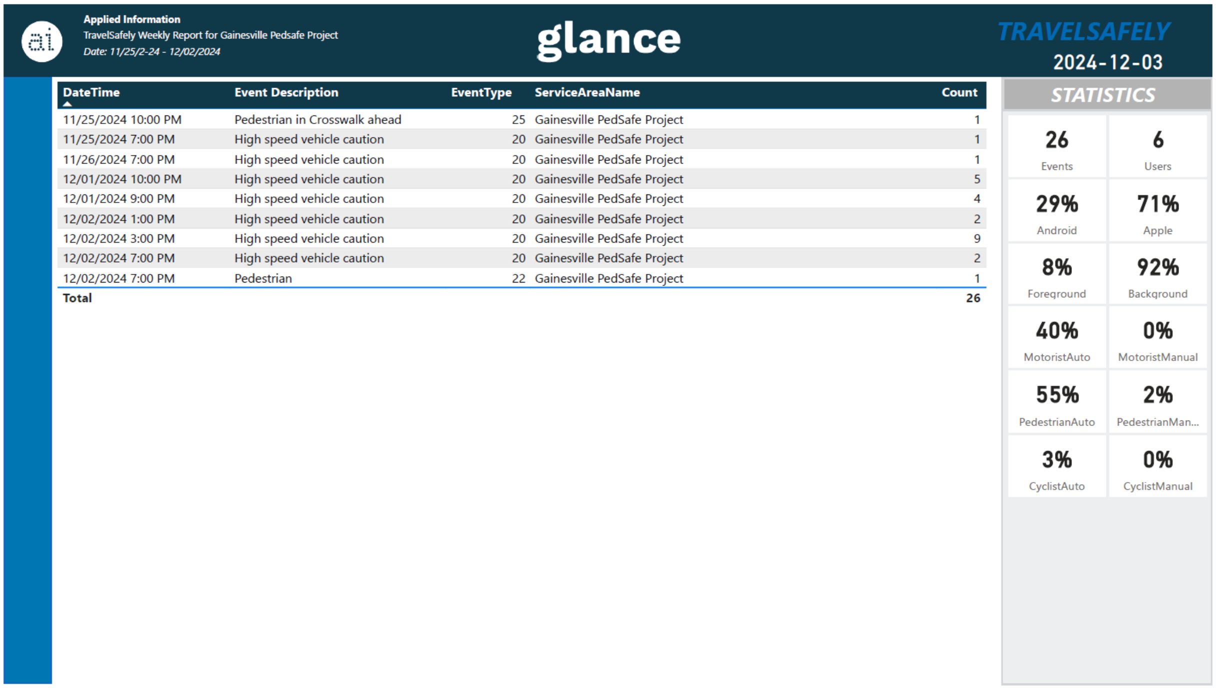


Figure 6-2 – The app usage weekly report (alert page)

Throughout the participant experiment period, the research team monitored the app's usage through weekly reports provided by the vendor. Table 6–5 summarizes the results from these reports over a four-week period. The summary includes the total number of events and unique users, the distribution of operating systems (Apple or Android), the percentage of app runtime spent in foreground and background modes, and the proportion of usage for each mode (motorist, pedestrian, cyclist). The app allows users to either manually select their mode of travel or rely on automatic detection based on their speed. The usage percentage for each mode is reported separately based on whether it was selected manually or detected automatically.

Table 6–5 – Summary of app usage reports during the test period of participant experiments

Dates (in 2024)	**Nov 4-10, 2024**	**Nov 11-17, 2024**	**Nov 18-24, 2024**	**Nov 25 - Dec 2, 2024**
Events	202	41	81	26
Users	22	21	23	6
Operating system (%) Apple	77	83	73	71
Operating system (%) Android	23	17	27	29

Dates (in 2024)	Nov 4-10, 2024	Nov 11-17, 2024	Nov 18-24, 2024	Nov 25 - Dec 2, 2024
Run time (%) Foreground	95	96	6	8
Run time (%) Background	5	4	94	92
Pedestrian (%) (Auto)	61	70	48	55
Pedestrian (%) (Manual)	17	6	6	2
Motorist (%) (Auto)	11	23	18	40
Motorist (%) (Manual)	11	0	23	0
Cyclist (%) (Auto)	0	0	4	3
Cyclist (%) (Manual)	0	0	1	0

The report summary indicates that most users accessed the app using Apple devices. During the first two weeks, participants predominantly operated the app in the foreground, whereas in the last two weeks, it was primarily used in the background. Pedestrian mode accounted for the highest proportion of usage among participants.

A comparison between the weekly usage reports and the number of participants attending orientation sessions indicates a discrepancy in app usage. Assuming the vendor's reports are accurate, the data indicates that participants did not use the app as frequently as they reported in the questionnaire. Specifically, 32 participants attended orientation sessions during the first two weeks (see Table 6–4), yet the maximum number of active users recorded in the same period was only 22 (see Table 6–5). This error may arise from participants not using the app correctly during the orientation session and the test period, or from inaccuracies in the vendor's report. When the research team inquired about this issue, the vendor stated that the report was accurate on their end.

6.2.5 Participant experiment insights gathered during in-person meetings

This section summarizes insights from feedback sessions on the app. These were categorized based on users' experiences while walking, cycling, and driving, overall impressions on the app's design, feedback on app features, suggestions for improving the app, and advantages and disadvantages of using the app.

Walking experience and perception of pedestrian alerts

- Some participants indicated they activated the flashing beacons but were unsure whether it was due to the app or camera detection, while others could not activate the beacons at all, and automatic triggering did not work.
- Participants found the app useful for visually impaired, color-blind, or disabled individuals, as well as for night detection and small children, although having a smartphone could be a challenge for children.
- Some participants received false alerts while they were inside nearby buildings to the study area, such as the Physics Building and Anderson Hall.
- Participants reported that the app failed to recognize cars in the inner lanes of the road.
- Participants indicated that they received audio alerts, but the sound was loud and inconvenient without headphones, especially at intersections and midblock crossings when there are a lot of people present, and participants did not feel it was convenient using the app in those situations.
- Participants indicated the app could be beneficial for tourists and other people unfamiliar with an area. They indicated that the app may be helpful during football game days.

<u>Cycling experience and perception of cycling alerts</u>

- Participants indicated they faced difficulties holding their phones and suggested the need for phone holders in cars or on bicycles. Several participants indicated they had to hold their phones in their hands to notice alerts, which they found inconvenient.
- Participants recommended adding bicyclist-to-bicyclist and pedestrian-to-bicyclist alerts for improved safety.

<u>Driving experience and perception of motorist alerts</u>

- Participants believed the app would benefit drivers more than pedestrians and cyclists.
- Participants felt less safe as the app could shift their focus to the phone, making them rely on technology instead of staying aware of their surroundings.
- Users found signal timing countdowns useful. Inconsistent signal light changes were noted as an issue.
- Participants reported the app turned off when using Google Maps, causing interruptions.
- Users found the alerts inconsistent, experiencing them as dangerous or scary. For example, they received a "Red light alert" while turning left on a major road with a green light, or a "High-speed vehicle" alert as a pedestrian when no vehicle was present.

<u>App's design and layout</u>

- Participants found the interface simple and user-friendly.
- Users experienced different screens and alerts on Android and Apple phones during orientation sessions, leading to inconsistencies.
- Users indicated they were unsure if the app is functioning properly when the screen showed no activity.

<u>Helpful or confusing features of the app</u>

- Participants reported the app frequently switched between motorist, pedestrian, and bicyclist modes, causing distractions.

- Participants using the app in background mode reported it did not work well.
- Participants felt the app did not significantly improve safety.
- Participants found signal timing countdown useful, but they also indicated it may encourage drivers to accelerate before the green light, potentially causing conflicts with pedestrians.

Suggestions to improve the app

- Optimizing the app's performance to use less battery. Participants noticed high battery usage and overheating of phones while using the app.
- A countdown timer for pedestrians, similar to drivers, could improve usability.
- Integration with Google Maps or OpenStreetMap, especially for unfamiliar users, as the app does not work simultaneously with Google Maps.
- Alerts could be displayed on car systems like Apple CarPlay and through pop-ups or widgets.
- Participants found the app's settings were not intuitive. The app should include explanations of modes and instructions for first-time users on how to enable different features.
- Participants suggested the app could be useful for insurance companies.
- Participants recommended syncing alerts and vibrations with smartwatches.
- Participants suggested adding speed alerts or providing speed and distance information to the existing alerts.

Advantages and disadvantages of the app

Advantages:

- Participants found the app useful since it eliminates the need to touch push buttons at crossings.
- Some participants feel safer as the app encourages awareness and attention to their surroundings.
- Some participants think that these alerts could assist planners in identifying safety hotspots and high-risk areas for crashes.

Disadvantages:

- Participants experienced distractions caused by frequent alerts and mode switching.
- Participants reported inconsistent alerts, including failure to detect pedestrians, delayed notifications, or missed alerts.

6.3 Pedestrian and bicyclist safety survey

A survey was conducted via Google Forms to evaluate user safety perception from the app that warns pedestrians and drivers about possible conflicts, and we received three responses. The results are shown in the Appendix H, **Error! Reference source not found.** to **Error! Reference source not found.**. Although the sample size was small, the findings suggest that:

- Users primarily used the app during the morning peak.
- Most users could not activate the RRFBs at midblock crossings.
- Willingness to use the app after training varied greatly among respondents.
- Most participants rated their satisfaction level as neutral.
- The main advantage identified was increased safety, while the main disadvantage was technical issues.
- All participants found the app distracting.
- Most participants reported following other pedestrians when jaywalking.
- All participants complied with walk/don't walk signals at intersections, but only some complied at midblock crossings.
- Most participants indicated that the app had no effect on their compliance with walk/don't walk signals.

Most participants felt somewhat safer at midblock crosswalks with a flashing beacon.

6.4 Summary and recommendations

This section presents the lessons learned and promising aspects derived from the insights gathered during the focus groups, feedback sessions, and survey. After that, we provide a list of the essential modifications that need to be implemented in the system to proceed with further implementation. The last part lists suggestions for further improvements, which are desirable but not essential.

6.4.1 Lessons learned

Participants felt the app could be more useful for drivers, but it introduced distractions, especially when alerts were inconsistent or when users were reliant on the app instead of focusing on their surroundings.

Participants mentioned during the group feedback sessions that they would likely use the app after the study period. However, their responses to the participant questionnaire indicated that they are not inclined to use the app once the study period ends. The responses during the in-person feedback sessions may have been influenced by "group think" effects.

6.4.2 Promising aspects

The participants suggested that the app has the potential to enhance awareness for visually impaired, color-blind, and disabled individuals, as well as for night-time detection and children, but the challenges of holding a smartphone remained a concern. Other promising aspects include the following:

- Some participants indicated the app may be beneficial for tourists and people unfamiliar with an area, particularly during busy times like game days.
- Participants indicated the app would benefit drivers more than pedestrians and cyclists.
- The app's design was praised for its simplicity.

- The app helps some participants feel safer by encouraging them to stay more aware and attentive to their surroundings.
- Participants considered the app useful because it removes the need to touch push buttons at crossings.
- Users found signal timing countdowns useful.

6.4.3 Essential modifications that need to be implemented in the system for further implementation

The participants generally found the app unreliable and indicated they would be unlikely to use it beyond this experiment. The following is a summary of items that must be resolved to facilitate wider implementation:

- Resolve issues with inconsistent, false, and late alerts, ensuring they provide accurate and timely information.
- Solve automatic mode-switching issues to avoid confusion and distractions for users.
- Optimize the app's performance to reduce battery consumption, as participants reported high battery usage and phone overheating during use.
- Improve the app's performance when running in the background to ensure consistent functionality and uninterrupted user experience, particularly when using other apps such as navigation tools.
- Address the issue of information overload by adopting a more balanced approach to alert frequency and content. Many participants reported feeling overwhelmed, as alerts change too quickly, making it challenging to process the information effectively.
- Simplify app settings and provide clear instructions for new users to better understand features and modes inside the application.
- Clearly communicate the app's operational status to users. Currently, users remain uncertain about whether the app is functioning correctly when the screen displays no activity, despite the presence of a network icon indicating connectivity to the infrastructure.
- Improve audio alerts to ensure they are user-friendly in crowded areas. Participants noted that the alerts were too loud and inconvenient to use without headphones, particularly at intersections and midblock crossings. Consider implementing adjustable volume settings or alternative alert methods to make the feature more practical.
- Replace the term "motorist" with a more intuitive label, such as "Driver Mode," to align with the car icon and reduce user confusion.
- Focus on improving detection accuracy to better identify pedestrians and activate RRFBs.

6.4.4 Additional recommendations for desirable but not essential features

In addition to the essential modifications that need to be implemented for wide deployment, participants provided a list of other desirable features, which are summarized below:

- Integrate the app's alerts with car systems (e.g., Apple CarPlay), smartwatches, and navigation apps (e.g., Google Maps) for better usability.

- Introduce a countdown timer for pedestrians, similar to the one for drivers, to enhance usability.
- Provide speed and distance information to users regarding potential conflict points while receiving alerts. This would help users better understand the urgency of the situation and allow for more informed decision-making.
- Add alerts for bicyclist-to-bicyclist and pedestrian-to-bicyclist interactions to enhance safety.
- Provide real-time information about accidents, crosswalks, and work zones to enhance user awareness and improve overall safety.
- Add features that could benefit other industries, such as insurance companies, by offering data on safety hotspots or driving behavior.
- Include both light and dark mode options to accommodate user preferences and lighting conditions.
- Make the app more accessible by providing a widget or floating screen on the main display for easy access.

7 Usability

This section discusses the usability of the app based on user perception via an on-line survey. A total of 45 participants completed the usability questionnaire to capture their experiences with the app, including usage patterns, alerts received, and satisfaction. The on-line survey questions are provided in Appendix I.

The results suggest that the usage varied widely, with some participants reporting no use and others using the app up to 10 days during the two-week period. Most participants received only one to five alerts, while nearly 27% reported receiving no alerts. About a quarter successfully activated RRFBs without push buttons, though almost half did not attempt this feature.

Perceptions of the app's usability were mixed. The interface was generally seen as intuitive, with 45.5% of participants rating it as such, though 18.2% found it confusing. Effectiveness ratings varied across road users: the app was perceived as most useful for drivers, moderately effective for pedestrians, and least effective for cyclists, who largely reported that their perception of the app is neutral or ineffective. Continued adoption appeared limited, as more than half of the participants indicated they were somewhat or very unlikely to use the app after the study.

Satisfaction levels also reflected mixed results: 40% were somewhat satisfied, but nearly 30% were somewhat dissatisfied, and another 27% were neutral. Reported advantages included increased safety (66.7%) and timely alerts (44.4%), while disadvantages centered on technical issues (44.4%), inaccurate alerts (42.2%), and battery consumption (33.3%). Although a majority of respondents did not find the app distracting, 44.4% cited concerns related to malfunctions, inconsistent alerts, and reduced situational awareness.

The complete results of the questionnaire are provided in Appendix G.

8 Safety

To evaluate the effects of the installation on the network safety, the research team conducted a crash analysis using historical data and compared crashes observed in the "before" period (which includes data from 2014-2018), to those in the "after" period (which includes data from 2021-2023). The "before" period was analyzed in a previous project (BDV31-977-120). To conduct that part of the analysis the research team visited each intersection and midblock crossing and provided an overview of the study location. However, since that time several changes have been made to several intersections and midblock crossings (change in signalization at intersections, number of lanes, one-way lane conversions etc.). For example, S14, S15, and S16 were unsignalized intersections in the "before" period but have since become signalized. Also, the number of midblock crossings has increased. Recent field observations of the study area identified sixteen (16) signalized intersections and ten (10) midblock crossings.

Therefore, the first subsection provides field observations for the "after" conditions. The second subsection presents the crash analysis for the "after" conditions and the third subsection provides the comparison between the "before" and "after" conditions. The last subsection presents the near-miss analysis using video observations.

8.1 Field Observations

Over the past few years, UF, in collaboration with CoG and FDOT, has undertaken a range of infrastructure and traffic improvements aimed at enhancing pedestrian safety across and around the campus including (University of Florida, 2024):

- One-way traffic conversions and bicycle enhancements:
    - New one-way patterns were introduced on NW 18th Street (southbound) and NW 17th Street (northbound), alongside modifications to Fletcher Drive, which now carries one-way northbound traffic up to University Avenue. These changes also create dedicated space for new bicycle lanes and signals.
- Signal upgrades for pedestrian protection:
    - Since 2021, new traffic signals were installed at key intersections along University Avenue, specifically at NW 16th Street (S15) and NW 19th Street (S14). Also, an unsignalized intersection was converted to a signalized intersection at Museum Road and Reitz Union Dr. (S16).
- Elevated crosswalk installations:
    - To enhance safety and visibility, two raised pedestrian crosswalks have been constructed. One is positioned at the main entrance to Ben Hill Griffin Stadium, and the other is immediately west of NW 14th Street. These crosswalks are now signalized and equipped with overhead lighting. These are built at sidewalk level, offering barrier-free access for all users and acting as traffic-calming measures by reducing vehicle speeds.
- Street lighting enhancements:

    - There is expanded and upgraded street lighting around the study area to improve conditions for both drivers and pedestrians, especially during nighttime hours, reducing the risk of collisions and enhancing overall safety perception.
- Additional network modifications:
    - Lowered speed limits (20 mph on campus), supported by increased signage to reinforce compliance.
    - Recalibrated signal timing to better manage traffic speeds and reduce pedestrian delays.
    - Tree trimming to improve sightlines and enhance visibility at intersections.
    - Installation of signage at the intersection of University Avenue and 13th Street (S6), explicitly instructing turning drivers to yield to pedestrians.

These changes are likely to affect safety and operations, making "before" and "after" comparisons difficult to attribute solely to the pedestrian warning system being evaluated.

Field observations of both signalized intersections and midblock crossings were conducted on September 29, 2024. Photos and notes documenting "after" conditions are provided in Appendix I, and Appendix J.

In summary, the following were observed:

- Several intersections now include bike signals, which in some cases increase pedestrian wait times.
- Accessibility issues were noted, such as trash bins obstructing pushbuttons or pushbuttons not working.
- Spillback and congestion were observed, especially at intersections near West University Avenue.
- Enhanced pedestrian safety measures were implemented at midblock crossings, including new signs, pedestrian islands, and flashing beacons.
- At some crossings, drivers failed to yield or drove above speed limits, raising safety concerns.
- Certain intersections now allow diagonal pedestrian crossings, improving accessibility.

8.2 Motorists and pedestrian and bicyclist crash analysis

Next, the research team analyzed crashes for the "after" conditions using historical crash data, focusing on pedestrian and bicyclist incidents, and compared the "before" to the "after" conditions crashes. The analysis was conducted for each corridor, by day of the week, and by time of day.

8.2.1 Crash data collection

The crash data analysis involved retrieving crash reports from January 1, 2021, to December 31, 2023, from the Florida Department of Highway Safety and Motor Vehicle (FLHSMV) via the Signal Four Analytics Database. The data are categorized into pedestrian and bicyclist incidents and were analyzed based on various factors including time of day, day of the week, location, severity, contributing factors, traffic control devices, at-fault party, maneuver, light condition, weather conditions, road surface conditions, and whether the crash was related to alcohol, distractions, drugs, or speeding. Data were also collected for up to 250 feet along cross streets intersecting the study corridors. Crashes involving sidewalk riding are classified as pedestrian since Florida statute recognizes that a bicyclist riding on sidewalks or crosswalks has the same rights and duties as a pedestrian (Florida Legislature, 2019). This analysis followed the methodology established in the previous project BDV31-977-120, which utilized data from May 2014 to May 2019 (Elefteriadou et al.,2023).

Table 8–1 provides a summary of crashes in the study area from January 1, 2021, to December 31, 2023.

Table 8–1 – Summary of crashes within the study network (January 2021 to December 2023)

Crash Type	Total Crashes	Fatal	Incapacitating	Others
All Mode	574	2	6	566
Vehicle	538	0	4	534
Pedestrian	22	2	2	18
Bicycle	14	0	0	14

Figure 8-1 shows where pedestrian, bicycle, and vehicle crashes occurred within the study area. These locations include signalized intersections (marked by a traffic light symbol), midblock crossings (marked by a pedestrian walking icon), and other areas like unsignalized intersections (marked by a red circle). The crashes at each intersection are formatted as Pedestrian/ Bicycle/ Motor Vehicle. For example, at the intersection of West University Ave and Gale Lemerand Dr, the sequence "5/1/129" indicates that from 2021 to 2023, there were 5 pedestrian crashes, 1 bicycle crash, and 129 crashes involving only vehicles. The three intersections with the highest number of pedestrian crashes are located along 13th Street, whereas the intersections with the most bicycle crashes are situated on Museum Road. Among the top three intersections for vehicle crashes, two are on 13th Street and one is on West University Avenue. This pattern differs from the findings of the previous study (BDV31-977-120), which identified all three high-crash intersections as being located on 13th Street.

Within the study area including cross streets, in the span of three years there were 533 vehicle crashes, 23 pedestrian crashes, and 14 bicycle crashes. There are on average 180 crashes per year, 10% of which involve a cyclist or a pedestrian. Pedestrians account for 100% of the fatality and 33% of the incapacitating crash counts. The total number of crashes was reduced compared to the previous study period from May 2014 to May 2019 of 220-240 crashes.

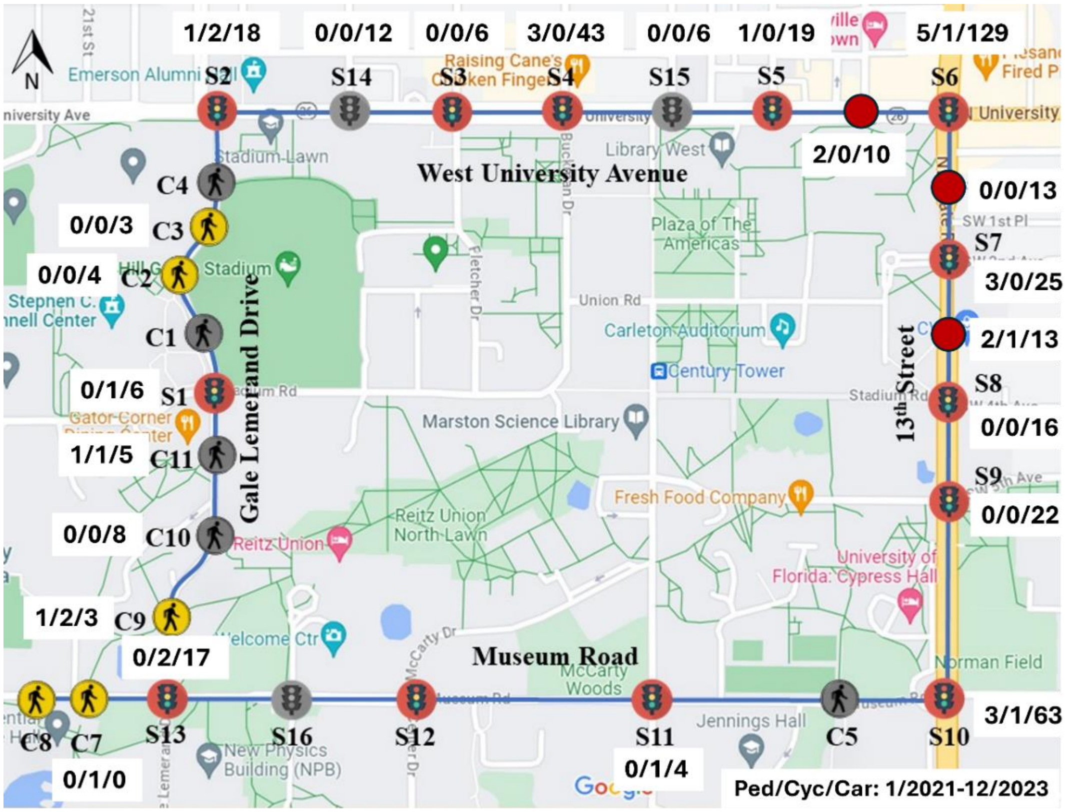


Figure 8-1 – Distribution of crashes along study corridors from 2021 to 2023

Figure 8-2 shows the pedestrian and bicycle crashes between 2015 and 2023.

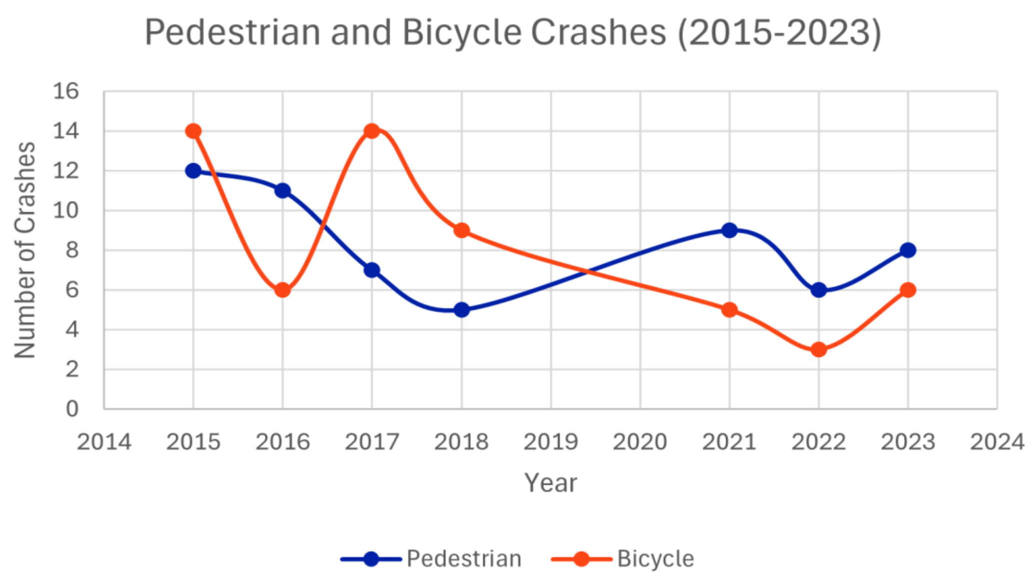


Figure 8-2 – Pedestrian and bicycle crashes from 2015 to 2023

8.2.2 Pedestrian crash analysis

Table 8–2 and Figure 8-3 show the number of pedestrian crashes along the four study corridors by year. Again, these results are based on the data obtained in the previous project (BDV31-977-120) 4, which utilized data from May 2014 to May 2019. Table 8–2 represents a summary of crashes in the study area from January 1, 2021, to December31, 2023. Compared to the previous study period, the number of crashes on Gale Lemerand Drive and West University Avenue remain the same, 13th Street sees more crashes, and Museum Road sees fewer crashes.

Table 8–2 - Pedestrian crashes by year

Year	Gale Lemerand Drive	West University Avenue	13th Street	Museum Road	All Roads
2015	3	6	1	2	12
2016	2	5	3	1	11
2017	1	1	1	4	7
2018	1	1	0	3	5
2021	1	4	4	0	9
2022	0	2	4	0	6
2023	1	2	4	1	8

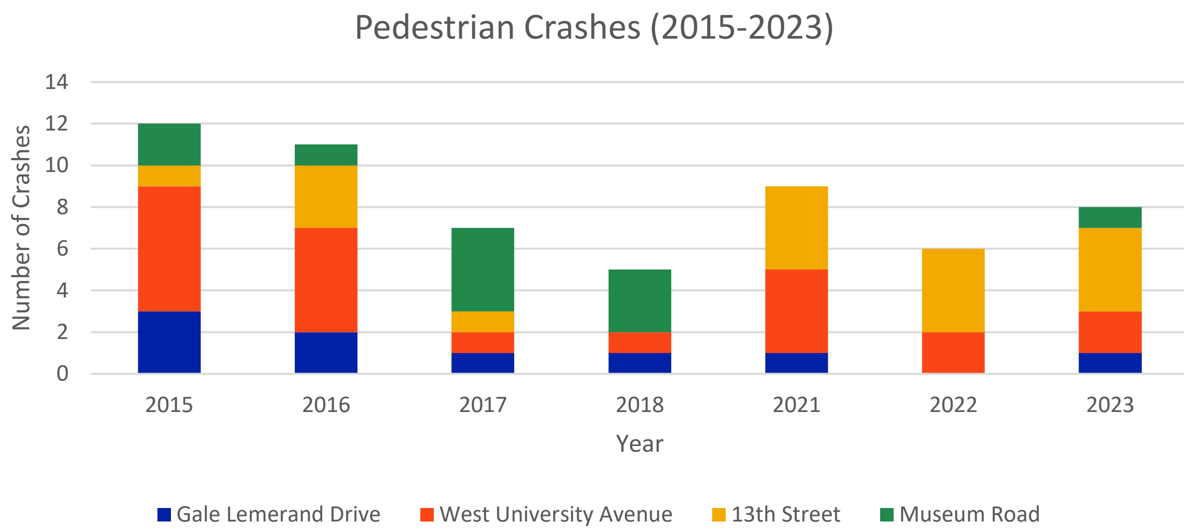


Figure 8-3 – Pedestrian Crashes by year

Figure 8-4 shows the distribution of pedestrian crashes by day of the week. Monday has the highest number of incidents, totaling 6, with incidents on all streets except Museum Road. Overall, the trend indicates crashes are more likely to occur on weekdays.

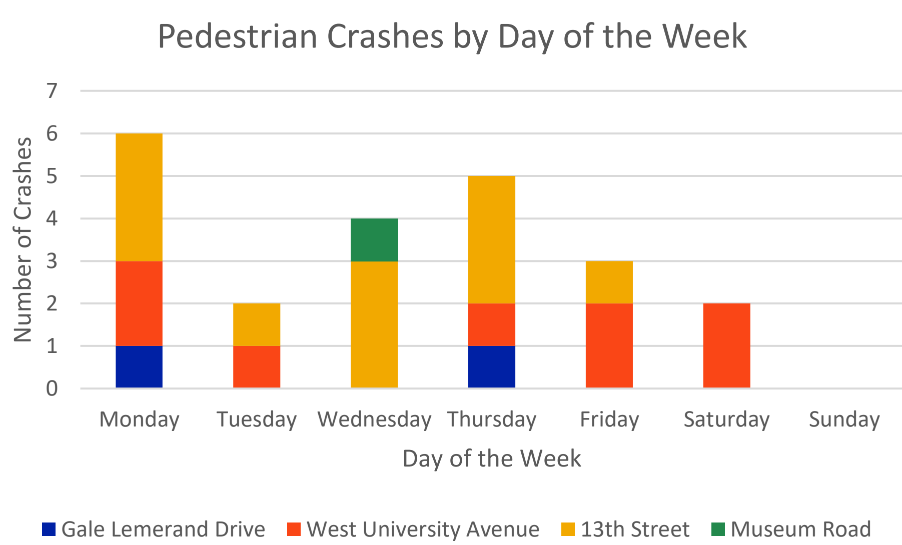


Figure 8-4 – Pedestrian crashes by day of the week

Figure 8-5 shows pedestrian crashes by month of the year. March has the highest number of crashes, with a total of four incidents. The number of crashes generally increases during the Fall and Spring semesters and decreases during breaks and summer.

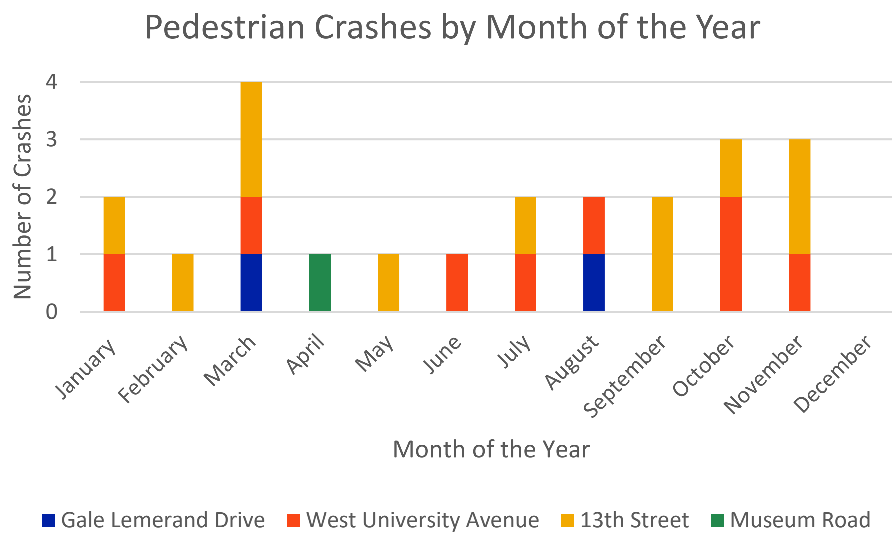


Figure 8-5 – Pedestrian crashes by month of the year

Figure 8-6 illustrates the distribution of incidents by time of day across four streets. Crashes are most frequent around midday and after noon The critical time period is between 12:00 PM to 4:00 PM, with a total of 7 crashes.

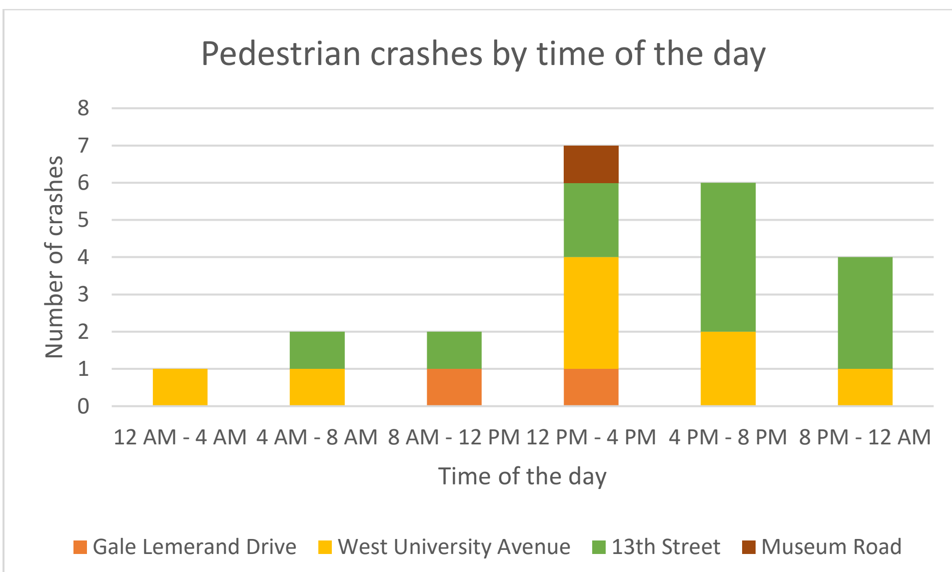


Figure 8-6 – Pedestrian crashes by time of the day

Table 8–3 presents the distribution of pedestrian crashes by contributing factors, determined using the narrative and diagram in each police report. The % does not sum up to 100% as there could be multiple factors for a crash. Failing to yield for pedestrians is a common cause of crashes. Reckless driving is a factor in 16.7% of the crashes. Alcohol was not a contributing factor for any reported crashes. In 72.7% of crashes, the driver was found at fault, while 65% of crashes occurred when the driver was taking a turn.

Table 8–3 – Pedestrian crash contributing factors

Crash Contributing Factors	% Crashes
Failed to see pedestrian	12.50%
Failed to yield for pedestrian	31.30%
Failed to yield for vehicle	10.40%
Improper turn	2.10%
Inattention	12.50%
Ran in front of vehicle	10.40%
Reckless driving	16.70%
Speeding	4.20%

8.2.3 Bicycle crash analysis

Table 8–4 and Figure 8-7 show the number of bicycle crashes from 2015 to 2023. The total number of crashes show fluctuations over the year but in general there have been fewer crashes after 2021.

Table 8–4 – Bicycle crashes by year

Year	Gale Lemerand Drive	West University Avenue	13th Street	Museum Road	All Roads
2015	5	2	4	3	14
2016	0	3	2	1	6
2017	4	4	4	2	14
2018	2	4	2	1	9
2021	2	1	1	1	5
2022	2	0	0	1	3
2023	3	0	2	1	6

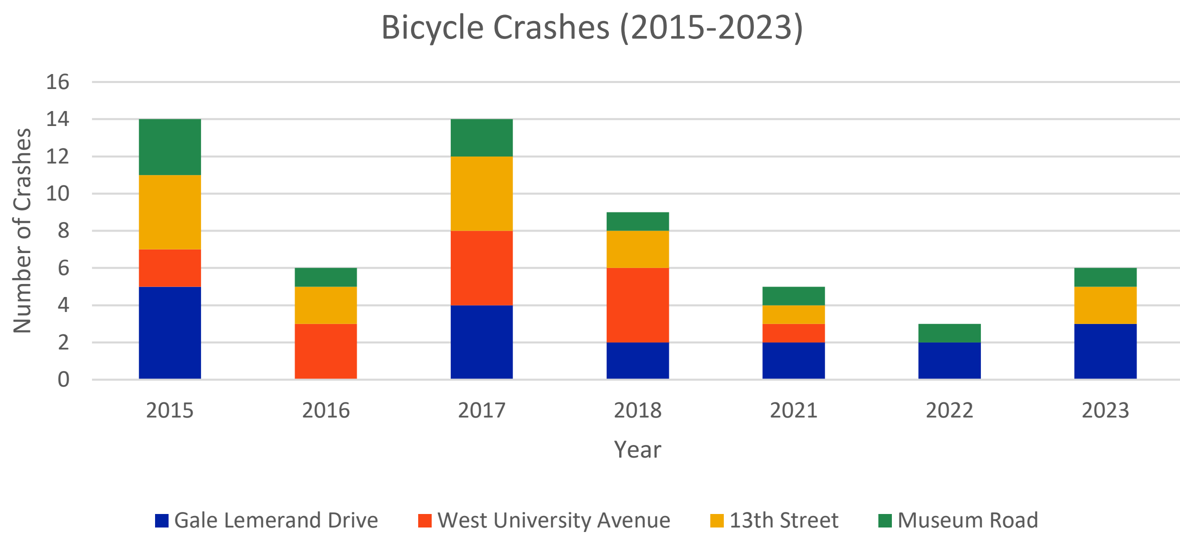


Figure 8-7 – Bicycle crashes by year

Figure 8-8 shows the number of crashes per day of the week. Tuesday and Wednesday have the highest number of incidents, totaling four each. Overall, the trend indicates that midweek days, particularly Tuesday and Wednesday, are associated with a higher frequency of incidents compared to the rest of the week.

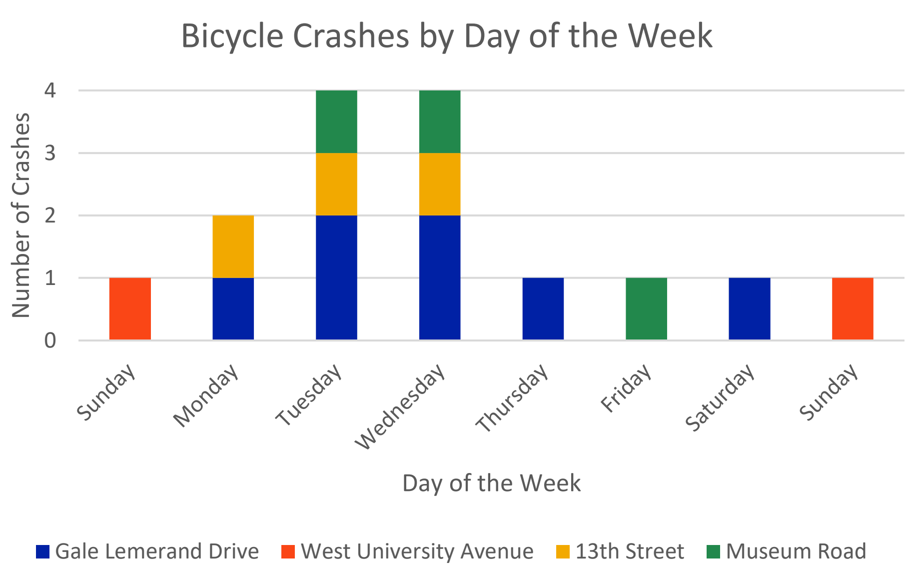


Figure 8-8 – Bicycle crashes by day of the week

Figure 8-9 presents the distribution of incidents by month and location along the four study corridors, with a total count for each month over three years. The data indicate that incidents are concentrated in specific months, with the majority occurring in the latter part of the year. November has the highest number of incidents, totaling three. March also has a relatively high count with three incidents, spread across different locations. The months of January, February, April, and May each have one incident. No incidents were recorded in June, July, August, and December.

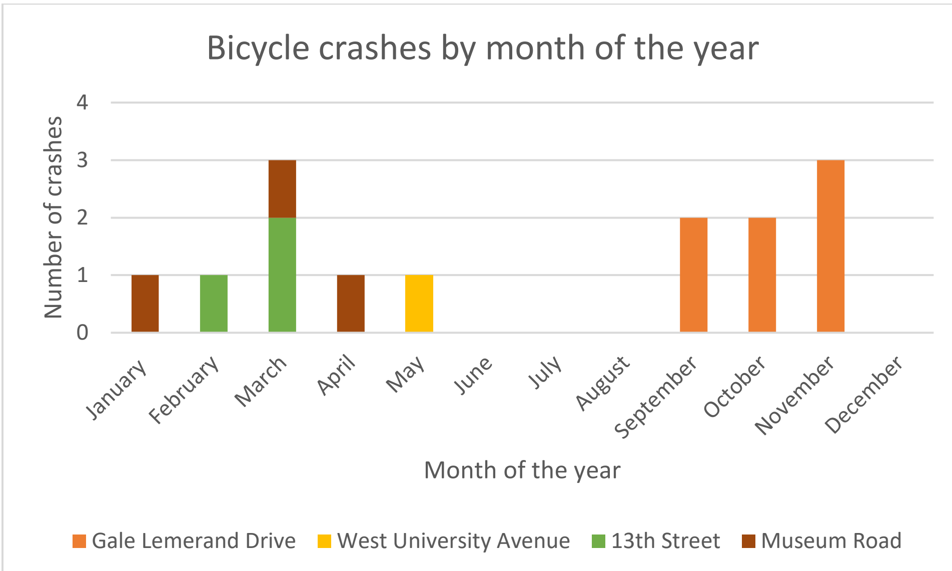


Figure 8-9 – Bicycle crashes by month of the year

Figure 8-10 shows the number of bicycle crashes by time periods of the day. The crashes are distributed throughout the day, with no crash reported from 12:00 AM to 4:00 AM. The peak activity time period is in the morning and early afternoon.

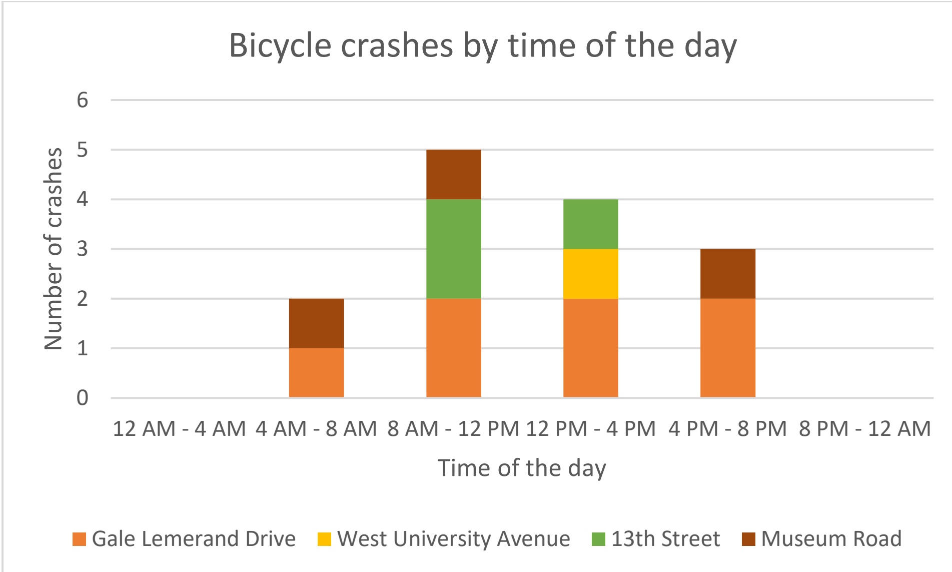


Figure 8-10 – Bicycle crashes by time of the day

Table 8–5 lists various contributing factors to bicycle crashes, with the percentages indicating how frequently each factor is involved in incidents. Crashes might have multiple factors, so the percentages do not sum to 100%. The most common contributing factors are Failed to Yield for Cyclist and Failed to See Cyclist, each accounting for 35.7% of crashes. Other significant factors include Failed to Yield for Vehicle at 21.4% and Inattention and Curvy Road, each at 14.3%. The driver was found at fault in 71.4% of the crashes. No crashes are reported to be due to impaired driving by alcohol or drugs.

Table 8–5 - Bicycle crash contributing factors

Crash Contributing Factors	% Crashes
Failed to see pedestrian	7.1%
Failed to yield for cyclist	35.7%
Reckless driving	7.1%
Failed to see cyclist	35.7%
Failed to see vehicle	7.1%
Ran in front of vehicle	7.1%
Improper turn	7.1%
Inattention	14.3%
Failed to yield for pedestrian	7.1%
Failed to yield for vehicle	21.4%
Curvy road	14.3%
Wrong way cycling	7.1%

8.2.4 Comparison of crash data before and after deployment

The data suggest that in the post-installation period, pedestrian and bicyclist crashes decreased in the four corridors surrounding the UF campus. Table 8–6 shows the overall changes in crash statistics from 2015-2018 to 2021-2023. As shown, there was a 12.4% reduction in pedestrian crashes (from 2.19 to 1.92) and a 56.6% reduction in bicyclist crashes (from 2.69 to 1.17). Combined pedestrian and bicyclist crashes decreased by 36.8% (from 4.88 to 3.08). Car crashes also saw a reduction of 28.3% (from 248 to 178).

Table 8–6 – Average number of crashes and net change

Category	2015-2018	2021-2023	Net Change
Ped	2.19	1.92	-12.4%
Bicycle	2.69	1.17	-56.6%
Ped + Bicycle	4.88	3.08	-36.8%
Car	248	178	-28.3%
Gale Ped	1.75	0.67	-61.9%
W Uni Ped	3.25	2.67	-17.9%
13th Ped	1.25	4	220.0%
Museum Ped	2.5	0.33	-86.7%
Gale Cyc	2.75	2.33	-15.2%
W Uni Cyc	3.25	0.33	-89.7%
13th Cyc	3	1	-66.7%
Museum Cyc	1.75	1	-42.9%

Between 2015 and 2018, pedestrian crashes were notably high, with 2015 and 2016 having the highest numbers (Elefteriadou, et al., 2023, Table 9). West University Avenue consistently recorded the highest number of crashes in the network, especially in 2015 and 2016. However, there was a general decline in the total number of pedestrian crashes each year from 2015 to 2018. Museum Road also saw a notable number of crashes in 2015 and 2017. After the system's installation, the number of pedestrian crashes generally decreased compared to the pre-2018 period, except for an increase in 2021. 13th Street sees an increase in pedestrians, surpassing the "before" numbers. While West University Avenue still sees a high number of crashes, it is not as dominant as it was before 2018. Museum Road saw no incidents in 2021 and 2022 but had one incident in 2023.

For bicyclist crashes, all roads saw a reduction post-installation compared to the pre-installment period. Out of the years following the system implementation, 2023 saw the most crashes with six incidents, which is the same number as the fewest crashes recorded in 2016 before the system was installed. West University Avenue experienced the most significant reduction in crashes, with only one crash recorded in 2021. Similarly, 13th Street also saw fewer incidents compared to pre-2018. Museum Road and Gale Lemerand Drive averaged one and two crashes a year respectively post-installation, compared to two and four crashes per year in the previous period.

8.3 Near-miss results from video observations

The near-miss data is the result of processing recorded videos from a fisheye camera located at the West University Avenue and 13th Street (S6) signalized intersection. Figure 8-11 shows a screenshot of the camera view at the intersection, capturing a near-miss situation involving pedestrians present at the crosswalk (ID 667) and median (ID 670) and approaching vehicles (ID 687).

Figure 8-11 – Camera view and a near-miss incident

Traffic footage videos were recorded and transmitted through a data pipeline located entirely within a UF computer server. These servers are kept in a locked, limited-access room on campus and can only be digitally accessed remotely via the Gatorlink Virtual Private Network (VPN). As the servers are behind a firewall, unauthorized users cannot gain access to the server.

Recorded traffic videos are 10 frames per second (fps) saved in ten-minute increments, in MP4 format. The fisheye cameras operate using the Gridsmart system and provide videos with a resolution of 1280x960 pixels. The algorithms used to process these videos include an adapted version of FastMOT[1] (Multiple Object Tracker), which uses a YOLO (You Only Look Once) model trained with Darknet[2]. Other algorithms, such as those used to calculate time-to-collision (TTC), are developed in-house and made available on Docker[3].

The end result of the pipeline is a text-only data structure that lists the trajectory and near-miss information, including the coordinates and classes of the entities involved (such as vehicle-to-vehicle or pedestrian-to-vehicle).

Once these videos are processed through the data pipeline, the trajectory and near-miss information are stored within a MySQL database for researcher analysis. When processing footage from a traffic stream, the image data are ephemeral and discarded once the pipeline has extracted the information from that frame. To perform data analysis, the information recorded in the MySQL database is retrieved and processed via Python scripts.

The following subsections provide results for the period before (October 2022) and after (October 2024) implementation. The third subsection compares results from these two periods, while the last subsection discusses challenges with near-miss data collection and analysis.

8.3.1 Results for October 2022

Figure 8-12 presents a heatmap visualization of near-miss incidents overlaid on a satellite view of the signalized intersection evaluated (S6). The heatmap utilizes a color gradient ranging from light yellow to dark red to indicate the intensity of near-miss activity. Light-colored areas represent low or no near-miss occurrences, while darker red zones show locations where near-misses have been more frequent or severe. This pattern shows that conflict points are concentrated around pedestrian crossing zones and turning vehicle paths. The diagram of vehicle movements shown in the heatmaps uses the labels shown in **Error! Reference source not found.**, and the diagram for pedestrian movements uses the labels shown in Table 8–9.

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[1]GeekAlexis (2025) *FastMOT* [GitHub repository]. Available at: https://github.com/GeekAlexis/FastMOT (Accessed: 04 November 2025).

[2] Hank-ai (2025) *Darknet* [GitHub repository]. Available at: https://github.com/hank-ai/darknet (Accessed: 04 November 2025)

[3] Maltgroup (2025) *Vid-TTC* [Docker repository]. Available at: https://hub.docker.com/r/maltgroup/ (Accessed: 04 November 2025)

Figure 8-12 – Heatmap of near-miss incidents in October 2022

Table 8–7 – Descriptions of vehicle movement labels

Label	Description
EBL_lane4_egress1	Eastbound Left, Lane 4, Egress to Lane 1
EBL_lane4_egress2	Eastbound Left, Lane 4, Egress to Lane 2
EBR_lane1_egress1	Eastbound Right, Lane 1, Egress to Lane 1
EBR_lane1_egress2	Eastbound Right, Lane 1, Egress to Lane 2
EBT_lane2	Eastbound Through, Lane 2
EBT_lane3	Eastbound Through, Lane 3
NBL_lane3_egress1	Northbound Left, Lane 3, Egress to Lane 1
NBL_lane3_egress2	Northbound Left, Lane 3, Egress to Lane 2
NBR_lane1_egress1	Northbound Right, Lane 1, Egress to Lane 1
NBT_lane1	Northbound Through, Lane 1
NBT_lane2	Northbound Through, Lane 2
SBL_lane3_egress1	Southbound Left, Lane 3, Egress to Lane 1
SBL_lane3_egress2	Southbound Left, Lane 3, Egress to Lane 2
SBR_lane1_egress1	Southbound Right, Lane 1, Egress to Lane 1
SBR_lane1_egress2	Southbound Right, Lane 1, Egress to Lane 2
SBT_lane1	Southbound Through, Lane 1
SBT_lane2	Southbound Through, Lane 2
WBL_lane3_egress1	Westbound Left, Lane 3, Egress to Lane 1
WBL_lane3_egress2	Westbound Left, Lane 3, Egress to Lane 2
WBR_lane1_egress1	Westbound Right, Lane 1, Egress to Lane 1
WBT_lane1	Westbound Through, Lane 1
WBT_lane2	Westbound Through, Lane 2

For example, EBL_lane4_egress_1 indicates the movement of vehicles that travel along the eastbound from lane 4 to lane 1; Ped_NS_2 indicates the movement for pedestrians crossing North to South, associated with Phase 2 (Eastbound Through).

Table 8–8 – Label of abbreviations of the pedestrian's movements

Label	Description
Ped_NS_2	Pedestrian crossing North to South, associated with Phase 2 (Eastbound Through)
Ped_SN_2	Pedestrian crossing South to North, associated with Phase 2 (Eastbound Through)
Ped_WE_4	Pedestrian crossing West to East, associated with Phase 4 (Northbound Through)
Ped_EW_4	Pedestrian crossing East to West, associated with Phase 4 (Northbound Through)
Ped_NS_6	Pedestrian crossing North to South, associated with Phase 6 (Westbound Through)
Ped_SN_6	Pedestrian crossing South to North, associated with Phase 6 (Westbound Through)
Ped_WE_8	Pedestrian crossing West to East, associated with Phase 8 (Southbound Through)
Ped_EW_8	Pedestrian crossing East to West, associated with Phase 8 (Southbound Through)

The underlying aerial imagery provides geographic and infrastructure context, including visible lane markings, crosswalks, sidewalks, and adjacent buildings. Over this map, a pixelated heatmap illustrates the spatial distribution of near-miss incidents between vehicles and pedestrians. As an example, eastbound vehicle and pedestrian movements are illustrated in Figure 8-13.

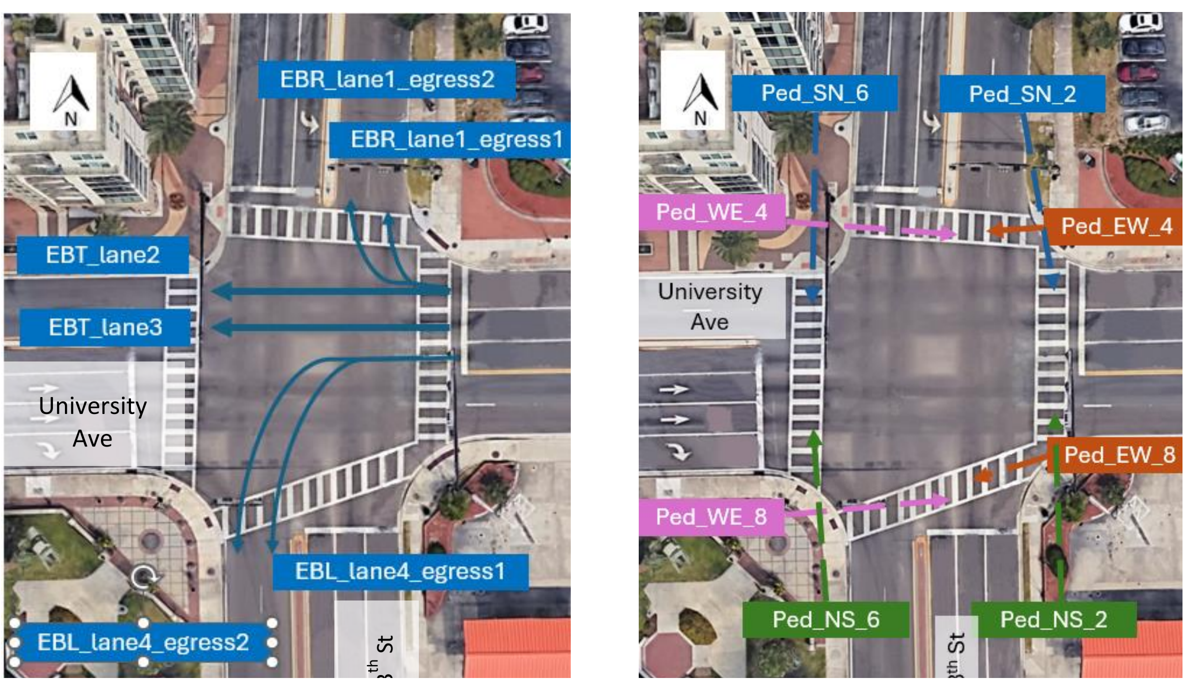


Figure 8-13 - EB vehicle and pedestrian movements labeled

Figure 8-14 shows conflicts of near-miss incidents between pedestrian and vehicular movements. Each cell contains the number of near-miss events recorded for a specific combination, with color intensity ranging from light yellow (lower frequencies) to dark red (higher frequencies). Several cells show high values representing the presence of critical hotspots where near-miss activity is concentrated. Some near-miss incidents were due to jaywalking. Based on Figure 8-12 and Figure 8-14, right turns from SB, WB, NB, and left turns from NB and EB are the most critical movements for vehicles.

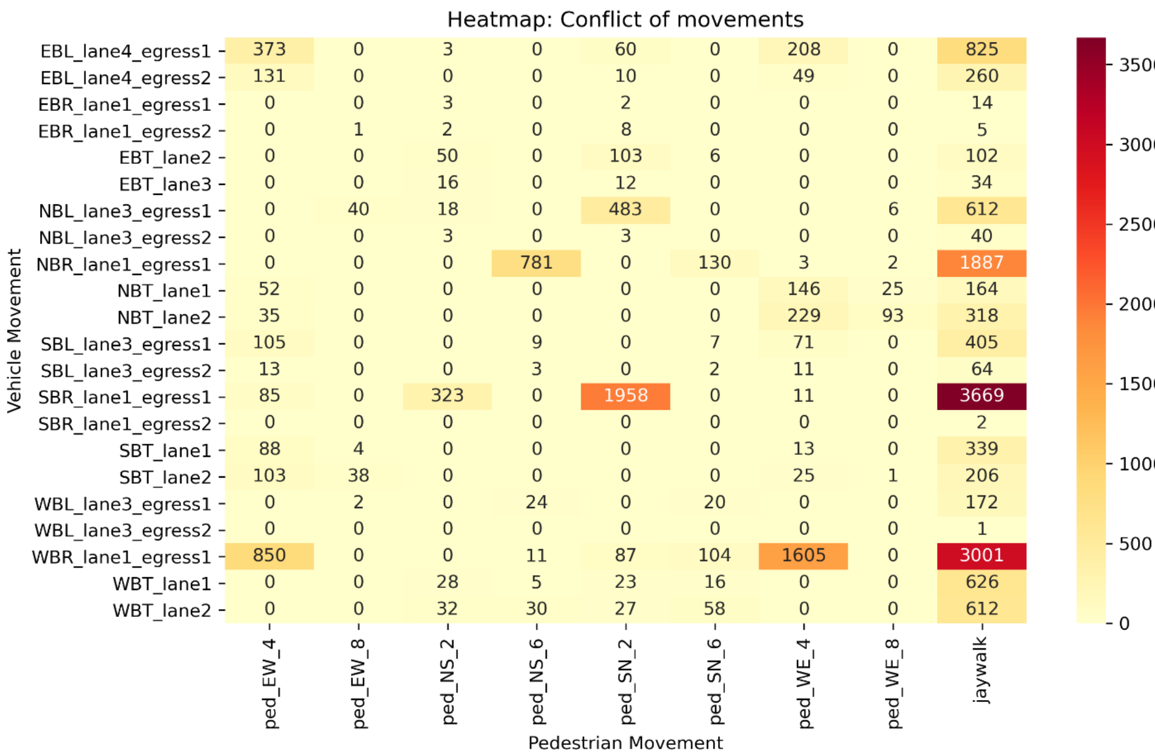


Figure 8-14 – Conflicts of pedestrian and vehicular movements in October 2022

Figure 8-15 shows the hourly trend of near-miss events at the intersection (S6) across days of the week. Each line represents one day, capturing variations in near-miss frequency throughout a 24-hour period. Near-miss activity begins to rise sharply during the morning hours, which aligns with typical weekday morning commute times. This peak is more pronounced on Monday, Tuesday, Wednesday, and Thursday, showing higher traffic and pedestrian activity during midweek.

The number of near-misses remains high during midday and begins to decline gradually into the evening hours. A smaller second peak is noticeable during late afternoon hours (around 4 PM to 6 PM) on most weekdays, indicating another period of high interaction between pedestrians and vehicles, related to evening commutes.

On weekends (Saturday and Sunday), the pattern differs. The morning rise is slower and the overall number of near-misses is lower, with a more spread-out and flattened activity curve. This reflects reduced commuting traffic and different pedestrian behavior during non-workdays.

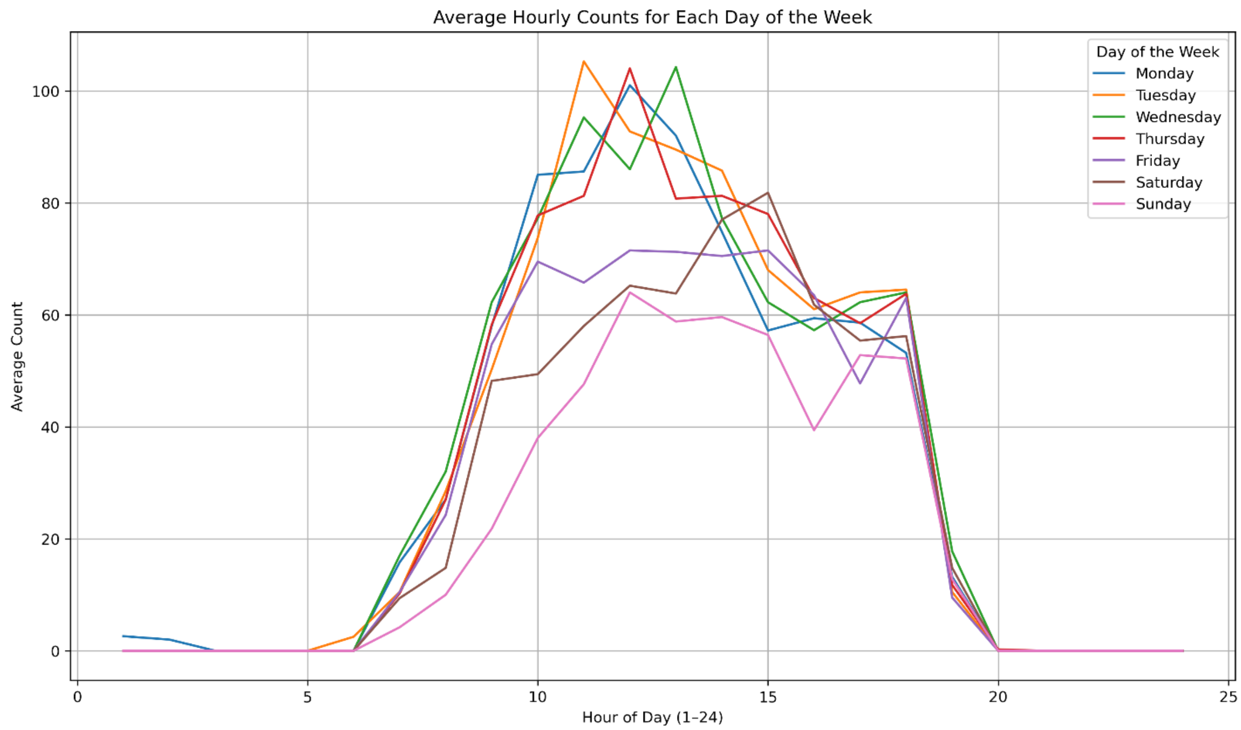


Figure 8-15 – Average hourly counts of near-misses for each day of the week in October 2022

Figure 8-16 shows a heatmap of the number of near-miss incidents by day and hour of the day during October 2022. Each cell in the matrix represents a specific hour on a specific day, and the value within the cell indicates the number of near-miss incidents recorded during that time. The color gradient, ranging from light yellow to dark red, corresponds to the intensity of incidents, with darker red shades indicating higher frequencies.

Peak near-miss activity occurs on weekdays. The cells with highest intensities are concentrated in midday periods, showing high pedestrian and vehicle traffic periods. In contrast, weekend days show fewer near-misses, with a more evenly distributed and lower overall count across the day. October 2nd, 8th, and 15th in 2022 were football game days in Gainesville, and therefore show a different pattern in comparison to similar days and times.

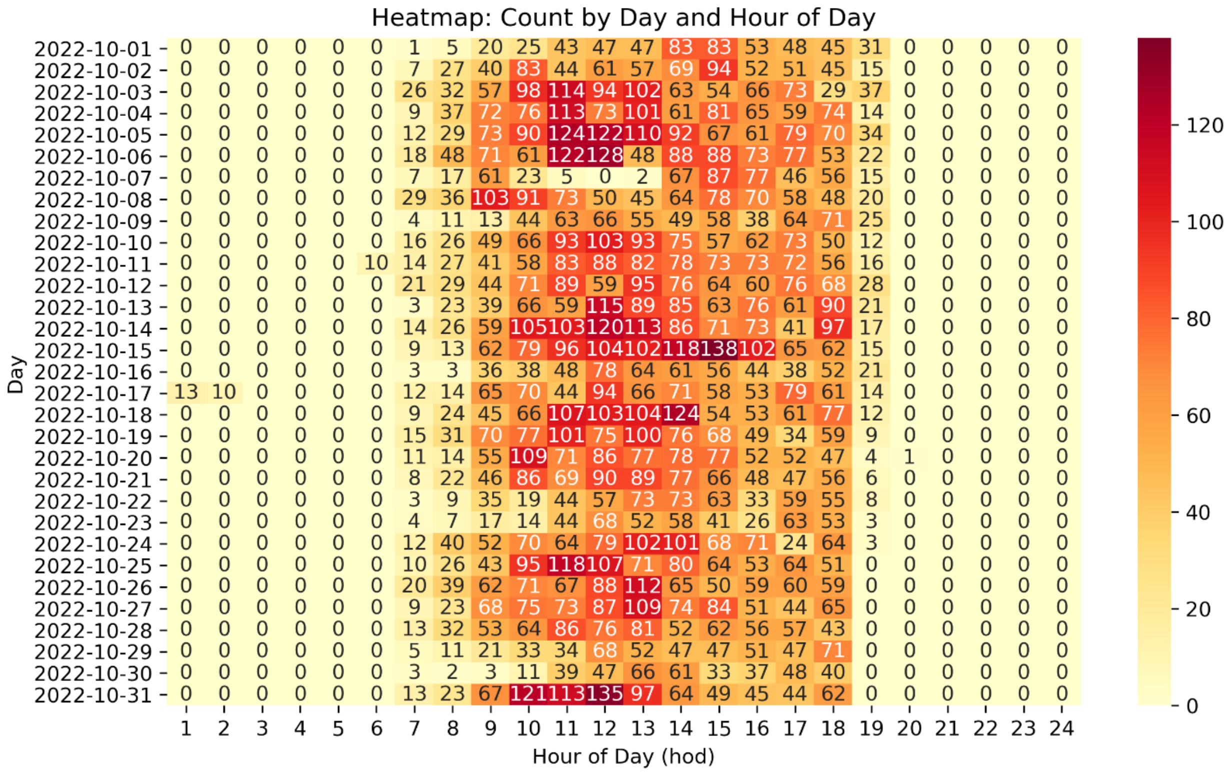


Figure 8-16 – Number of near-miss incidents by day and hour of day in October 2022

8.3.2 Results for October 2024

The near-miss data extracted from video footage for October 2024 were analyzed using the same methodology applied to the October 2022 dataset. Figure 8-17 shows a heatmap of the spatial distribution of near-miss incidents between pedestrians and vehicles. Figure 8-18 shows the number of near-miss incidents for each pedestrian and vehicular movement. These figures show that right turns from WB, NB, SB, and left turns from NB and EB are still the most critical movements.

Figure 8-17 – Heatmap of near-miss incidents in October 2024

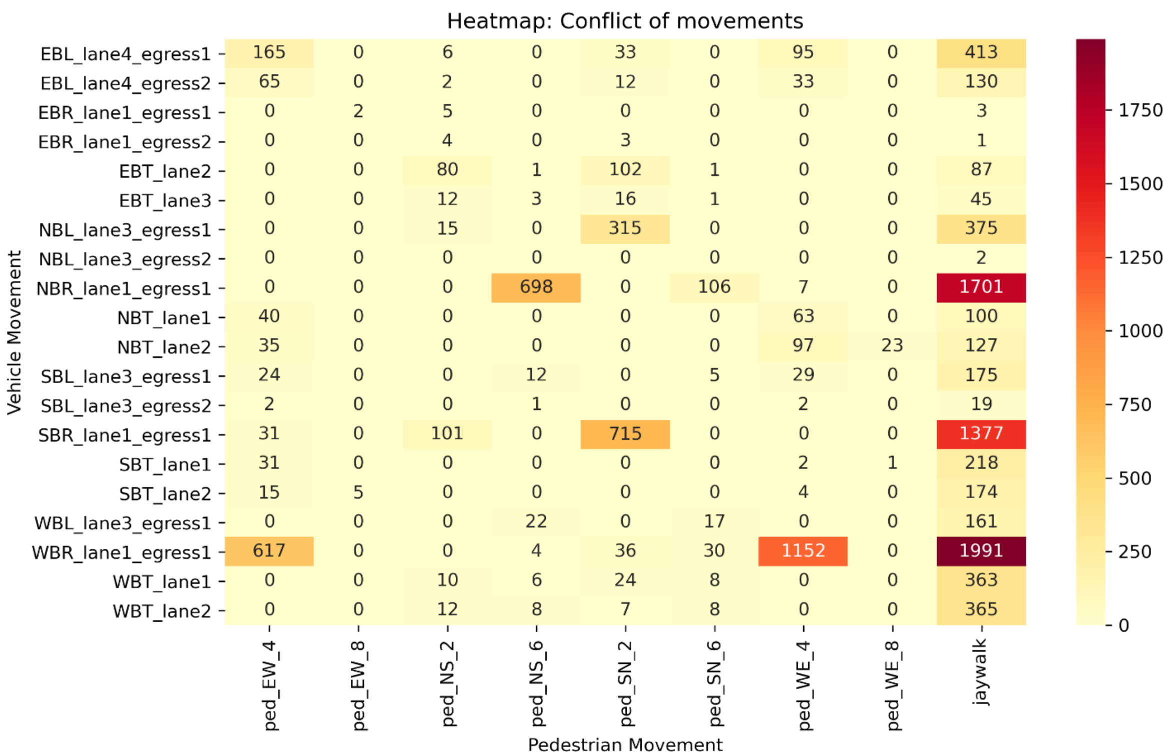


Figure 8-18 – Conflicts of pedestrian and vehicular movements in October 2024

Figure 8-19 shows the patterns related to time-of-day and weekday versus weekend trends. Near-miss incidents are most frequent during the morning and evening peak hours. Monday has the highest number of incidents, especially during the morning.

Weekend days show a lower number of near-misses. Wednesday has lower incident rates compared to the others. This trend is likely due to lower overall travel demand and a shift in pedestrian and vehicle activity patterns.

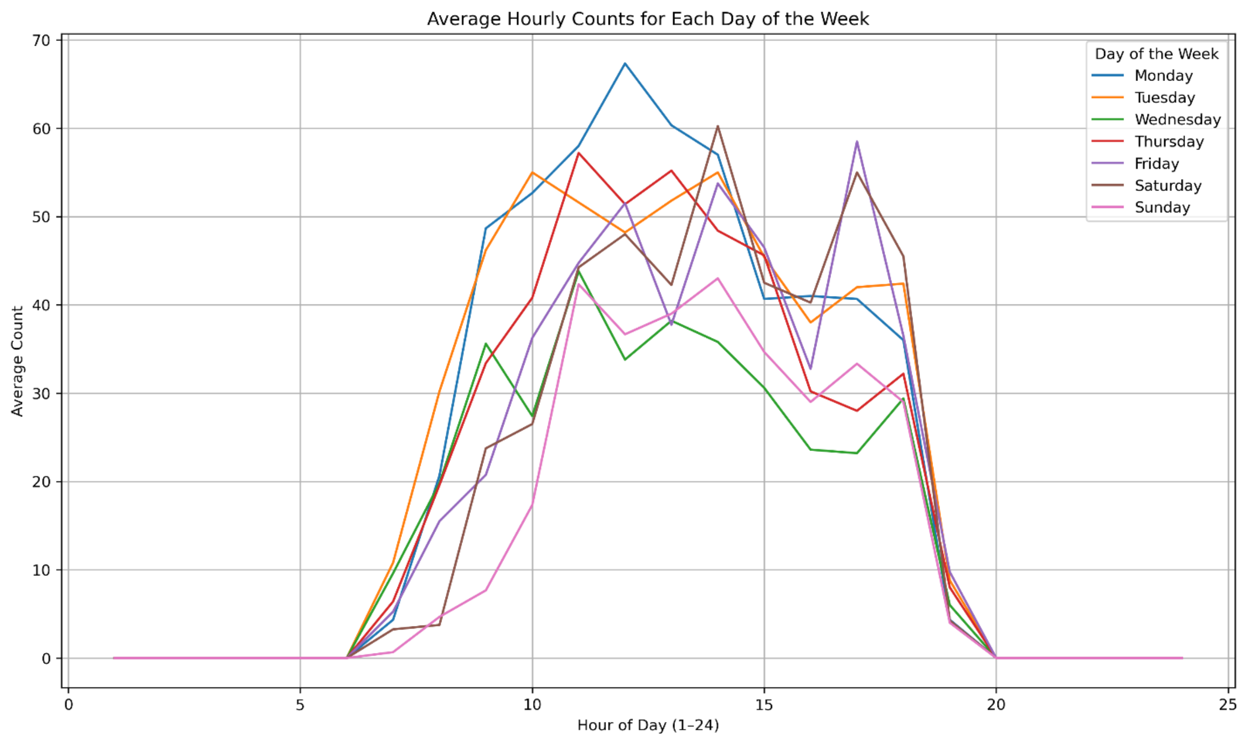


Figure 8-19 – Average hourly counts for each day of the week in October 2024

Figure 8-20 presents the distribution of near-miss incidents by date and hour throughout October 2024. Each cell in the matrix corresponds to a specific hour on a particular day, with the numerical value representing the number of recorded near-miss events during that time. The color scale, ranging from light yellow to dark red, visually indicates the frequency of incidents (darker shades of red highlight periods with higher concentrations of near-misses).

The figure reveals that near-miss incidents are more frequent on weekdays, with peak activity generally occurring during midday hours when both pedestrian and vehicular traffic are at their highest. In contrast, Saturdays and Sundays show fewer incidents, with a more uniform and lower distribution across the day. October 5th and 19th, identified as football game days in Gainesville, show distinct patterns of near-miss activity that differ from typical trends observed on other days.

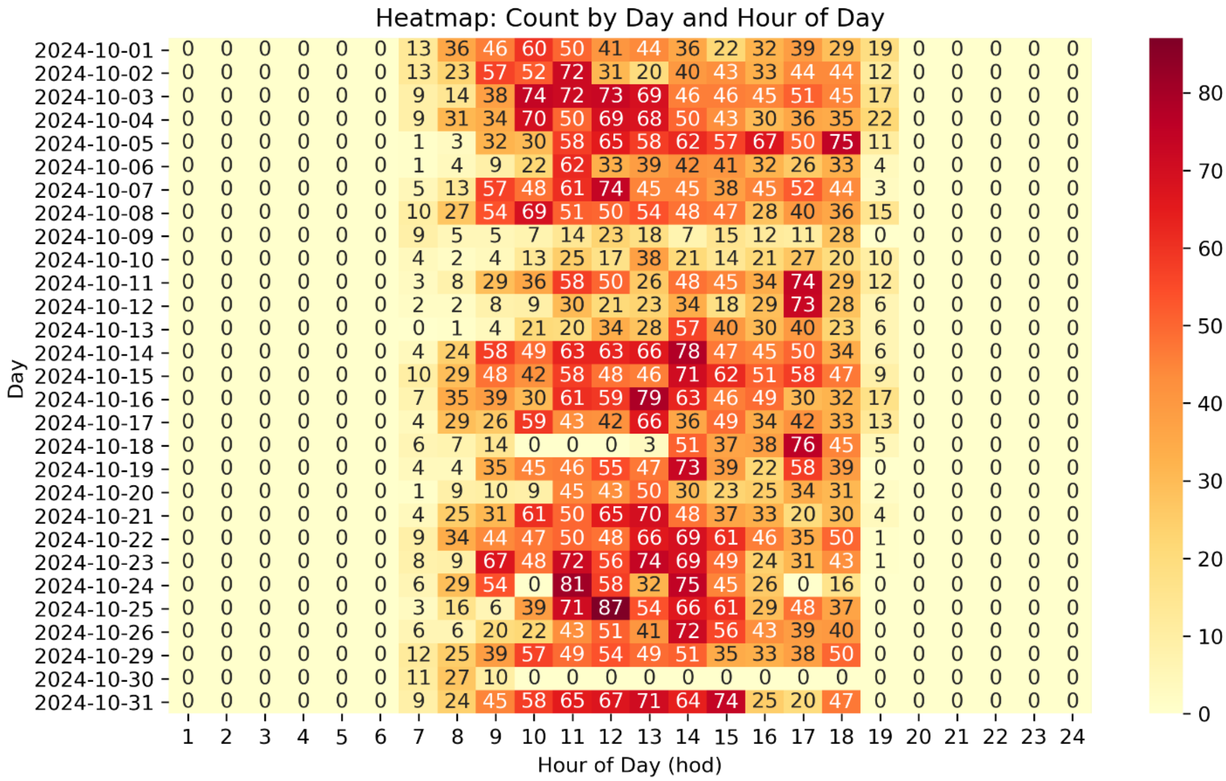


Figure 8-20 - Number of near-miss incidents by day and hour of day in October 2024

8.3.3 Comparison of near-misses before and after deployment

Table 8–9 provides the initial total number of records and the count of unique records, distinguished by the IDs assigned to each pedestrian and vehicle within the camera's field of view. It also includes the total duration of video footage analyzed for near-miss detection. Additionally, the table reports the number of near-miss incidents per hour, rounded to the nearest whole number. A comparison between the before and after periods indicates a reduction in the frequency of near-miss incidents, with the rate decreasing from 48 to 31 incidents per hour.

Table 8–9 – Summary of data and duration of videos

	October 2022	**October 2024**
Initial records	26,890	14,312
Unique records	22,236	12,808
Total duration of videos (sec)	1,670,331.40	1,472,924.87
Total duration of videos (hour)	463.98	409.14
Average near-miss incidents per hour	48	31

Figure 8-21 compares the spatial distribution of near-miss incidents at the signalized intersection (S6) for two time periods: October 2022 (left) and October 2024 (right). The background is a satellite image of the intersection, overlaid with red dots representing the location of each detected near-miss event. Figure 8-22 shows the heatmap of the distribution of near-misses.

In the 2022 image, there is a dense concentration of near-misses, especially in the northern and western crosswalk areas, and parts of the eastern crosswalk. This suggests that during that year, there were frequent conflicts between pedestrians and vehicles, particularly in those zones. The clustering of incidents may indicate issues such as poor visibility, inadequate signal timing, or high pedestrian-vehicle interaction.

The 2024 image shows a reduction in the number and density of near-miss incidents, particularly in the crosswalks. While near-misses still occur, they appear more evenly distributed and less concentrated, suggesting an overall improvement in pedestrian safety. This change may be attributed to safety interventions implemented between 2022 and 2024, such as signal timing adjustments, infrastructure modifications, technology deployments, and enhanced pedestrian detection technologies.

Figure 8-21 – Comparison of near-miss incidents in October 2022 and October 2024

Figure 8-22 – Heatmap comparison of near-miss incidents in October 2022 and October 2024

Figure 8-23 compares the number of near-miss incidents by turning movement in 2022 and 2024. The movements are divided into left-turning, right-turning, and through-movement vehicles. In all three categories, the number of near-misses is lower in 2024 compared to 2022. The right-turning vehicles have the highest number of incidents in both years, but there is a large decrease in incidents for 2024. The left turning and through movement incidents also dropped slightly.

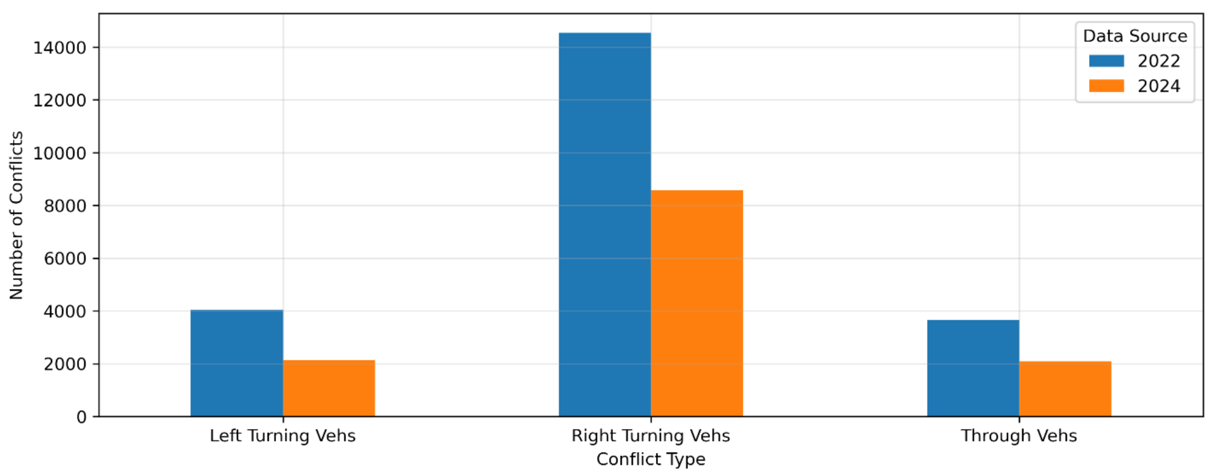
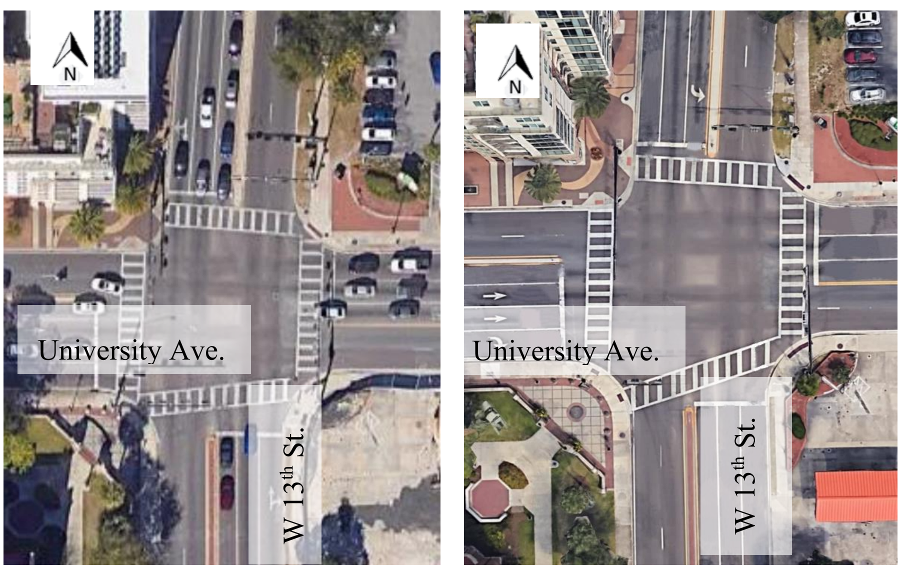


Figure 8-23 – Comparison of turning conflicts

The overall reduction in the number of near-miss incidents is most likely due to changes in the roadway network between the before and after study periods. Figure 8-24 presents photos taken of the intersection at West University Avenue and 13th Street (S6) on September 13, 2019, during the previous project (BDV31-977-120), while Figure 8-25 shows photos captured on October 8, 2023, at the same location, where the near-miss analysis was conducted. Figure 8-26 provides an aerial view of the intersection (S6) during the before and after periods. The lane configuration and geometric design remain largely unchanged; however, one notable modification is the slight adjustment of the southern crosswalk's angle, which has been realigned to form a more rectangular shape consistent with the other crosswalks. Additionally, the reduction could be due to other changes in the network. For example, upstream on West University Ave., there are several new speed tables, new pedestrian crossings (between S2 and S14, and between S5 and S6), and signals (S14 and S15), which tend to slow down the vehicles before they approach the intersection (S6).

Figure 8-24 – Photos of the intersection at W Univ. Ave. & 13 St. (S6) in the previous project (September 13, 2019)

Figure 8-25 – Photos of the intersection at W Univ. Ave. & 13 St. (S6) in the current project (October 8, 2023)



After Before

Figure 8-26 – Aerial view of the intersection at W Univ. Ave. & 13 St. (S6)

8.3.4 Challenges with near-miss data collection

During the near-miss analysis, the research team faced some difficulties with collecting and analyzing the data but worked to overcome these issues. The first challenge was encountered during the creation of heatmaps for near-miss incidents. In the October 2024 dataset, the research team observed a hotspot with an unusually high number of incidents, prompting further investigation into why this specific location showed such a concentration of near-misses.

Figure 8-27 presents the initial heatmap generated from the data. Upon closer examination, including a review of the video footage, the team discovered that the near-miss detection algorithm was mistakenly identifying a sign located on the median as a pedestrian, which led to false detections at that spot (see Figure 8-28). This sign was not present at the same location in October 2022, as found from Google Street maps and indicated by the red circle in Figure 8-29. The position of the camera used for data collection is marked by the yellow circle in the same figure.

To address this issue, the research team retrained the model using data collected at different times of the day, under varying weather conditions, and with a larger set of pedestrian samples to improve accuracy. The final results presented in the previous sections are based on this updated model, which demonstrated improved performance and reliability.

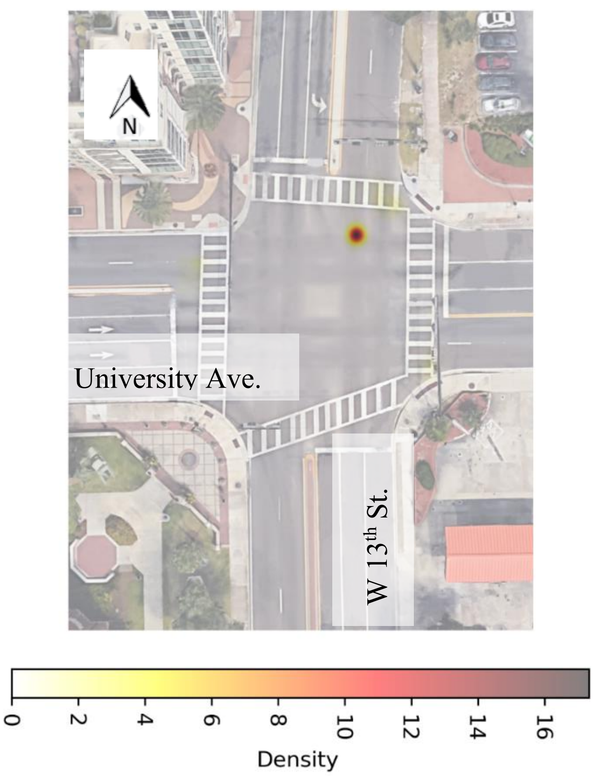


Figure 8-27 – Initial heatmap generated from October 2024 data with unusual hotspot

Figure 8-28 – False detection of the fisheye camera (ID 359)

September 2023 July 2024

Figure 8-29 – Fisheye camera and the sign on the median in different periods

The researchers also identified an ongoing challenge related to the limitations of the camera in accurately detecting and locating pedestrians on the map. As shown in Figure 8-30, some near-miss incidents appear to be located on sidewalks, which is not correct. In the figure, the camera location is marked with a green circle, and the near-miss incidents are represented by red dots. This issue arises in the area shown by yellow circles because the camera and algorithm have difficulty estimating events that occur at a greater distance from their position. As a result, the algorithm may incorrectly assign the location of these incidents, placing them on sidewalks rather than within the roadway or crosswalk areas where the interactions actually occurred. The areas with errors in distance estimation are located in the boundaries of the camera's field of view, as shown in Figure 8-11. Although this issue has not been resolved, it does not affect the overall conclusions, as this area has a proportionally similar number of near-miss incidents observed, and influence both the before and after periods equally. Potential solutions, such as installing additional cameras at the intersection or integrating other sensors through data fusion methods, could improve the accuracy of detecting and locating pedestrians and vehicles, and enhance the identification of near-miss events.

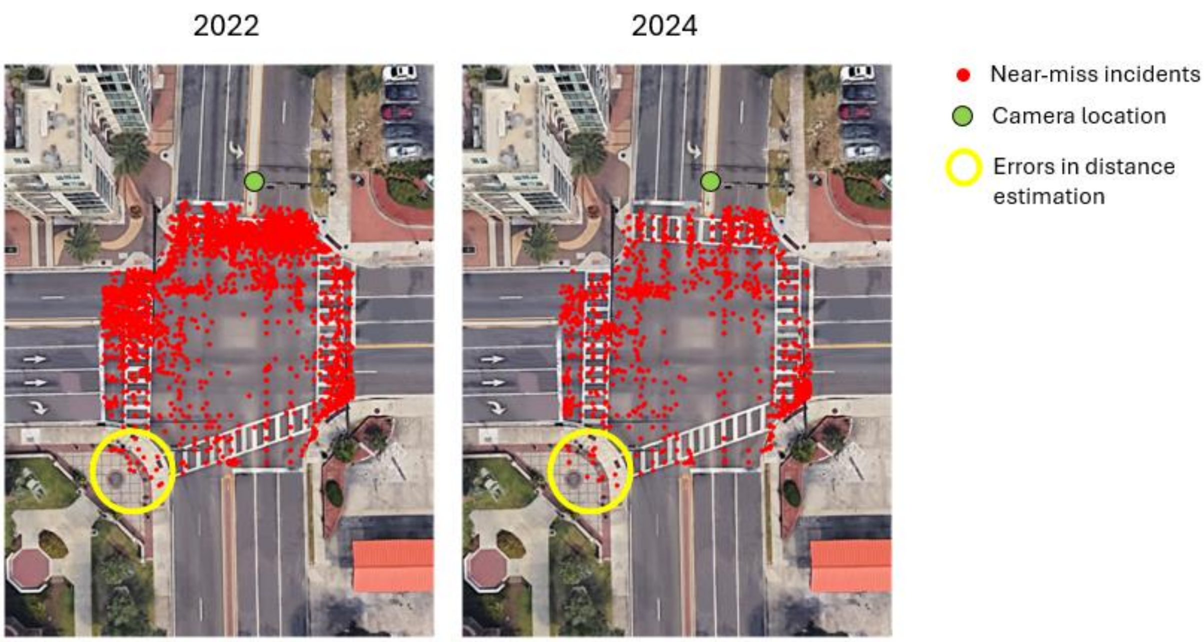


Figure 8-30 – Near-miss incidents located on crosswalks in October 2022 and October 2024

9 Mobility

This section discusses the traffic operational performance analyses, travel time analyses, and speed analyses conducted in the study area after system implementation.

The methodology used in this subtask follows the same methodology as in the previous study (BDV31-977-120). Data were collected at three signalized intersections along West University Avenue to assess highway capacity and operational performance. West University Avenue was chosen due to its high rate of pedestrian and bicyclist crashes. West University Avenue & 13th St. experiences the highest traffic volumes. In the “before” condition, the research team had also evaluated the performance of the unsignalized intersection at Museum Road & Reitz Union Drive. However, this location is now a signalized intersection, and thus this location was not analyzed as it is not possible to conduct a direct comparison.

As indicated above, the number of accidents and near-misses peaked at midday; therefore, midday was selected as the peak hour for the operational analysis to maintain consistency with the peak-hour criteria used in the data collection for the before-implementation analysis.

9.1 Traffic operational analysis for “after” conditions

Considering the available traffic movement data (Tuesday, Wednesday, and Thursday), Thursday was selected for the operational analysis due to the higher frequency of incidents with pedestrians and near misses. The data collection dates available and included in this study for each intersection are shown in Table 9–1.

Table 9–1 - Data collection dates by location

Location	**Data collection date**
W Univ. Ave. & 13th St. (S6)	15-Oct-25
W Univ. Ave. & 17th St. (S4)	3-Apr-25
W Univ. Ave. & Gale Lemerand Dr. (S2)	3-Apr-25

The following subsections discuss the data collection and analysis results.

9.1.1 Data collection

The data collection followed the Highway Capacity Manual (6th Edition)[4] procedures. Traffic flow data were provided by the City of Gainesville, obtained through Gridsmart cameras. Given that the midday peak had the highest number of pedestrians, we selected the 15-minute peak hour flow from 12 PM to 1 PM to conduct the LOS analyses.

The required data for highway capacity analysis includes geometric design data, traffic flow data, and signal timing data, which are discussed below.

9.1.1.1 Geometric data

Geometric data were obtained using the aerial view from Google Maps. The intersection of W Univ. Ave. & 13th St. (S6) has four approaches, as shown in Figure 9-1. The northbound, southbound, and westbound approaches have three lanes and a left-turn bay of 310 ft., 470 ft. and 240 ft. respectively. All approaches have an exclusive through lane and a shared through and right turn lane. The eastbound approach has four lanes including a nearly 450-ft. left-turn bay, two exclusive through lanes, and a dedicated right-turn bay of approximately 240 ft. There is no on-street parking along any of the approaches. The approach grade is assumed to be 0% for all approaches. The geometric design information, such as number of lanes per approach, lane width, grade, turn bay length used as input for capacity analysis are provided in Appendix K. Compared with the "before" scenario, at the intersection W. Univ Ave & 17th St, the southbound traffic direction is restricted for vehicles, as shown in Figure 9-2. Another important change along the corridor is the placement of traffic calming devices and the reduction of the speed limit from 30 mph to 25 mph. Figure 9-1, Figure 9-2, and Figure 9-3 show the current intersection layout, used for the "after" analysis.

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[4] Highway Capacity Manual (2016). A Guide for Multimodal Mobility Analysis. Transportation Research Board, Washington, DC.

Figure 9-1 – Intersection of W Univ. Ave. & 13th St.

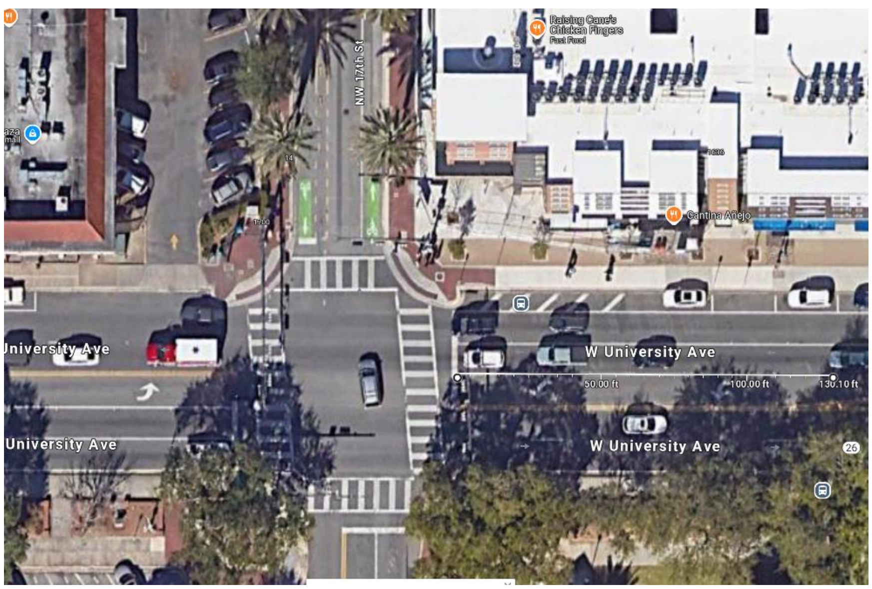


Figure 9-2 – Intersection of W. Univ Ave & 17th St.

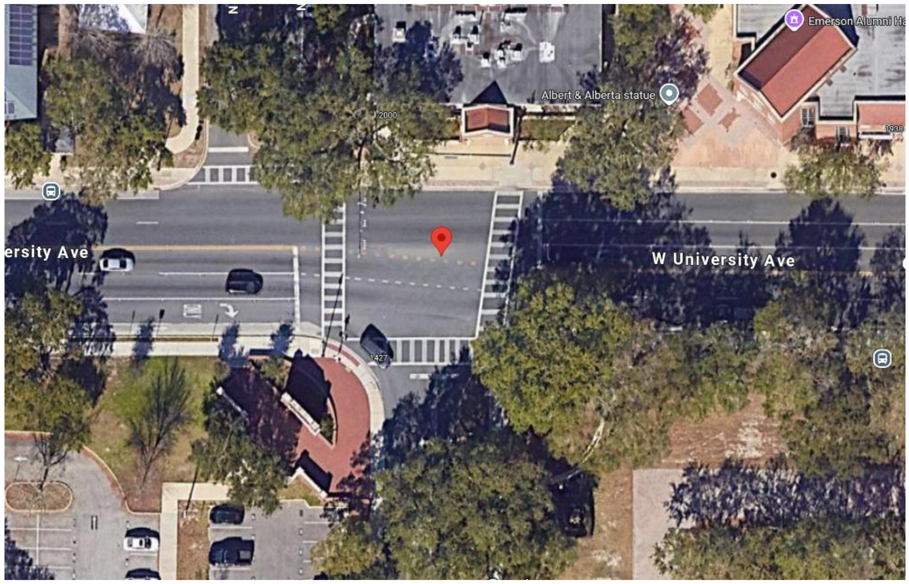


Figure 9-3 – Intersection W. Univ Ave & Gale Lemerand Dr.

9.1.1.2 Traffic data

The 15-minute peak hour flows from 12 PM to 1 PM were selected to conduct the LOS analyses given that the midday peak had the highest number of pedestrians. The traffic flow counts by vehicle type and turning movements were received from the City of Gainesville, obtained through camera detectors from Gridsmart cameras. The traffic flow by turning movements, and the percentage of heavy vehicles in the peak hour were used as input for the analysis.

9.1.1.3 Signal timing data

Signal timing data were obtained from the City of Gainesville, through the Advanced Traffic Management System (ATMS) database. The signal timings for the study signalized intersections are provided in Appendix K.

9.1.3 Results

The operational analysis for the signalized intersections was conducted using the HCS software. Analysis results are presented for both vehicular LOS and pedestrian LOS. The analysis results are presented in Table 9–2. As shown, the vehicular LOS for the intersection of W Univ. Ave. & 13th St. is estimated to be F, with an average control delay of 92 seconds per vehicle. The LOS of the other two intersections is B. The pedestrian LOS for the crosswalks of W Univ. Ave. & 13th St. is C, whereas pedestrian LOS is found to be B for the other intersections. The detailed HCS analysis and results are provided in Appendix K.

Table 9–2 – HCM analysis results for “after” conditions

Signal	Motorized vehicle			Pedestrians	
	Peak Hour Flow (veh/h)	Control delay (s/veh)	LOS	Pedestrians (peds/h)	Ped LOS
W Univ. Ave. & 13th St (S6)	2572	92.2	F	776	C
W Univ. Ave. & 17th St (S4)	1188	16.2	B	364	C
W Univ. Ave. & Gale Lemerand Dr. (S2)	1512	11.7	B	48	C

The HCM analysis of three signalized intersections showed that the W Univ. Ave. & 13th St (S6) is the most critical intersection along the West University Avenue corridor, with a vehicular LOS F. The other two intersections operate at LOS B. The LOS F in the W Univ. Ave. & 13th St (S6) was likely due to a higher number of vehicles in the westbound direction for the peak-hour analyzed. The LOS for pedestrians remains C for all three intersections analyzed in this corridor.

9.2 Travel time and speed for “after” conditions

Travel time and speed data were obtained from the RITIS database. The data obtained consists of the average speed and Travel Time Index from West University Ave. between Gale Lemerand Drive and 13th Street. Both average speed and Travel Time Index data are aggregated in intervals of 15 minutes and were obtained for two weeks each. The analysis included data for two full weeks from Monday, January 27 to Sunday, February 2, 2025, and from Monday, March 31 to Sunday, April 6, 2025.

The travel time analysis used the Travel-Time Index (TTI) averaged across weekend days (Saturday and Sunday) and weekdays (Monday through Friday) for both travel directions and by time of day (Figure 9-4 and Figure 9-5). The TTI is the ratio of the travel time during the peak period to the time required to make the same trip at free-flow speeds. The two figures show that for some time periods the TTI is less than 1, which is not expected. According to the HERE website which provided the travel time data, they assume that the free flow speed is the 80th percentile of weekend overnight probe vehicle speeds. It is possible that the speeds along University Ave. are relatively low at night, and they produce non-typical TTI values.

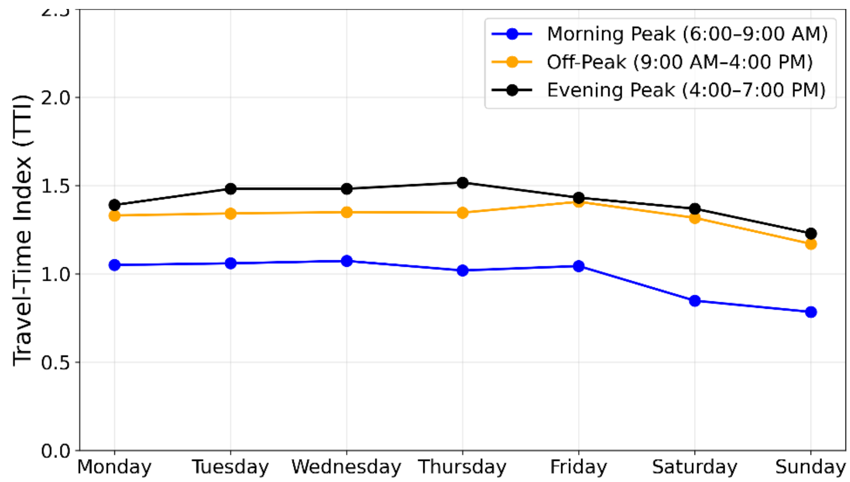


Figure 9-4 – Average TTI by weekday in the Westbound direction

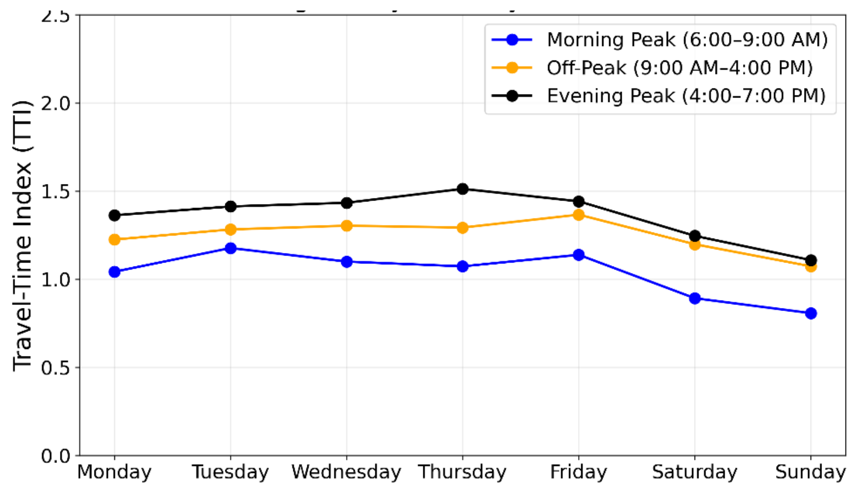


Figure 9-5 – Average TTI by weekday in the Eastbound direction

As shown, evening peaks (shown in black) exhibit the highest TTI values for both directions, indicating that the evening is the most congested peak hour in the road segment. The morning peak TTI is relatively lower, particularly in the eastbound direction, suggesting better conditions compared to evening commutes. Off-peak periods generally show flatter TTI values during the workweek.

As expected, weekday TTI levels are consistently higher than those for weekends. Fridays show a small dip in evening TTI, possibly reflecting early departures from work or staggered travel patterns. Sunday consistently has the lowest TTI values across all time periods, indicating better traffic flow conditions and minimal congestion.

The average speed per direction is presented in Figure 9-6, and Figure 9-7. The results indicate traffic patterns consistent with the results shown in the TTI graphs.

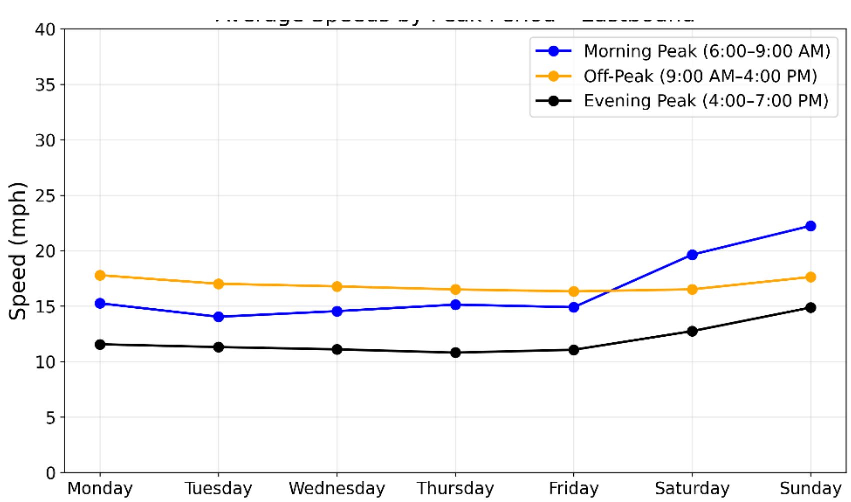


Figure 9-6 – Average speed (mph) for the Eastbound direction by weekday

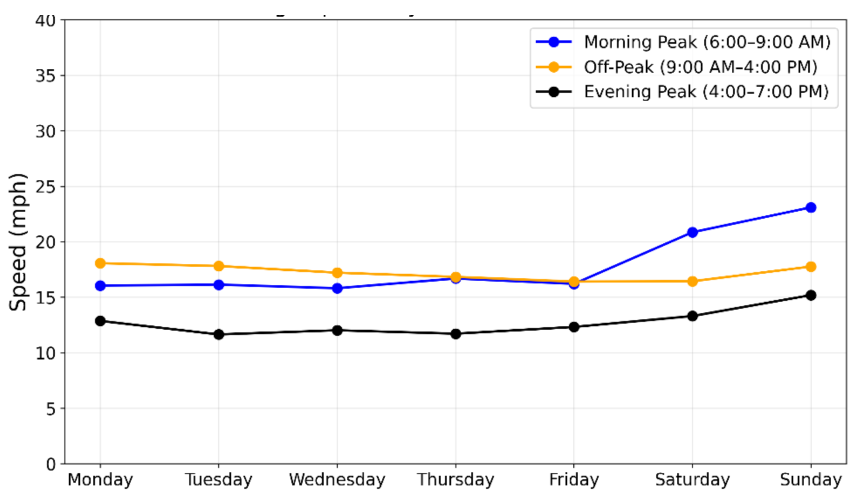


Figure 9-7– Average speed (mph) for the Westbound direction by weekday

As expected, during the peak hours, the weekend days have a lower average speed than weekends. Off-peak periods maintain relatively stable speeds during the week, with slightly better performance on Sundays. The evening peak has lower average speed when compared with the morning and off-peak. In both directions, Sunday has the highest speeds for all peak periods, indicating a significant traffic reduction on weekends. Even though the average speed in the off-peak is lower, this period still contains most of the bicycle crashes. This may occur due to the higher number of students and staff commuting by bike at that time.

9.3 Comparison of traffic conditions before and after deployment

The before and after operational conditions were compared considering the metrics of traffic delay, Level of Service (LOS), Travel time index (TTI), and average speed in the corridor.

9.3.1 Delay and LOS comparison

The delay and LOS were obtained using traffic counts from a typical week in 2022 for the "before" scenario and from 2025 for the "after" scenario. Delay and LOS were obtained using HCS version 2025, which applies the HCM 7th edition, and the results are summarized in Table 9–3 for motorized vehicles, and in Table 9–4 for pedestrians.

Table 9–3 – Delay and LOS results for motorized vehicles at the three signalized intersections

Signal	Before (2022)			After (2025)		
	Peak Hour (veh/h)	**Control delay (s/veh)**	**LOS**	**Peak Hour (veh/h)**	**Control delay (s/veh)**	**LOS**
W Univ. Ave. & 13th St (S6)	3417	50.63	D	2572	92.2	F
W Univ. Ave. & 17th St (S4)	1272	13.7	B	1188	16.2	B
W Univ. Ave. & Gale Lemerand Dr. (S2)	2089	12.25	B	1512	11.7	B

Table 9–4 – Delay and LOS results for pedestrians at the three signalized intersections

	Before (2022)		After (2025)	
Signal	**Pedestrians (peds/h)**	**LOS**	**Pedestrians (peds/h)**	**LOS**
W Univ. Ave. & 13th St (S6)	583	C	776	C
W Univ. Ave. & 17th St (S4)	20	B	364	C
W Univ. Ave. & Gale Lemerand Dr. (S2)	114	B	48	C

The HCM analysis from the three signalized intersections indicated that:

- For motorized vehicles, the most critical location is W Univ. Ave. & 13th St (S6), which reached LOS F despite having lower vehicle flow than before. This is mainly due to a higher concentration of vehicles traveling in the westbound direction in the after scenario. Intersections S2 and S4 maintained LOS B, even with reduced traffic volumes; the results are likely influenced by lower speed limits that decreased overall vehicle throughput.
- For pedestrian flow, volumes increased at S6 and S4 but decreased at S2. As a result, LOS dropped to level C at S6 and S4. S2 remained at LOS C as in the "before" scenario.

9.3.2 Travel time and speed comparison

Probe data were used as discussed above to obtain travel times for both the "before" and the "after" scenarios. The average speed and travel time index (TTI) were obtained from 2020 for the "before scenario", and from 2025 for the "after" scenario.

9.3.2.1 Speed comparison

A weekday was selected to evaluate the traffic speed changes. Monday was chosen because it recorded the highest number of pedestrian crashes. Figure 9-8 and Figure 9-9 show the speed distribution throughout the day: the average speed in the *before* scenario is shown in blue, while the *after* scenario is shown in orange.

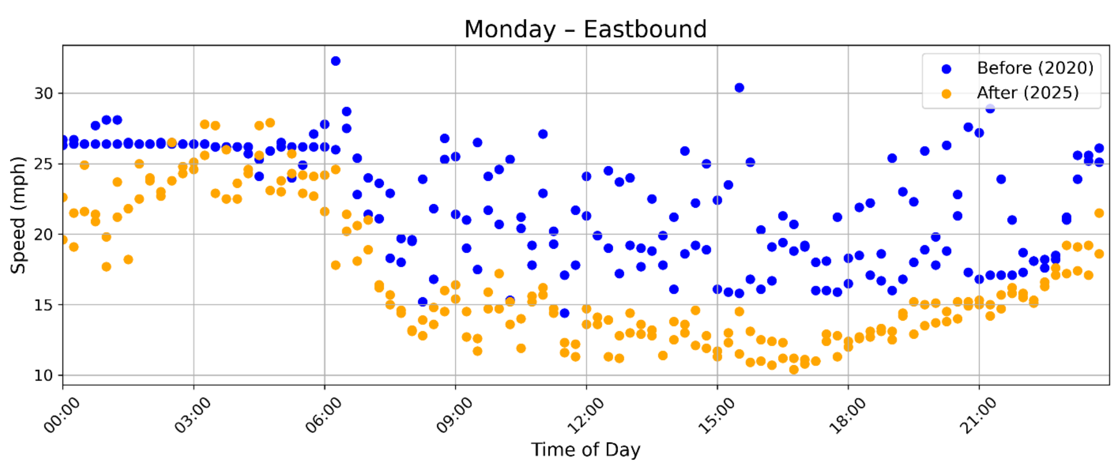


Figure 9-8 – Speed distribution for the Eastbound direction, aggregated in 15-minute intervals

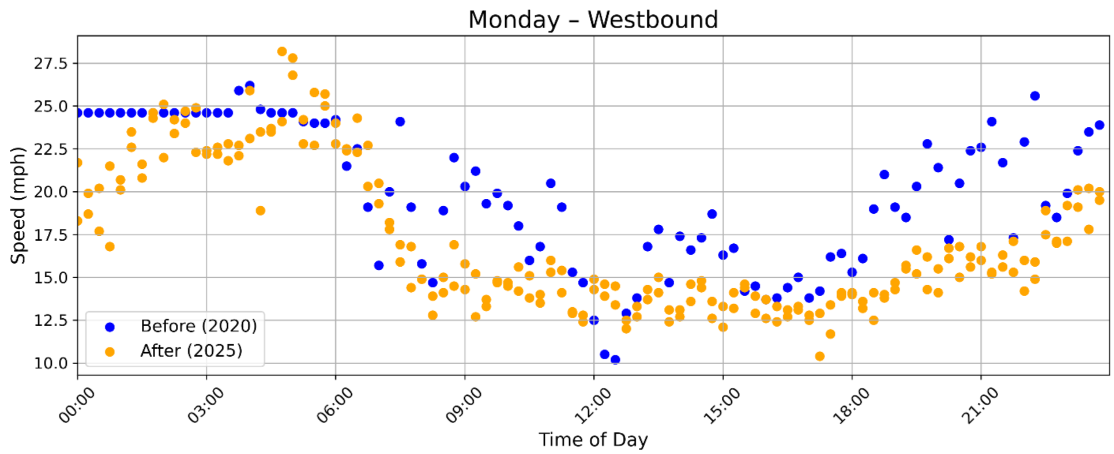


Figure 9-9 – Speed distribution for the Westbound direction, aggregated in 15-minute intervals

For both traffic directions, westbound (WB) and eastbound (EB), the results indicate a reduction in average vehicle speeds from 2020 to 2025. This reduction can be attributed to a combination of factors:

- Posted Speed Limit Changes: A reduction in the posted speed limit—from 30 mph in 2020 to 25 mph in 2025—directly impacts observed travel speeds.
- Increased Traffic Demand: Growth in some vehicle flow directions, and especially pedestrian volumes, may have contributed to more frequent congestion and lower operating speeds.
- Traffic Calming Measures: The implementation of traffic calming strategies—such as elevated pedestrian crosswalks—appears to have effectively reduced speeds along the corridor.
- The most significant speed reductions are observed between 8:00 AM and 7:00 PM, when travel demand is typically higher. This suggests that increased pedestrian activity and vehicle volume, specifically during these times, may be impacting the average speed of the vehicles in this corridor.
- During the early morning peak (around 5:00 AM – 7:00 AM), the average speeds remain relatively unchanged between the scenarios.
- Traffic data from the after scenario show fewer instances of high-speed peaks throughout the day compared to 2020. This flatter speed profile suggests that physical interventions—such as speed tables or raised crosswalks—have been successful in creating a more uniform traffic flow.
- Even though the average speed in the afternoon (1:00 PM – 6:00 PM) is lower in the after scenario, this period still has most of the bicycle crashes, very likely due to the higher number of students and staff commuting by bike at that time.

The before and after scenarios were also compared based on the average speed during peak hours throughout the week. The results from eastbound and westbound indicated the same patterns. To illustrate the difference between the before and after, the results for westbound direction are shown in Figure 9-10 for the morning peak hour, Figure 9-11 for the midday peak, and Figure 9-12 for the evening peak.

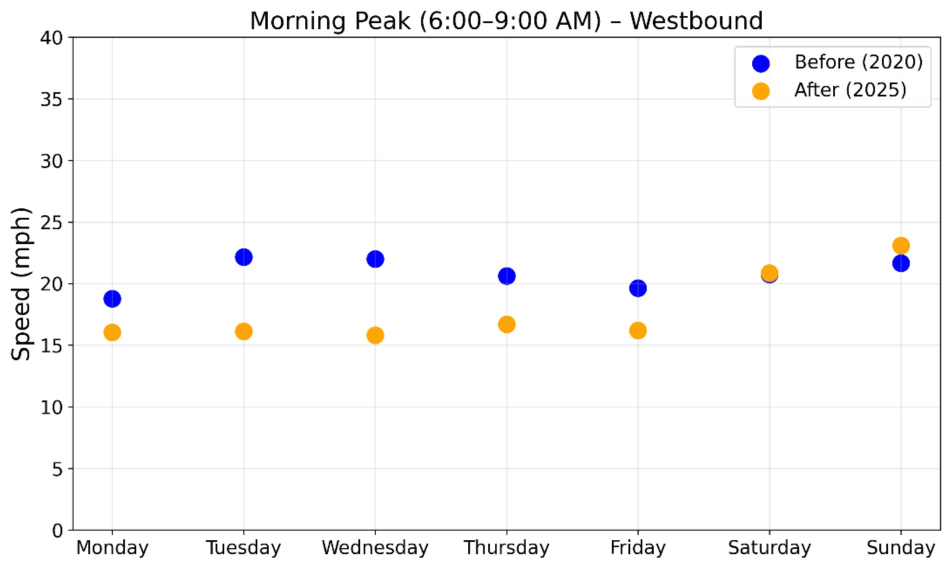


Figure 9-10 – Average speed (mph) during the morning peak hour (6:00 - 9:00 AM) by weekday for the westbound direction

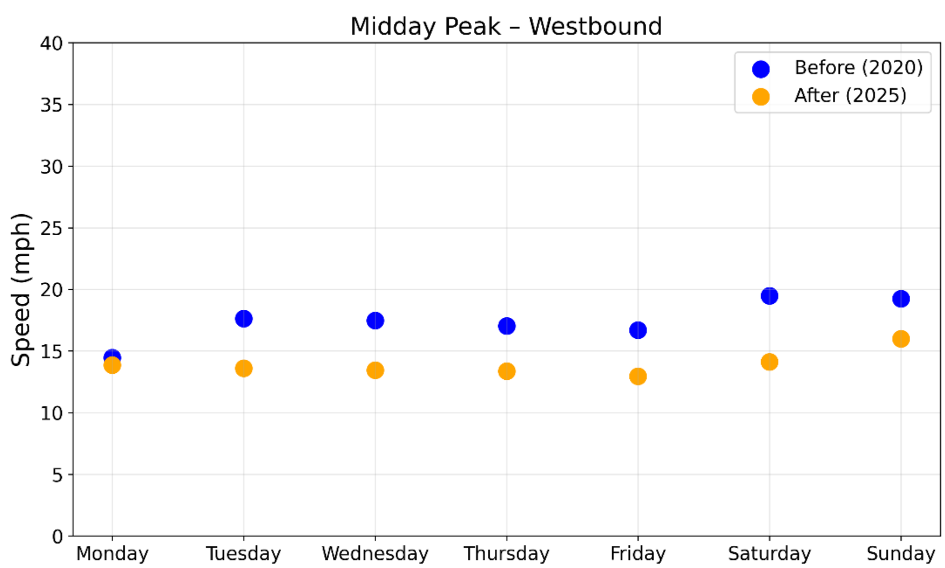


Figure 9-11 – Average speed (mph) during the midday peak hour (12:00 PM - 1:00 PM) by weekday for the westbound direction

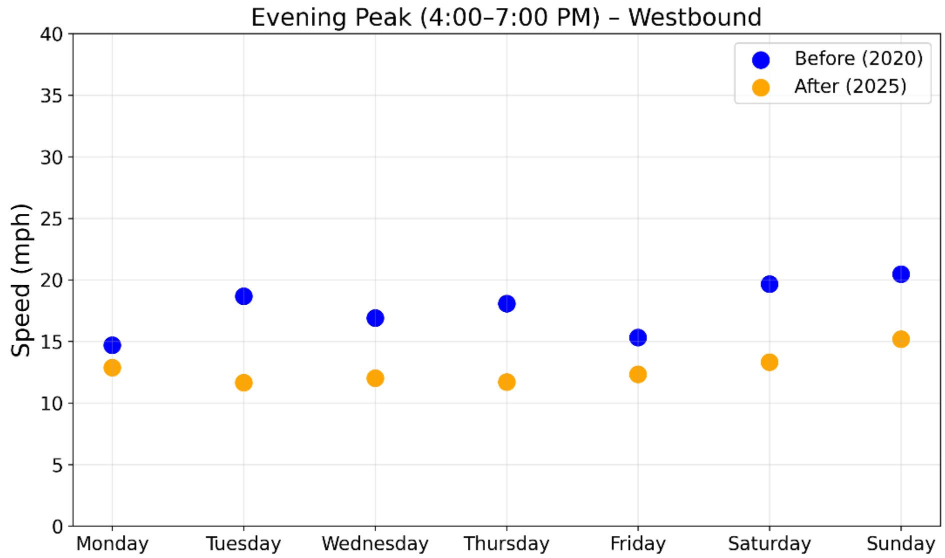


Figure 9-12 – Average speed (mph) during the evening peak hour (4:00 – 7:00 PM) by weekday for the westbound direction

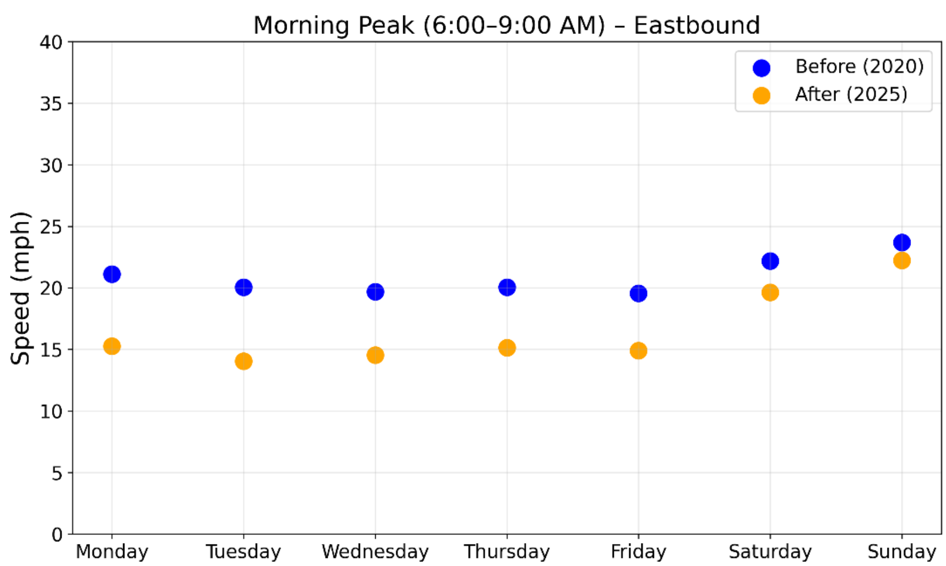


Figure 9-13 – Average speed (mph) during the morning peak hour by weekday (6:00 – 9:00 AM) for the eastbound direction

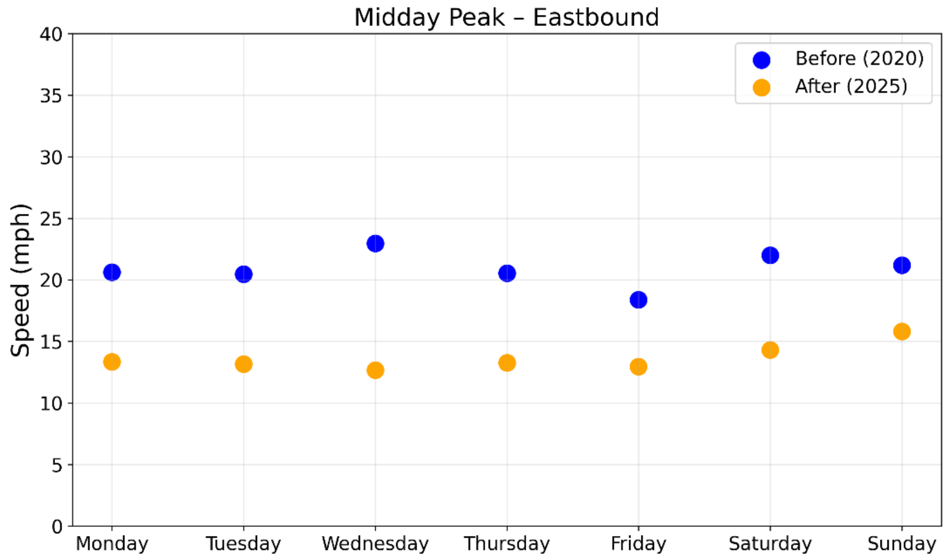


Figure 9-14 – Average speed (mph) during the midday peak hour (12:00 – 1:00 PM) by weekday for the eastbound direction

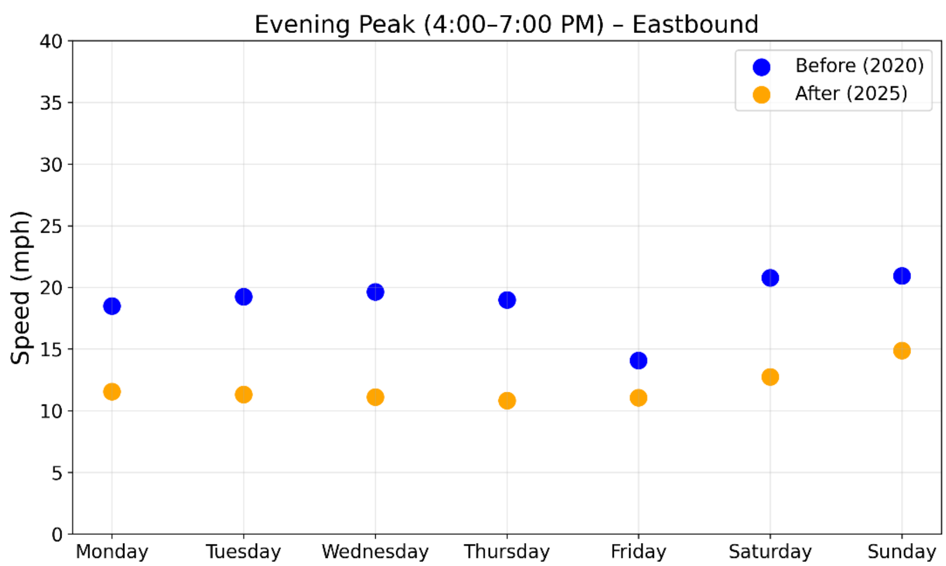


Figure 9-15 – Average speed (mph) during the evening peak hour (4:00 – 7:00 PM) by weekday for the eastbound direction

The results from the evaluation of average speed by peak hour indicate that:

- In general, the after scenario has a lower average speed in both traffic directions.
- Monday had the smallest reduction in average speed, especially in the midday peak.

- During the morning peak (Figure 9-10), no speed reduction was observed on Saturday, and an unexpected speed increase was recorded on Sunday. These patterns were seen in both the westbound and eastbound directions.
- In the after scenario, slightly higher speeds were observed on Mondays, Saturdays, and Sundays compared to other weekdays. These same days also had a higher number of pedestrian crashes, suggesting that the increased crash frequency may be related to the slightly higher average speeds.

9.3.2.2 Travel time index (TTI) comparison

The travel time analysis considered the Travel Time Index (TTI), averaged separately for weekdays (Monday through Friday) and weekend days (Saturday and Sunday), as shown in Figure 9-16 and Figure 9-17.

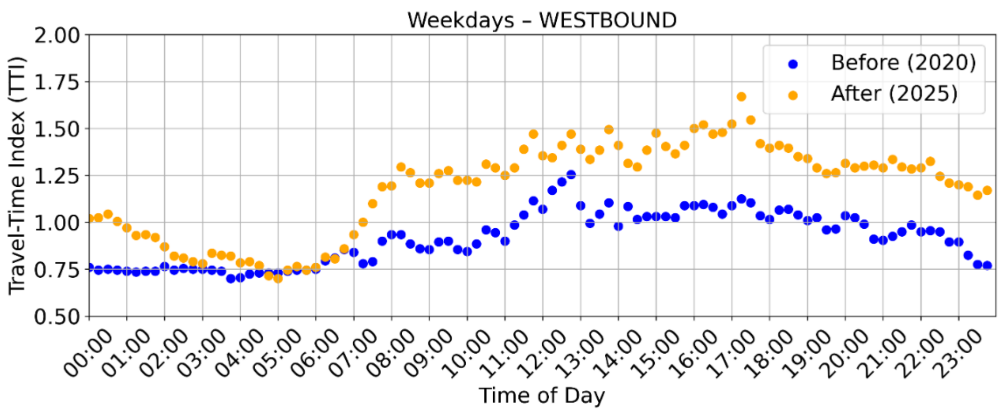


Figure 9-16 – Average Travel-Time Index for weekdays and westbound direction

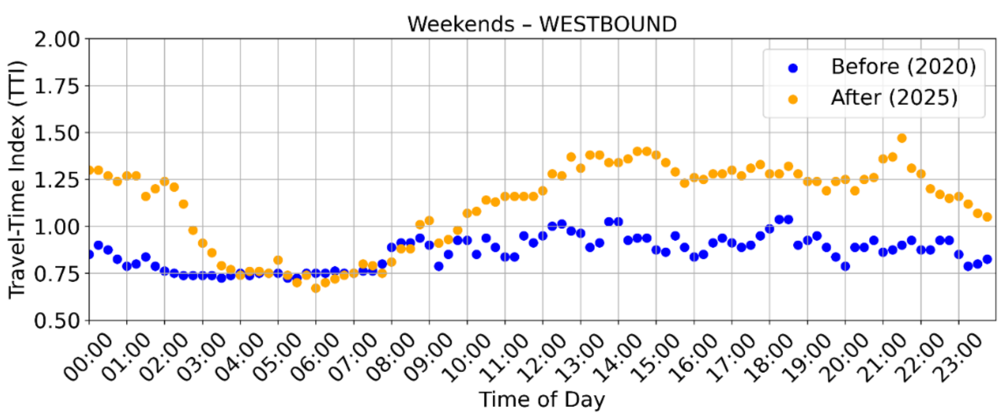


Figure 9-17 – Average travel time index for weekend and westbound direction

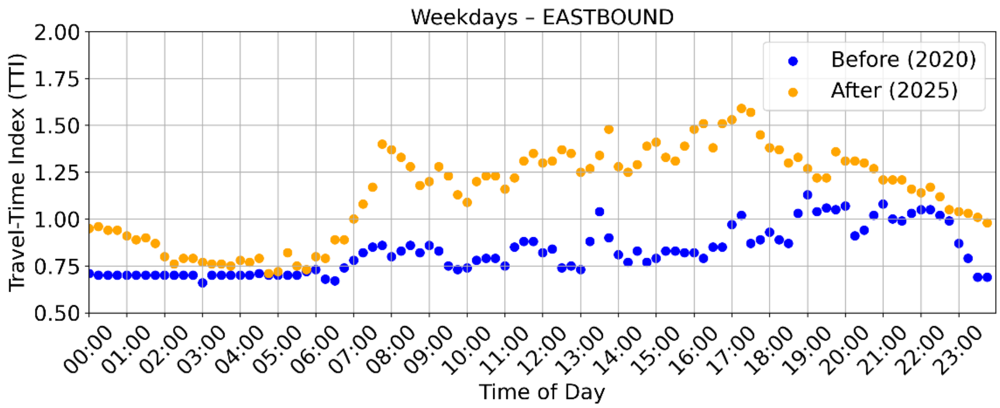


Figure 9-18 – Average travel time index for weekdays and eastbound direction

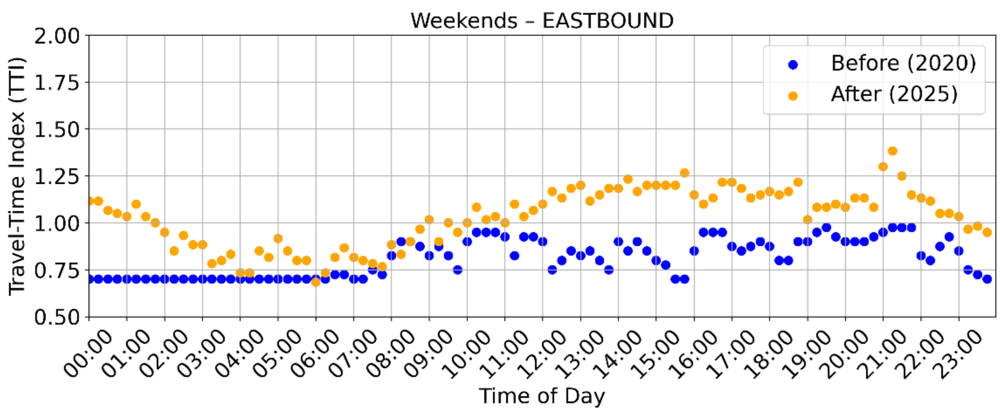


Figure 9-19 – Average travel time index for weekdays and eastbound direction

The TTI comparison between the "before" and "after" scenarios indicates that:

- Average TTI values were consistently higher in 2025, especially between 7:00 AM and 2:00 AM, with an average increase of 30% compared to the before scenario. This rise is likely due to traffic calming measures, increased travel demand, and reduced speed limits in the after scenario.
- On weekdays, the TTI peak occurred at midday in the before scenario, while in the after scenario, the peak shifted to around 5:00 PM.
- On weekends, the highest TTI in the before scenario was around 11:30 AM, whereas in the after scenario, it shifted to around 8:30 PM.
- The most noticeable TTI increases were after 7:00 AM on weekdays and after 9:00 AM on weekends, indicating higher congestion during those periods in the after scenario.

- During nighttime (2:00 AM to 6:00 AM), no significant differences in TTI were observed between the scenarios.

The following can be concluded from the travel time and speed data analysis:

- Average speeds decreased from 2020 to 2025 in both eastbound and westbound directions. This decrease is most likely due to traffic calming devices installed along West University Ave.
- The most significant speed reductions occurred between 8:00 AM and 7:00 PM, especially during midday and evening peaks.
- Weekend and Monday speeds were slightly higher in the after scenario, aligning with higher pedestrian crash frequencies on these days.
- 2025 data show fewer high-speed peaks, indicating more consistent speeds throughout the day.
- TTI values were consistently higher in 2025, especially from 7:00 AM to 8:00 PM, indicating increased congestion and longer travel times. The average TTI rose by approximately 30% between 2020 and 2025.

9.4 Effectiveness of pedestrian-phase recall and its effects on delay and travel time

Pedestrian phase calls can originate from various sources, including cameras, the app, and push buttons. These variable input methods aim to minimize unnecessary pedestrian phases when no pedestrians are present, thereby reducing vehicle delays and enhancing traffic efficiency. According to the vendors, pedestrian calls triggered by push buttons are direct inputs to the controller and are not recorded. Furthermore, the system does not differentiate between calls initiated by the camera and those from the app. Due to the lack of clarity in the data, and because the Signal Phasing and Timing (SPaT) data only indicate active pedestrian phases without identifying the source of activation, it is currently not possible to evaluate the effectiveness of the variable pedestrian phase recall in reducing delay and travel time.

10 Data Management and Software Platform

This section discusses the data management for this project and addresses the following:

- Data download
- Data archival and storage
- Data analysis
- Data access and security

10.1 Data download

Data management focused on the following types of data:

- RRFBs activated from PIDs
- Ped phase calls from push buttons
- Ped phase calls from PIDs
- Pedestrian location and direction
- Vehicle location, direction, speed, classification
- Number of vehicle alerts
- Number of non-motorized transport (NMT) alerts

During the development of the scope of work for this project, it was anticipated that the research team would receive data for each of these categories. However, due to the nature of the system, we had to adjust the specifics of the data obtained under each category, as some types of data were not available. The following subsections describe the data obtained under each category, while the last subsection discusses the management and uploading of data into the ITS Hub. Table 10–1 summarizes the dates of the data collection by type of data category, and it is referenced throughout the report.

Table 10–1 – Data collection dates for each data source

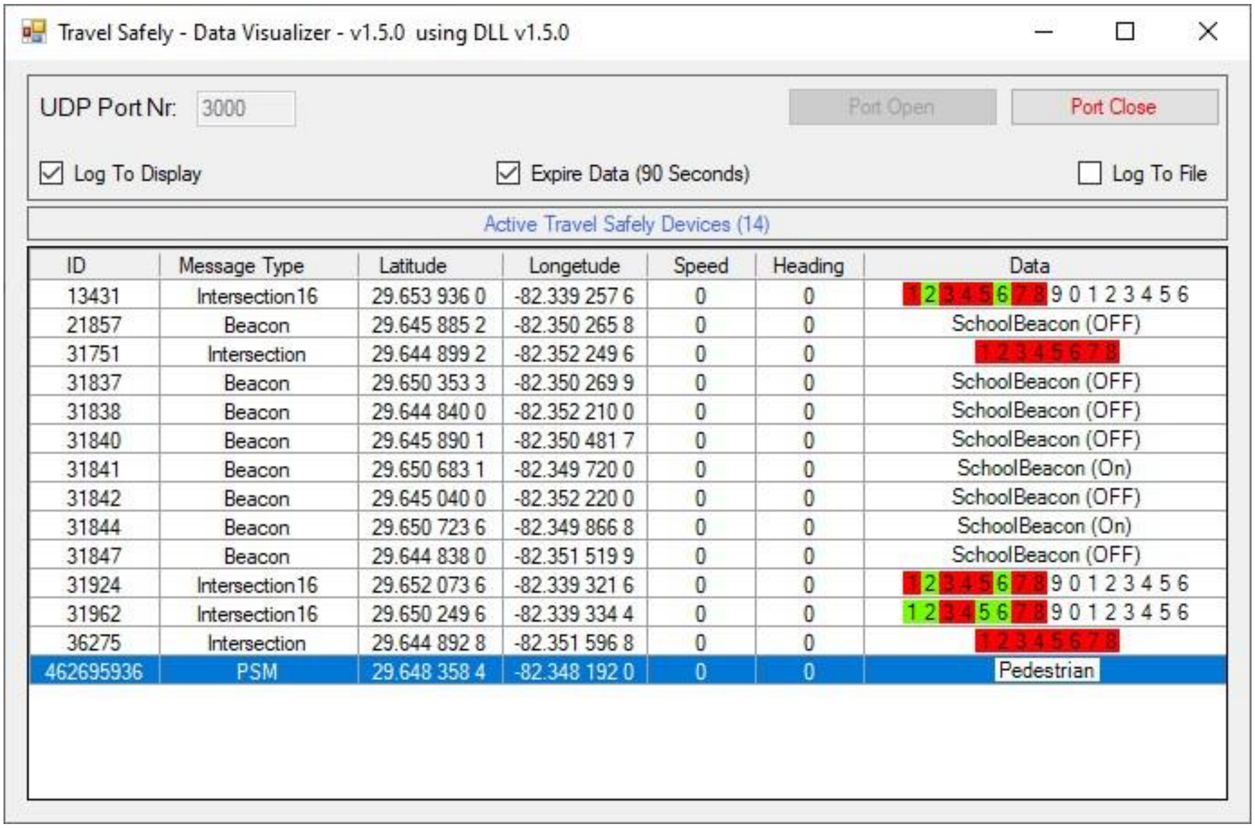
Data source	Data collection dates
OBU	2024/04/23 2024/05/01 2024/05/23 2024/06/28 2024/01/26 2024/02/23
RSU	2024/01/26 2024/02/23 2024/04/23 2024/04/01 2024/05/23 2024/06/28
App (Visualizer)	2024/05/01 2024/05/23 2024/06/10 2024/06/28 2024/11/6 - 2024/11/13
App (Route)	2024/04/23 2024/05/01 2024/06/10
App (Alerts)	November 3, 2024 – December 8, 2024
Pedestrian detections from cameras	November 2023 – January 2024

10.2 RRFBs activated from PIDs

Pedestrians and cyclists can activate the RRFBs using the Travel Safely application (the app). The RRFB activations and status changes (on or off) are recorded through the Travel Safely data visualizer (the visualizer). However, these data do not specify the source of each activation, therefore it is not known whether the activation is triggered by a camera, push button, or the app.

The visualizer provides information in the form of messages from users (pedestrians, cyclists, and drivers) and infrastructure (intersections and RRFBs). Figure 10-1 shows a screenshot of the received messages as displayed in the data visualizer. These data are logged in a text file, with each line representing a message with attributes separated by commas.

The visualizer receives data from the Glance Cloud and serves as a tool for logging data. The Glance Cloud also sends data to the Glance portal (glance.appinfoinc.com), which displays real-time information on the map. Figure 10-2 presents a screenshot of the Glance portal view.



ID	Message Type	Latitude	Longetude	Speed	Heading	Data
13431	Intersection16	29.653 936 0	-82.339 257 6	0	0	1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6
21857	Beacon	29.645 885 2	-82.350 265 8	0	0	SchoolBeacon (OFF)
31751	Intersection	29.644 899 2	-82.352 249 6	0	0	1 2 3 4 5 6 7 8
31837	Beacon	29.650 353 3	-82.350 269 9	0	0	SchoolBeacon (OFF)
31838	Beacon	29.644 840 0	-82.352 210 0	0	0	SchoolBeacon (OFF)
31840	Beacon	29.645 890 1	-82.350 481 7	0	0	SchoolBeacon (OFF)
31841	Beacon	29.650 683 1	-82.349 720 0	0	0	SchoolBeacon (On)
31842	Beacon	29.645 040 0	-82.352 220 0	0	0	SchoolBeacon (OFF)
31844	Beacon	29.650 723 6	-82.349 866 8	0	0	SchoolBeacon (On)
31847	Beacon	29.644 838 0	-82.351 519 9	0	0	SchoolBeacon (OFF)
31924	Intersection16	29.652 073 6	-82.339 321 6	0	0	1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6
31962	Intersection16	29.650 249 6	-82.339 334 4	0	0	1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6
36275	Intersection	29.644 892 8	-82.351 596 8	0	0	1 2 3 4 5 6 7 8
462695936	PSM	29.648 358 4	-82.348 192 0	0	0	Pedestrian

Figure 10-1 – Screenshot of the Travel Safely data visualizer

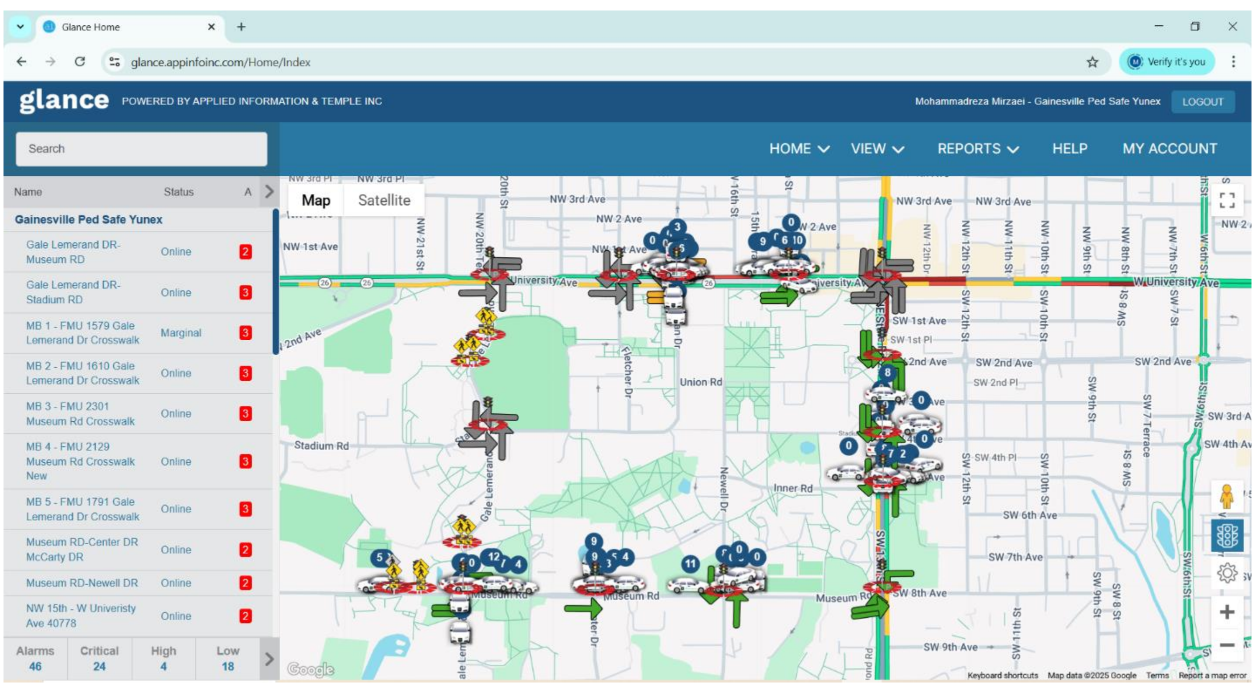


Figure 10-2 – Screenshot of the Glance portal view

Each message has an ID, message type (intersection, beacon, PSM, vehicle, etc.), latitude, longitude, speed, heading, and additional data based on each message type (see Figure 10-1). For the intersection message type, the data column shows the SPaT information and the active green phase. For the beacon message type, the data column shows the status of the RRFB (on, or off). The PSM message type indicates "pedestrian" or "cyclist" in the data column. The vehicle message type indicates whether the vehicle is a privately owned vehicle (labeled "neutral") or an emergency vehicle. Table 10–2 summarizes the message type categories.

Table 10–2 – Received message types and their categories

Message type	Data type
Intersection, Intersection16	'enSPATMessage'
PSM	'Pedestrian', 'Cyclist'
Beacon	'SchoolBeacon (On)', 'SchoolBeacon (OFF)'
Vehicle	'Neutral', 'Emergency'

These data were recorded during the tests with the app (see Table 10–1). Additionally, the visualizer data were collected during the participant experiments (see Table 10–1). Table 10–3 shows the number of messages recorded by date and by type.

Table 10–3 – Number of messages obtained by type

Date	Beacon	Intersection	PSM	Vehicle
06-11-24	84,956	232,706	24,340	2,372,890
07-11-24	115,763	373,617	36,079	4,616,307
08-11-24	105,957	378,661	14,335	6,134,610
09-11-24	103,674	373,409	284	4,461,164
10-11-24	94,970	365,708	289	4,333,762
11-11-24	121,214	361,263	14,205	4,342,602
12-11-24	153,599	375,183	8,372	5,367,212
13-11-24	22,951	134,834	975	457,161

10.3 Ped phase calls from push buttons

As indicated earlier, pedestrian phase calls from pushbuttons are not directly accessible. The vendors indicated that ped calls from push buttons are direct inputs to the controller, and these data are not recorded. However, the SPaT information shows the active phases at the intersection. These data are available from both the visualizer and from RSUs at intersections.

The SPaT data are logged encoded and therefore need to be converted. The converted data show the signal color for each phase, as shown in Figure 10-1. These data are available from the tests described in Section 5.

Furthermore, RSUs send SPaT information to road users at each intersection. Because the RSU data size is large, these were only recorded during test runs conducted to evaluate the system reliability (see Table 10–1).

10.4 Ped phase calls from PIDs

Pedestrian phase calls from PIDs are not directly accessible. PSMs sent from PIDs to the FMU activate the pedestrian phase directly on the controller. The log of PSMs from PIDs is available using the data visualizer, but it does not identify which PSM sent the ped phase call.

As indicated above, SPaT data can provide information on active phases in the intersection. Although SPaT data do not reveal the source of pedestrian calls, they provide information regarding active signal phases, as described in Section 4 of this report.

10.5 Pedestrian location and direction

The pedestrian location and direction are available from the visualizer, user route data from the app, and pedestrian detections from cameras.

The visualizer provides pedestrian location, direction, and speed. These data are obtained from pedestrians using the app. Each pedestrian using the app sends their location, direction, and speed to the Glance Cloud, and these data are accessible using the visualizer. The visualizer shows this message along with its associated information.

The app offers an option to record route information directly on the phone. These data included bearing, latitude, longitude, speed, timestamp, and record route ID. Researchers recorded route data with their phones during the evaluation of the system reliability (see Table 10–1).

The ground truth data were collected from cameras during the system reliability evaluation (see Table 10–1). The data included the direction of pedestrians crossing the study intersections. These data were collected manually for three intersections (S2-WUA & GL, S4-WUA & 17th St, and S6-WUA & 13th) in rainy and sunny weather conditions. The videos were recorded based on

FDOT standard specification 995-2.8[5] during nine periods of the day for a total of 2 hours and 45 minutes for each intersection and weather condition.

The data included the file name in which the video is saved, the start time and end time of the detection area activation, the passing time if the pedestrian is not detected by the detection area, crosswalk (north, east, west, south), detection area in the camera field of view, direction (north, east, west, south), observed (1 if observed else 0), detected (1 if detected by the system in detection area), detected type (the class of detected object by algorithm such as pedestrian, bicyclist, car, etc.), observed type (the true class of observed object in the camera footage such as pedestrian, bicyclist, car, etc.), error start and end time and the duration and type of it if exists.

10.6 Vehicle location, direction, speed, classification

These data were generated from the app users while they were in driving mode, from vehicles detected by cameras, or from test runs using OBUs as described in Section 3 and Section 4.

The visualizer data provide information about the app users in driving mode and vehicles detected by cameras. The research team collected these data during the system evaluation. The visualizer provides the location, direction, speed, and classification of vehicles ("neutral" or "emergency"), as discussed in Section 4.

Cameras detect vehicles at intersections and midblock crossings, generate the Basic Safety Message (BSM), and send it using RSUs. The RSUs forward these BSMs to Glance Cloud and the visualizer. Vehicles using OBUs generate BSMs and send them to RSUs. RSUs send these BSMs to other vehicles or road users. As indicated above, the RSU data were recorded during the system evaluation (see Table 10–1).

The OBU data were collected during tests conducted for the system evaluation (see Table 10–1). The data follow the message structure outlined in the SAE J2735_2016 standard[6]. This standard was developed to define message structures for connected vehicle communication applications. It establishes a framework for communication between vehicles (V2V), between vehicles and infrastructure (V2I), and with other road users (V2X). One of the most important aspects of SAE J2735_2016 is its set of standardized message types. The BSM is central to V2V

5

Florida Department of Transportation. (2023-24). Standard Specifications for Road and Bridge Construction. Table 995-2: Data Collection Periods. Retrieved from [https://www.fdot.gov/programmanagement/implemented/specbooks/default.shtm]

6 SAE International. (2016). SAE J2735_2016: Dedicated Short-Range Communications (DSRC) Message Set Dictionary. Warrendale, PA: SAE International.

communications, providing vehicle information such as position, speed, acceleration, braking status, and heading. The SPaT message conveys traffic signal status and timing information, while the Map Data (MAP) message provides details regarding road geometry, lane configurations, and intersection layouts. The Traveler Information Message (TIM) supports traveler advisories. The PSM in the SAE J2735 standard (SAE International, 2016) is designed to enhance the safety of vulnerable road users (VRUs) such as pedestrians and bicyclists by transmitting real-time location, speed, acceleration, and movement status to nearby vehicles and infrastructure.

10.7 Number of vehicle alerts

Vehicle alerts are available from the weekly reports of the app usage, alerts provided by Applied Information, and the messages received from OBUs during test runs.

The OBU data do not include individual alerts displayed on the OBU screen, but they include the messages that were sent/received to/from RSUs. Table 10–4 shows the number of messages received by OBU in the test runs conducted for the system evaluation.

Table 10–4 – Types and number of messages received by OBU

	Test date	
	1/26/2024	2/23/2024
Test duration (min)	52	45
SPAT	51722	53081
TIM	16290	14045
PSM	14505	15303
MAP	6267	5172

The vendor provided the app usage weekly reports during participant experiments. Figure 6-1 and Figure 6-2 show a sample of the app usage weekly report from November 25, 2024, to December 2, 2024. The weekly report has a summary of alerts, but the vendor also provides individual alerts, which include alert type, latitude, longitude, and time.

10.8 Number of NMT alerts

The vendor provided alerts from NMT (pedestrians and cyclists) during participant experiments. Table 10-5 provides a summary of the alerts received in the app during participant experiments.

Table 10–5 – Summary of alerts in the app during participant experiments

	Nov 4-10, 2024	**Nov 11-17, 2024**	**Nov 18-24, 2024**	**Nov 25-Dec 1, 2024**	**Dec 2-8, 2024**
Red light	1	0	0	0	0
Pedestrian (amber)	42	0	12	0	2
Pedestrian (red)	10	0	10	0	0
Pedestrian in crosswalk ahead	32	8	25	1	0
High speed vehicle caution (amber)	108	29	27	11	32
High speed vehicle (red)	9	0	3	0	0

10.9 Data management

This section discusses the data management for this project and addresses the following:

- Data download
- Data archival and storage
- Data analysis
- Data access and security

10.9.1 Data download

In summary, the research team recorded information and data from the following sources:

- OBU
- RSU
- App data, including the visualizer data, route data, and alerts
- Pedestrian detections from camera recordings

Table 10–6 shows the sources used to collect the data discussed above.

Table 10–6 – Data sources used for each component evaluated

	OBU	**RSU**	**App (Visualizer)**	**App (Route)**	**App (Alerts)**	**Pedestrian detections from cameras**
RRFBs activated from PIDs			Beacon (on/off)			
Ped phase calls from push buttons		SPaT				
Ped phase calls from PIDs		SPaT	PSMs and SPaT			
Pedestrian location and direction		PSM	PSM	Route data		Pedestrian counts and directions
Vehicle location, direction, speed, classification	BSM	BSM	Vehicle (BSM)	Route data		
Number of vehicle alerts					• Red light • Pedestrian (amber) • Pedestrian (red) • Pedestrian in crosswalk ahead	
Number of NMT alerts					• High speed vehicle caution (amber) • High speed vehicle (red)	

10.9.2 Data archival and storage

The OBU data are logged in Packet Capture (PCAP) files, and the Wireshark software is used to read PCAP files and convert data to other formats, such as JSON, for further analysis.

The RSU data are logged in text files in Extensible Markup Language (XML) format. Each message in the data is preceded by a timestamp indicating the minute it was recorded. The RSU data for each intersection or midblock crossing is recorded separately. Table 10–7 shows the list of intersections and midblock crossings along with their ID, and area (whether it is under the City of Gainesville or the University of Florida) in the data.

Table 10–7 – List of locations and their corresponding ID in the data

Location ID	Location	Area	ID
S1	Gale Lemerand Drive @ Stadium Road	UF	556
S2	University Avenue @ Gale Lemerand Drive	COG	5056
S3	University Avenue @ NW 18th Street/Fletcher Drive	COG	5057
S4	University Avenue @ Buckman Drive/17th Streer	COG	5058
S5	University Avenue @ NW 15th Street	COG	5059
S6	University Avenue @ SW 13th Street	COG	5060
S7	SW 13th Street @ Union Road/SW 2nd Avenue	COG	5360
S8	SW 13th Street @ Stadium Road/SW 4th Avenue	COG	5560
S9	SW 13th Street @ Inner Road/SW 5th Street	COG	5660
S10	SW 13th Street @ Museum Road	COG	5960
S11	Museum Road @ Newell Drive	UF	659
S12	Museum Road @ Center Drive McCarty drive	UF	657
S13	Gale Lemerand Drive @ Museum Road	UF	656
C3	Midblock 1	UF & COG	6005
C2	Midblock 2	UF & COG	6006
C8	Midblock 3	UF & COG	6007
C7	Midblock 4	UF & COG	6008
C9	Midblock 5	UF & COG	6009
C5	Midblock 6 (Not installed)	UF & COG	6010

Regarding the app data, the visualizer data are logged in a text file, with each message as a line in the file. A comma separates each attribute in these messages. The route data are logged in JSON format in text files. The alerts are provided in an Excel file for each week. Figure 10-3 shows a sample from the visualizer data log.

```
2024/05/01 15:54:31.194,2136507238,Vehicle,29.6503115,-82.3390727,0,331,,Neutral
2024/05/01 15:54:31.194,2138312837,Vehicle,29.6503251,-82.3393003,0,7,,Neutral
2024/05/01 15:54:31.250,10559,Intersection,29.6486368,-82.3497280,0,0,FF0000,enSPATMessage
2024/05/01 15:54:31.261,31845,Beacon,29.6500549,-82.3501249,0,0,,SchoolBeacon (On)
2024/05/01 15:54:31.272,2138312848,Vehicle,29.6502780,-82.3392699,0,357,,Neutral
```

Figure 10-3 - Sample of data from data visualizer

The pedestrian detections from cameras are collected in an Excel file. Each sheet in the Excel spreadsheet represents the location and weather conditions (for example, S4-WUA & 17th St-Sunny).

10.9.3 Data analysis

The OBU and RSU data were analyzed to obtain the reliability of the communication between OBUs and RSUs.

The app data, including the visualizer data and the user route data, were used to evaluate the communication between the apps and infrastructure. The alerts provided by Applied Information were used to monitor the usage of the app during the participant experiments.

The pedestrian detection from camera recordings data were used to evaluate the accuracy of camera detection for pedestrians.

10.9.4 Data access and security

To record OBU data, the research team directly connected a laptop to the OBU via the Local Area Network (LAN) and collected data logs that were sent and received by the OBU. A Secure Shell (SSH) connection was used to connect the OBU. After recording the data, the data were copied to the project's UF Dropbox folder using WinSCP and removed from the OBU.

The RSU data were retrieved from a Virtual Machine (VM) hosted on the University of Florida's Information Technology servers. The logged RSU data remain within the VM infrastructure. Finally, the data is copied to the project's UF Dropbox folder.

The visualizer is a software code that runs on a VM (cise-rsuconnect.ad.ufl.edu) hosted on the University of Florida's Information Technology servers. This VM connects to servers from Applied Information to receive data from Glance Cloud.

These VMs are only accessible to users on the UF network, which are protected by a firewall and available to outside, authorized users via a Virtual Private Network (VPN). Furthermore, the VMs allow only a list of specified users who are members of the research lab, further protecting the traffic data.

10.9.5 ITS hub submission

The data collected in this project have been submitted to the USDOT ITS Datahub (https://its.dot.gov/data/data-submission). The data are available to third parties through this portal. The data file structure is as follows:

- Data
    - OBU

✓ test_OBU_TSApp_2024_04_23
✓ test_OBU_TSApp_2024_05_01
✓ test_OBU_TSApp_2024_05_23
✓ test_OBU_TSApp_2024_06_28
✓ test_run_2024_01_26
✓ test_run_2024_02_23

-
    - RSU

✓ 01-26-2024
✓ 02-23-2024
✓ 04-23-2024
✓ 05-01-2024
✓ 05-23-2024
✓ 06-28-2024

-
    - TravelSafely
        - Alerts

✓ Gainesville Pedsafe Yunex Project Data 3-10Nov24
✓ Gainesville Pedsafe Yunex Project Data 11-17Nov24
✓ Gainesville Pedsafe Yunex Project Data 18-24Nov24
✓ Gainesville Pedsafe Yunex Project Data 25Nov-1Dec24
✓ Gainesville Pedsafe Yunex Project Data 2-8Dec24

-
    -
        - RecordRoute

✓ 2024_04_23
✓ 2024_05_01
✓ 2024_06_10

-
    -
        - VisualizerData

✓ SafetyDataLog_2024_05_01
✓ SafetyDataLog_2024_05_23

- ✓ SafetyDataLog_2024_06_10
- ✓ SafetyDataLog_2024_06_28
- ✓ SafetyDataLog_2024_11_13

    - ▪ Pedestrian_detections_from_camera_recordings

10.9.6 Challenges in data management and recommendations

This section summarizes challenges during project data collection and recommendations for further deployment of connected vehicle pilots in other locations.

- **Hardware operational status and maintenance**: To ensure data are correctly recorded from different sources, the deployed technology must function effectively without relying on offline devices. During previous tasks, several issues were encountered, including malfunctions with RSUs, Field Monitoring Units (FMUs) responsible for transferring app data to the infrastructure, and cameras. Additionally, maintenance challenges such as miswirings, lack of batteries, and the need to replace devices were observed.

- **Large size of data**: The data recorded in this project involve communication between multiple users and the infrastructure. Due to their high frequency and large volume, the limited storage and space available prevent the recording of all the data. The research team collected data only as necessary during tests to fulfill the objectives of the project tasks.

- **Different data formats from various sources**: For ease of use, connected vehicle data should be recorded in a standardized format. However, in this project the RSU data are in XML format, the OBU data are stored in PCAP files, and the Travel Safely application data are recorded in text format. This variety of data formats necessitates further conversion to facilitate analysis.

11 Conclusions and Recommendations

This section summarizes the conclusions of the study and provides recommendations derived from the comprehensive evaluation of the Gainesville Pedestrian-Bicyclist Connected Vehicle Pilot. The conclusions synthesize findings related to hardware and software evaluations, user perception studies, safety analysis, mobility impacts, and data management considerations. The recommendations aim to guide future deployment, maintenance, and enhancement of CV technologies for vulnerable road user safety.

11.1 Hardware and software evaluation

This study evaluated the ability of pedestrian detection devices to identify and warn pedestrians, and the main findings are:

- Pedestrian detection accuracy varied widely (12.9%–95.2%), with some intersections (S4 and S6) performing at ~76% on average, but some intersections (S2) showing only 18.6% accuracy.
- Weather and lighting strongly influenced detection reliability: sunny conditions yielded better accuracy (69.6%) than rainy (61.1%), with peak performance in the afternoon (82.7%).
- The communication system between OBUs and RSUs showed high reliability (96.3%), but maintenance issues and offline RSUs affected data completeness.
- Smartphone application reliability was high for cloud communications (99.1% PSMs received), but alert delivery was inconsistent, with delays observed when pedestrians were already in crosswalks.

11.2 User perception of the system

The user perception was evaluated through focus groups, participant experiments, and surveys to assess the smartphone application designed to provide alerts to pedestrians and reduce traffic accidents. This evaluation focused on understanding the usability, effectiveness, and user acceptance of the app. The main conclusions are:

- Focus groups revealed moderate trust in the technology along with concerns about distraction and dependence on smartphone usage.
- Participants appreciated safety-focused alerts but expressed frustration with inconsistent or delayed notifications.
- App adoption was limited, but participants indicated willingness to continue usage if system reliability improves.
- Participants felt the app was more beneficial for drivers than for pedestrians or cyclists, since drivers valued advance alerts while pedestrians often found notifications unnecessary or distracting.
- The app showed promise for people with disabilities (e.g., visually impaired or color-blind users), and for tourists or event visitors unfamiliar with the area.

- Users experienced false or missed alerts and noted that alerts differed across Apple and Android devices.
- Many pedestrians indicated they would not download the app voluntarily, seeing little personal benefit compared to physical infrastructure like flashing beacons.
- Participants strongly suggested integration with navigation systems (Google Maps, Apple CarPlay, Waze) and wearable devices (smartwatches) to make the app less intrusive and more practical.

11.3 Safety analysis

The user safety was assessed using historical crash data and video analysis, focusing on pedestrian and bicyclist incidents. The main conclusions are:

- Crash data analysis confirmed persistent pedestrian and bicyclist crash concerns, particularly along University Avenue.
- The annual average of ~180 crashes in 2021–2023 is lower than the 220–240 crashes/year recorded during the 2014–2019 period, indicating some overall safety improvement.
- From 2015–2023, West University Avenue consistently had the highest pedestrian crash frequency, while 13th Street showed a significant increase. Museum Road showed the greatest reduction (-86.7%).
- Bicycle crashes decreased 56.6% overall (2.69/year in 2015–2018 to 1.17/year in 2021–2023). West University Avenue had a significant decline (-89.7%), reducing from 3.25/year to 0.33/year. However, 13th Street still recorded 1 crash/year.
- In pedestrian crashes, the most common causes were failure to yield (31.3%), reckless driving (16.7%), and driver inattention (12.5%). Drivers were found at fault in 72.7% of pedestrian crashes, with 65% occurring during turning movements.
- Near-miss data suggested reductions after deployment. There was a reduction in near-miss frequency from 48 incidents/hour in October 2022 to 31 incidents/hour in October 2024, a 35% decrease. Improvements were most visible at crosswalks and right-turn conflicts, though near-misses remain concentrated at busy turning locations.
- Right-turning vehicles produced the highest number of near-miss conflicts in both years, but with a large drop in 2024. Left-turning and through-movement conflicts also declined.
- The safety improvements cannot be attributed to the system as there have been significant changes in the study network between the “before” and “after” periods of analysis, many of them to address safety concerns.

11.4 Mobility analysis

The mobility analysis evaluated level of service (LOS), delay, travel time, and average speed using probe data from the study corridor and three intersections after system implementation. The main findings are:

- HCM analyses of the three studied intersections indicated that the intersection at W. University Ave. & 13th St (S6) operated at LOS F during the peak hour for motorized traffic, while S4 (W. Univ. & 17th St.) and S2 (W. Univ. & Gale Lemerand Dr.) both operated at LOS B. Pedestrian levels of service were consistent across sites, averaging LOS C.
- The operational analysis confirmed S6 (W. Univ. & 13th St.) as the most critical bottleneck of the corridor, primarily due to high westbound volumes during the afternoon peak.
- Along West University Avenue (between Gale Lemerand Dr. and 13th St.), weekday evening peaks exhibited the highest congestion, with TTI consistently above 1.5. Weekends showed significantly lower TTIs, with Sunday presenting the lowest congestion levels across all time periods.
- Speed profiles indicated that evening peak speeds dropped below 15–20 mph, while morning peak speeds were higher. Sundays consistently showed the highest speeds in both directions.
- Although cameras, push buttons, and the app could all trigger pedestrian phases, the system did not differentiate the source of activations. As a result, it was not possible to quantify delay savings attributable to variable pedestrian recall. Vendors reported that push-button activations were not logged, and SPaT data only reflected active pedestrian phases, not the input source.
- While added pedestrian phases slightly increased delays at some intersections, the overall impacts on mobility were minimal, and there were no major adverse effects on vehicle operations. The balance between enhanced safety for pedestrians and minor traffic delay was considered acceptable.
- When comparing the before and after scenarios, it was observed that the University Avenue corridor experienced longer delays, higher congestion (TTI), and reduced speeds, largely due to traffic calming and lower speed limits.
- The overall outcome indicates that traffic mobility efficiency was reduced, but this was offset by the intended benefits of safer crossings and more uniform traffic speeds.

11.5 Data management and software platform

The processes of data download, archiving and storage, analysis, access, and security were evaluated. The datasets analyzed included information from RRFB activations triggered by PIDs, pedestrian phase calls from push buttons and PIDs, pedestrian location and direction, vehicle location, direction, speed, and classification, as well as the number of vehicle alerts and non-motorized transport (NMT) alerts. The project generated data from multiple sources, including OBUs, RSUs, TravelSafely app logs (alerts, route, visualizer), pedestrian detections from cameras, and RRFB activations.

The main findings are:

- Hardware reliability issues were identified during this project. Monitoring through the Glance portal (May–July 2024) showed that 12 of 13 intersection FMUs were online, but 4 of 5 midblock FMUs were offline. This represents a major reliability concern, as FMUs are critical for transferring app and detection data to controllers.

- The system produced very large datasets due to the high frequency of connected vehicle messages. Not all data could be stored continuously; instead, the research team collected data selectively during tests to meet task objectives.
- The project identified data format inconsistencies: different components use incompatible formats. These differences required substantial post-processing and conversion to standard formats before analysis.
- Project data (OBU, RSU, app alerts, pedestrian detections, and safety logs) were successfully submitted to the USDOT ITS DataHub, making them accessible for third-party research and national CV pilot integration.

11.6 Recommendations

The following are recommendations for improving the overall functionality and reliability of the system:

11.6.1 Pedestrian detection system

- Redesign detection zones to better encompass pedestrian trajectories, reducing false negatives and accounting for heading direction.
- Extend detection algorithms to include scooters and other micro-mobility devices, which were misclassified as bicycles or pedestrians.
- Enhance algorithms for low-light and rainy conditions, as many false positives occurred during dark periods due to poles and shadows.
- Deploy automated ground truth data collection methods, rather than relying exclusively on manual video review, to monitor ongoing accuracy.

11.6.2 Communication system

- Establish proactive maintenance protocols for RSUs and FMUs, particularly at solar-powered midblock crossings where downtime was common.
- Reduce latency in message delivery by implementing faster positioning technologies (e.g., RTK GPS) and optimizing server architecture.
- BSM by source (camera vs. OBU) to allow evaluation of device-specific reliability.
- Adjust system configurations to deliver pedestrian alerts when users are entering crosswalks, instead of after crossing is nearly complete.

11.6.3 Smartphone application

- Expand pilot testing and encourage wider app adoption to capture a broader user base and improve system representativeness.
- Work with vendors to reduce alert delays by minimizing cloud processing time, potentially via localized servers.
- Enable smartphone-based logging of transmitted and received messages to enhance reliability evaluation.

- Improve user interface design to minimize distraction and ensure consistency across pedestrian, cyclist, and motorist modes.

11.6.4 User perception and behavior

- Develop public education campaigns to improve trust in CV safety applications.
- Explore incentive programs through partnerships with local agencies to increase app usage.
- Integrate human factors considerations to ensure alerts support, rather than replace, user decision-making.

11.6.5 Safety and mobility

- Continue long-term monitoring of crash and near-miss data to assess sustained safety benefits.
- Deploy automated near-miss detection tools (e.g., AI-based video analysis) to improve efficiency and consistency.
- Refine pedestrian phase recall strategies to balance pedestrian safety and vehicle mobility, avoiding unnecessary delay.

11.6.6 Data management and system integration

- Implement standardized archival and cloud-based storage protocols with secure backup systems.
- Require FMUs to log all message paths (cloud ↔ FMU, FMU ↔ controller) to support reliability analysis.

11.7 Closing remarks

The Gainesville Connected Vehicle Pilot represents a significant step toward deploying innovative safety technologies for pedestrians and bicyclists. The findings underscore the importance of reliable detection, seamless communication, robust maintenance, and strong user engagement. By addressing the identified challenges and implementing the outlined recommendations, FDOT and its partners can enhance the effectiveness of CV deployments, ultimately contributing to safer, more efficient, and more resilient urban mobility systems.

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Appendix A – Overview of deployment components

Table A1– Deployment components description

#	Component	Location	Purpose	System support
1	Roadside Units (RSUs)	All traffic signals and midblock crossings	V2I communications using CV2X to process detection logic and broadcast Personnel Safety Message (PSM) and pedestrian and bicyclist presence detection information. Communicates with PID.	Receives Basic Safety Message (BSM) from vehicles. Receives PSM from Non- Motorized Vehicles (NMTs) Supports active (geofence) detection of vehicles and NMTs. Supports CV2X alert transmission to PIDs and OBUs
2	CV2X compatible controllers	All traffic non-midblock signals	To process traffic signal controller information to SAE J2735 (SAE International, 2016) format for RSU use, as needed.	Enables real-time traffic signal information availability for V2I. Supports roadway vehicle detection (all vehicles) Feed NMT location, direction, and alerts to the project data warehouse
3	Passive pedestrian/ bicyclist detection	All traffic signals and Midblock crossings	To detect presence and counts of pedestrian walking speed and dissemination.	Improve bicyclist and pedestrian safety at signals. Provide pedestrian and bicyclist presence information
4	Active pedestrian/ bicyclist detection (geofence) using PID	All traffic signals and midblock crossings	Active system detection of NMT presence in crosswalk (geofence). Request pedestrian phase at traffic signal controller or activate RRFB.	Provide pedestrian and bicyclist presence information. Geofence detection Inform driver of NMT location, direction, and speed Request pedestrian phase at traffic signal controller or activate RRFB
5	Midblock crossing RRFBs	All midblock crossings	To alert vehicular traffic of pedestrian midblock crossings.	Improve NMT safety at midblock crossings. Draw motorists' attention to the pedestrian and bicyclist crossings
6	On-Board Units (OBUs)	Test vehicles	To provide two-way communications between RSUs and OBUs; to generate driver alerts.	Human Machine Interface (HMI) to driver Alert driver of NMT presence Broadcast BSM to RSU Receive NTM alert from RSU
7	Advance Vehicle Detection of Travel Mode	Upstream of all traffic signals and midblock crossings	To detect motorist, pedestrian, and bicycle presence in advance of approaching the midblock crossings and signalized intersections.	Provide RSU with OBU-equipped vehicle location, direction, classification, and speed in vehicle geofence. Detect and count all vehicles. Alert NMTs vehicle arrival

Appendix B – Screening questionnaire

Pedestrian and bicyclist safety focus group

Project Title: FDOT AID-Pedestrian Bicyclist Safety Project (BED31-977-23)
IRB#ET00024607
Principal Investigator: Lily Elefteriadou

Dear participant,
Thank you for your interest in the "*Pedestrian and bicyclist safety focus group*" study.

In this study, we will show you a smartphone application that warns pedestrians and drivers about possible conflicts. We would like to know your feedback on the application.

This document is a screening questionnaire, and we use your answers to place you in the right group.

Please contact us if you have any questions:

- **Email**: m.mirzaei@ufl.edu
- **Phone number:** +1 (352)-721-4415

Sign in to Google to save your progress. Learn more

* Indicates required question

Please state your **first and last name** *

Your answer

Please provide your **contact number** *

Your answer

Figure B-1 – Questionnaire for pedestrian and bicyclist safety focus group

Please provide your **email address** *

Your answer

Please provide your **mailing (physical) address and zip code** *
(This information will be used for payments)

Your answer

What is your **age**? *

- 18-25
- 26-35
- 36-45
- 45-55
- 56-64
- 65 or older

What is your **gender**? *

- Male
- Female
- Non-binary
- Prefer not to say

Figure B-2 – Questionnaire for pedestrian and bicyclist safety focus group (continued)

Do you currently hold a valid **driver's license**? *

- ○ Yes
- ○ No

Do you have any **accessibility needs or requirements** that we should be aware of to ensure you can fully participate in the focus group? *

- ○ Yes
- ○ No

If your answer is "**Yes**" for previous question, please describe:

Your answer

How often do you drive, walk, or bike in an average week **on the University of Florida campus**? *

	0 days	1-3 days	4-5 days	6-7 days
Drive	○	○	○	○
Walk	○	○	○	○
Bike	○	○	○	○

Figure B-3 – Questionnaire for pedestrian and bicyclist safety focus group (continued)

10/3/24, 3:57 PM Pedestrian and bicyclist safety focus group

How often do you drive, walk, or bike in an average week outside of the University of Florida campus **(off-campus)**? *

	0 days	1-3 days	4-5 days	6-7 days
Drive	○	○	○	○
Walk	○	○	○	○
Bike	○	○	○	○

Next

Clear form

Never submit passwords through Google Forms.

This form was created inside of University of Florida. Report Abuse

Google Forms

https://docs.google.com/forms/d/e/1FAIpQLSdFIP5phM3BAC41mOIItLbdN7KNLeW-5dt1E0eFKWheOkrNJw/viewform 4/5

Figure B-4 – Questionnaire for pedestrian and bicyclist safety focus group (continued)

Appendix C– Focus group agenda

- **Part 1-Introduction: (5 min)**

  The session began with an introduction to the purpose of the study and the technology being evaluated.

  - Ensured confidentiality and obtained consent.
  - Introduced the research team and the purpose of the focus group.
  - Explained the focus group process and the importance of participant feedback.
- **Part 2- First part of questions: (20 min)**

  Researchers asked the first part of the questions regarding participants' experiences on campus.
- **Part 3-Presentation: (15 min)**

  Researchers presented the app, demonstrating its features and functionality.

  - Presented the background of the project and study area.
  - Demonstrated key features of the app
  - Explained how the app alerts pedestrians/drivers to avoid traffic accidents.
  - Presented videos from the driver and pedestrian view to show how users receive alerts.
  - Questions and answers
- **Part 4-Discussion and Feedback Collection**: **(40 min)**

  Participants engaged in a guided discussion to provide feedback on their initial impressions of the app's usability, design, and perceived effectiveness. Detailed feedback was gathered through structured, open-ended questions.

  - The second part of the focus group questions were asked and discussed with participants.
  - Wrap-Up and Thank You [Information provided on the next steps and how the feedback will be used.]

Appendix D– Focus group questions

UF | Transportation Institute
UNIVERSITY *of* FLORIDA

IRB#ET00024607

Project Title: FDOT AID-Pedestrian Bicyclist Safety Project (BED31-977-23)

Principal Investigator: Lily Elefteriadou

Introduction (10 min)

Focus group questions

Experiences on campus (20 min)

- Describe your experience walking as a pedestrian on the University of Florida campus. (7 min)

Answer:____

____

____

____

- Describe your experience cycling at the University of Florida campus. (6 min)

Answer:____

____

____

____

- Describe your experience while driving at the University of Florida campus. (7 min)

Answer:____

____

____

____

Presentation (15 min)

I-STREET

Figure D-1 – Questions asked during the focus groups

UF | Transportation Institute
UNIVERSITY of FLORIDA

IRB#ET00024607

Project Title: FDOT AID-Pedestrian Bicyclist Safety Project (BED31-977-23)

Principal Investigator: Lily Elefteriadou

Discussion (40 min)

- Have you used the Travel Safely app or similar apps before? (2 min)
  - No
  - Yes

    If yes, what was the name of the application? ________________________________
- What were your **initial thoughts** on the app after the presentation? (6 min)

____

- What did you think of **motorist alerts**? (3 min)

____

- What did you think of **pedestrian alerts**? (3 min)

____

- Do you **jaywalk**? Or **not yield to pedestrians at crosswalks**? How **frequently**? (2 min)

____

- Do you think this app will have an influence on **jaywalking** or **not yielding to pedestrians at crosswalks**? (3 min)

____

- What do you think about the **app's design and layout**? (6 min)

____

- Were there any **features** that you found **helpful**? (3 min)

____

- Were there any **features** that you found **confusing**? (3 min)

____

- What changes would you **suggest to improve the app**? (3 min)

____

- What do you think are the **advantages and disadvantages** of using the **app** compared to older traffic safety tools such as **traffic signals** or **flashing beacons**? (6 min)

____

- Are you **interested in taking part in the next step** of the study? (Yes/No)

I-STREET

Figure D-2 – Questions asked during the focus groups (continued)

Appendix E– Feedback session questions

Transportation Institute
UNIVERSITY *of* FLORIDA

IRB#ET00024607

Project Title: FDOT AID-Pedestrian Bicyclist Safety Project (BED31-977-23)

Principal Investigator: Lily Elefteriadou

Feedback sessions for Task 3.2
December 2024

1 Introduction (5 min)

Project background, overview of this part of the study, and purpose of the feedback sessions

Roundtable introductions

2 Experiences on campus (15 min)

2.1.1 Describe your experience walking, cycling, and driving on the University of Florida campus.

3 Discussion (40 min)

3.1 Overall experience with the app (15 min)

3.1.1 Had you used the Travel Safely app or similar apps before? If yes, what was the name of the application?

3.1.2 What do you think are the **advantages and disadvantages** of using the **app**?

3.1.3 Have you been able to activate Rectangular Rapid Flash Beacons (RRFBs) at midblock crossings without using push buttons?

3.2 Usability (15 min)

3.2.1 What is your perception of the **interface** of the Travel Safely app?

3.2.2 What did you think of **motorist alerts**?

3.2.3 What did you think of **pedestrian/cyclist alerts**?

3.2.4 Were there any **features** that you found **helpful/ confusing**?

3.2.5 What changes would you **suggest to improve the app**?

3.3 Safety (10 min)

3.3.1 Did your perception of traveler safety change when using the app?

As a pedestrian?
As a bicyclist?
As a motorist?

I-STREET

Figure E-1– Questions asked during the focus group (continued)

Appendix F– Participant experiment questionnaire

Participant questionnaire - Pedestrian and bicyclist safety

Project Title: Evaluation of the Gainesville Pedestrian and bicyclist connected vehicle pilot
* This research project (Contract#: BED31-977-23) is funded by the Florida Department of Transportation (FDOT) and conducted by the University of Florida.
IRB#: ET00024607 - FDOT AID-Pedestrian Bicyclist Safety Project
Principal Investigator: Lily Elefteriadou

Dear participant,
Thank you for your interest in the "*Pedestrian and bicyclist safety*" study. In this study, we are evaluating a smartphone application that warns pedestrians and drivers about possible conflicts. We would like to obtain your feedback on the application.

Participants need to complete the following steps to receive a $75 gift card:

1. Attend an orientation session and download the app (1 hour, in-person)
2. Use the application for two weeks
3. Respond to the online questionnaire (30 minutes)
4. Attend feedback session and collect the gift card (1 hour, in-person)

You have already completed the orientation session. At the completion of using the app for two weeks please respond to these questions.

Please contact us if you have any questions:

- **Email**: m.mirzaei@ufl.edu
- **Phone number:** +1 (352)-721-4415

* Indicates required question

1. Please state your first and last name *

____

2. Please provide your contact number *

____

Figure F-1– Participant questionnaire

3. Please provide your email address *

4. Which date and time works better for you to participate in a feedback session and gift card pickup? *

Check all that apply.

- [ ] Monday, December 2, 2:30 PM - 3:30 PM
- [ ] Tuesday, December 3, 12:00 PM - 1:00 PM
- [ ] Wednesday, December 4, 1:00 PM - 2:00 PM
- [ ] Thursday, December 5, 12:30 PM - 1:30 PM

5. Please confirm the following statements *

Mark only one oval.

- ◯ I confirm that I have downloaded and used the app several times. I confirm that the responses I provide in this questionnaire are truthful and based on my own experience using the app. *Skip to question 6*
- ◯ I have not downloaded and not used the app. *Skip to section 2 (I have not downloaded and not used the app.)*

I have not downloaded and not used the app.

Thank you for your input. It is unfortunate you are not able to complete your participation in this study.

Please contact us if you have any questions:

- **Email**: m.mirzaei@ufl.edu
- **Phone number:** +1 (352)-721-4415

Figure F-2 – Participant questionnaire (continued)

App usage

Project Title: FDOT AID-Pedestrian Bicyclist Safety Project (BED31-977-23) IRB#ET00024607
Principal Investigator: Lily Elefteriadou

6. In the last two weeks, how many days did you use the app?

Mark only one oval.

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14

Figure F-3 – Participant questionnaire (continued)

7. How many alerts did you receive in the last two weeks? *

Mark only one oval.

- No alerts received
- 1-5
- 6-10
- more than 10

8. Have you been able to activate Rectangular Rapid Flash Beacons (RRFBs) at midblock crossings without using push buttons? *

Mark only one oval.

- Yes
- No
- I have not tried

9. During what times did you travel in the study area the most? (Select all that apply) *

Check all that apply.

	AM Peak (7:00 AM - 9:00 AM)	AM Off-peak (9:00 AM - 12:00 PM)	Afternoon Off-Peak (12:00 PM - 5:00 PM)	PM Peak (5:00 PM - 7:00 PM)	Night (7:00 PM - 7:00 AM)	Not applicable
Drive	☐	☐	☐	☐	☐	☐
Walk	☐	☐	☐	☐	☐	☐
Bike	☐	☐	☐	☐	☐	☐

Figure F-4 – Participant questionnaire (continued)

10. What is your perception of the interface of the Travel Safely app?

Mark only one oval.

- Very intuitive
- Intuitive
- Neutral
- Somewhat confusing
- Very confusing

11. How does the app serve different road users? *

Mark only one oval per row.

	Very effectively	Effectively	Neutral	Ineffectively	Very ineffectively
Driver					
Pedestrian					
Cyclist					

12. How likely are you to use the app after the study? *

Mark only one oval.

- Very likely
- Somewhat likely
- Neutral
- Somewhat unlikely
- Very unlikely

Figure F-5– Participant questionnaire (continued)

Overall experience with the app

Project Title: FDOT AID-Pedestrian Bicyclist Safety Project (BED31-977-23) IRB#ET00024607
Principal Investigator: Lily Elefteriadou

13. What is your level of satisfaction with the Travel Safely application? *

Mark only one oval.

- Very satisfied
- Somewhat satisfied
- Neutral
- Somewhat dissatisfied
- Very dissatisfied

14. What do you see as the main advantages of using the Travel Safely app for you? * (Select all that apply)

Check all that apply.

- [ ] Increased safety
- [ ] Convenience
- [ ] Timely alerts
- [ ] Better navigation
- [ ] Other: ______________________

Figure F-6 – Participant questionnaire (continued)

15. What do you see as the main disadvantages or challenges of using the Travel Safely app for you? (Select all that apply) *

Check all that apply.

- [ ] Technical issues
- [ ] Battery consumption
- [ ] Inaccurate alerts
- [ ] User interface difficulties
- [ ] Other: ______________________

16. Do you find the app distracting? *

Mark only one oval.

- ( ) Yes *Skip to question 17*
- ( ) No *Skip to question 18*

Distraction

Project Title: FDOT AID-Pedestrian Bicyclist Safety Project (BED31-977-23) IRB#ET00024607
Principal Investigator: Lily Elefteriadou

17. Briefly explain how you found the app to be distracting *

____
____
____
____
____

Safety

Project Title: FDOT AID-Pedestrian Bicyclist Safety Project (BED31-977-23) IRB#ET00024607
Principal Investigator: Lily Elefteriadou

Figure F-7 – Participant questionnaire (continued)

18. Using the Travel Safely app will reduce unsafe behaviors, such as jaywalking, or not yielding to pedestrians as a driver. *

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

19. Do you jaywalk or follow other pedestrians when they jaywalk? *

Mark only one oval.

- Yes
- No
- Maybe

20. How often do you comply with walk/don't walk signal indications at: *

Mark only one oval per row.

	Always	Often	Sometimes	Rarely	Never
Intersections					
Midblock crossings					

Figure F-8 – Participant questionnaire (continued)

21. Did the app affect your level of compliance with walk/ don't walk sign?

Mark only one oval.

- Strongly increase compliance
- Somewhat increase compliance
- No effect on compliance
- Somewhat decrease compliance
- Strongly decrease compliance

22. How do midblock crosswalks with flashing beacons affect your perception of safety? *

Mark only one oval.

- I feel much safer
- I feel somewhat safer
- No difference
- I feel less safe
- I do not feel safe

Figure F-9 – Participant questionnaire (continued)

23. Rate your perception of the effectiveness of the following traffic safety technologies in improving pedestrian and cyclist safety: *

Mark only one oval per row.

	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
Smartphone apps (like Travel Safely)	⬭	⬭	⬭	⬭	⬭
Rectangular Rapid Flash Beacons (RRFB)	⬭	⬭	⬭	⬭	⬭
Traditional traffic signals with push buttons for pedestrians	⬭	⬭	⬭	⬭	⬭

Comments

Project Title: FDOT AID-Pedestrian Bicyclist Safety Project (BED31-977-23) IRB#ET00024607
Principal Investigator: Lily Elefteriadou

24. If you have other comments to share, please add them here:

____

____

____

____

____

Figure F-10 – Participant questionnaire (continued)

Appendix G – Participant questionnaire results

A total of 45 participants completed a questionnaire aimed at capturing their overall experience with the app, usage patterns, and safety perceptions. The data were collected during Nov 4-17, 2024, from 32 participants and during Nov 18- Dec 2, 2024, from 13 participants. All participants confirmed that they had downloaded and used the app multiple times, however, some of them reported 0 days of usage. Additionally, participants attested that their responses were truthful and based on their personal experiences.

Usage

How many days participants used the app

Figure G-1 shows the distribution of how many days participants used the app over a two-week period. Usage patterns vary widely, with some participants reporting no app usage (e.g., 0 days) and others using the app more consistently (e.g., 10 days). The usage varies widely, with peaks around 3, 6, and 10 days. Six days has the highest frequency, with 10 participants using the app. A notable number of 7 participants used the app for 10 days.

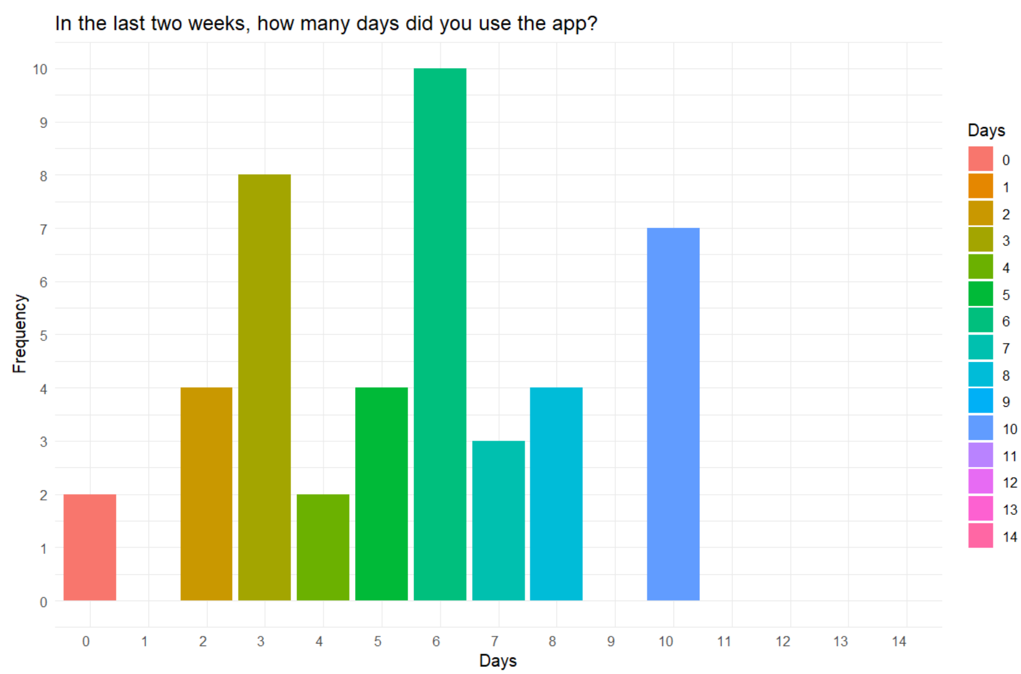


Figure G-1– Distribution of the number of days participants used the app in the two-week period

Number of alerts received

Figure G-2 displays the distribution of alerts participants received in the two-week period. 48.9% of participants received 1–5 alerts, which is the largest portion. 26.7% of participants reported receiving no alerts. 20% of participants received 6–10 alerts. A small percentage of participants (approximately 4.4%) received more than 10 alerts.

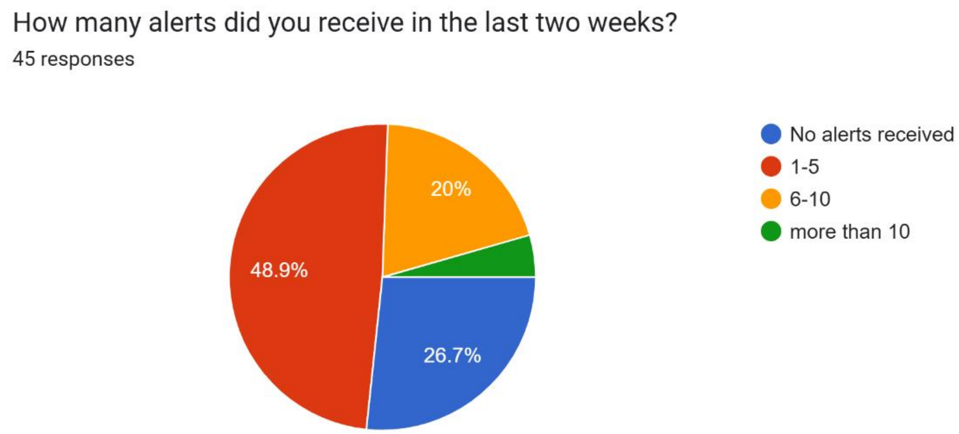


Figure G-2 – Number of alerts received in the two-week period

Activating Rectangular Rapid Flashing Beacons (RRFBs) at midblock crossings

Figure G-3 shows participants' responses regarding their ability to activate Rectangular Rapid Flash Beacons (RRFBs) at midblock crossings without using push buttons. 46.7% of participants indicated that they had not tried activating the RRFBs. 28.9% reported that they could not activate the RRFBs without using push buttons. 24.4% of participants successfully activated the RRFBs without push buttons.

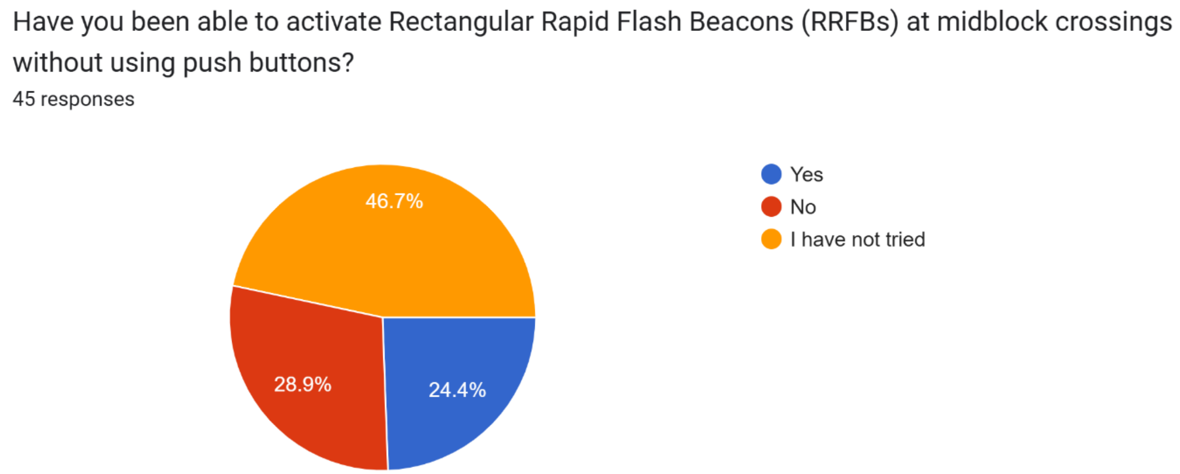


Figure G-3 – Activating Rectangular Rapid Flashing Beacons (RRFBs) at midblock crossings

Walking, driving, and biking in different periods of the day

Figure G-4 displays the frequency of use by transportation mode and in each time period of the day. The data are divided into five time periods:

- AM Peak (7:00 AM - 9:00 AM)
- AM Off-Peak (9:00 AM - 12:00 PM)
- Afternoon Off-Peak (12:00 PM - 5:00 PM)
- PM Peak (5:00 PM - 7:00 PM)
- Night (7:00 PM - 7:00 AM)

The "Not applicable" category indicates that participants do not walk, drive, or bike during any of the periods.

The chart shows that walking (green bars) has the highest frequency during the AM Off-Peak (9:00 AM - 12:00 PM) and Afternoon Off-Peak (12:00 PM - 5:00 PM) periods. Driving (blue bars) is most frequent during the PM Peak (5:00 PM - 7:00 PM) and Night (7:00 PM - 7:00 AM) period. Biking (red bars) shows a peak during the Afternoon Off-Peak (12:00 PM - 5:00 PM) and PM Peak (5:00 PM - 7:00 PM) but has lower frequencies during the Night times (7:00 PM - 7:00 AM).

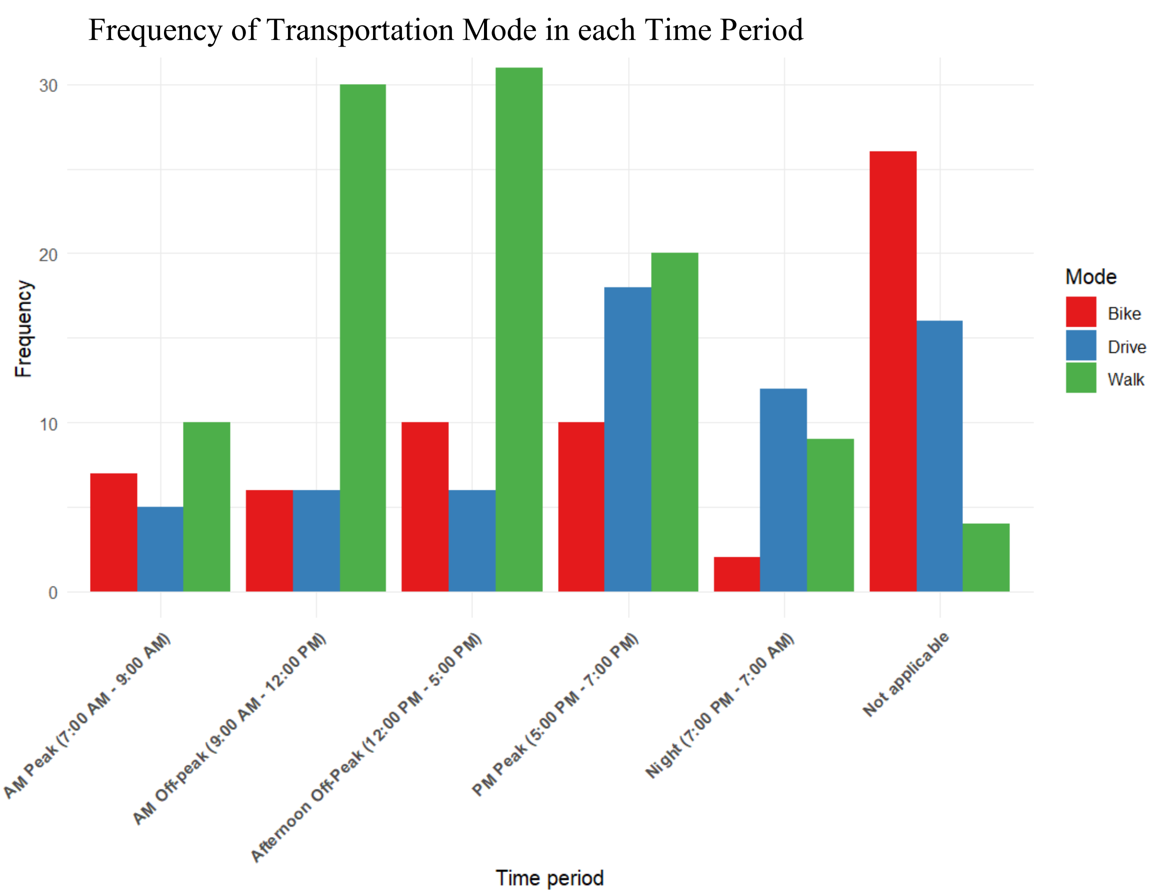


Figure G-4 – Frequency of transportation mode in each time period of the day

User perceptions of the app interface

Figure G-5 represents the user perceptions of the app interface. The majority of respondents found the interface to be intuitive (45.5%), with only a small portion considering it very intuitive (6.8%) or somewhat confusing (18.2%). 29.5% had a neutral perception of the interface. No responses indicated that the interface was very confusing.

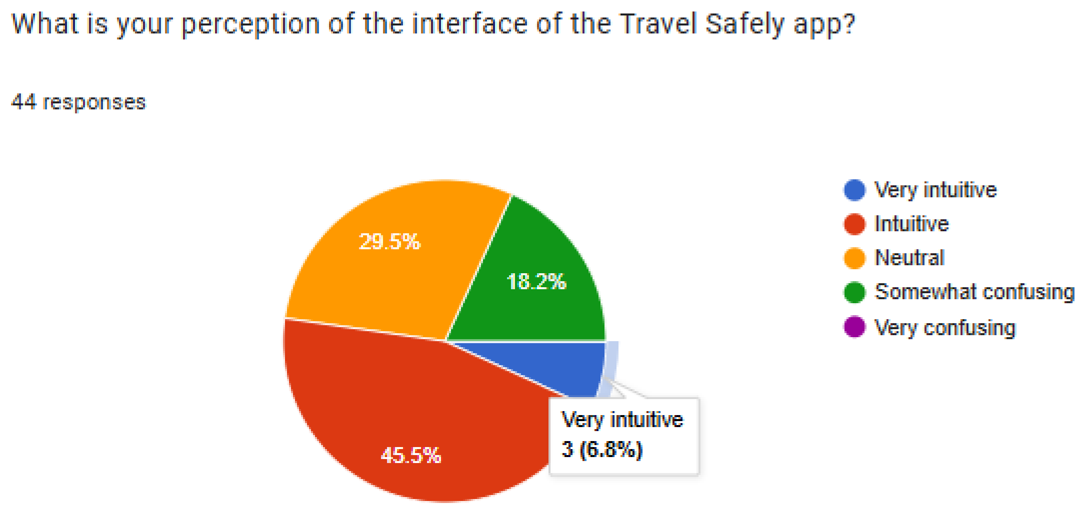


Figure G-5 – Perception of the interface of the app

Effectiveness of the app in serving different types of road users

Figure G-6 shows how effectively the app serves different types of road users: drivers, pedestrians, and cyclists. The effectiveness is categorized into five levels: Very effectively (blue), Effectively (red), Neutral (orange), Ineffectively (green), Very ineffectively (purple).

Observations show that:

- Drivers:
  - The majority of responses are in the Effectively (19 responses) and Neutral (19 responses) categories.
  - A smaller number of users (3 responses) find it Ineffectively serving drivers.
- Pedestrians:
  - The responses are distributed among Effectively (16 responses), Neutral (13 responses), and Ineffectively (12 responses) categories.
  - There are a few responses (4 responses) for Very effectively.
- Cyclists:
  - Most responses (28 responses) fall under the Neutral category, with a notable proportion in the Ineffectively category (10 responses).
  - A smaller number of users (2 responses) find it Very ineffectively serving cyclists.

- Very few cyclists reported the app serving them Effectively (4 responses) or Very effectively (1 response).

In summary, the app seems to serve drivers the best, pedestrians moderately well, and cyclists the least effectively.

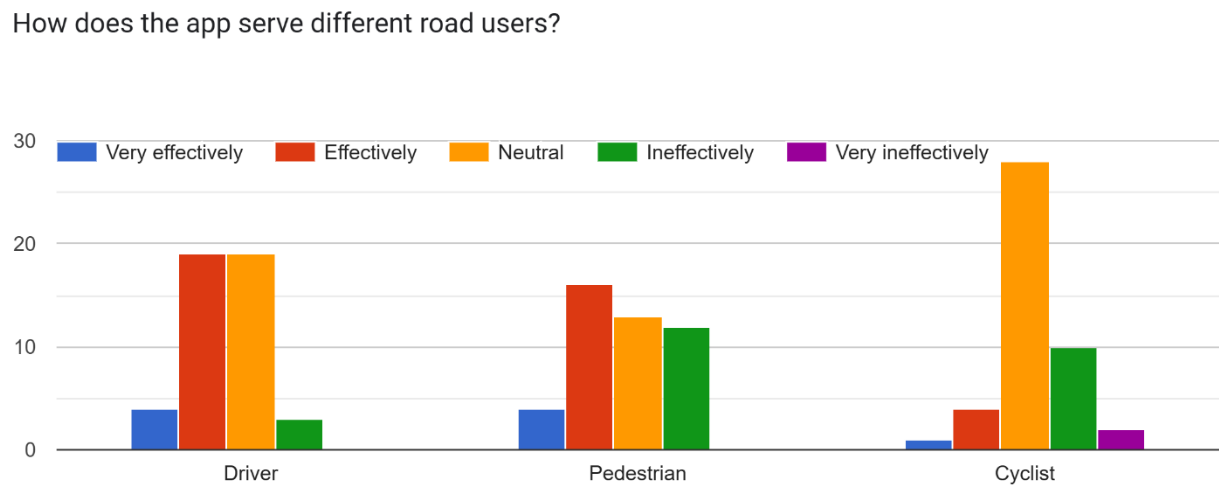


Figure G-6 – Effectiveness of the app in serving different types of road users: drivers, pedestrians, and cyclists

How likely participants are to use the app after the study

Figure G-8 shows how likely participants are to use the app after the study. The likelihood is divided into five categories:

- Very likely (blue): 4.4% (2 respondents)
- Somewhat likely (red): 26.7% (12 respondents)
- Neutral (orange): 15.6% (7 respondents)
- Somewhat unlikely (green): 28.9% (13 respondents)
- Very unlikely (purple): 24.4% (11 respondents)

The majority of respondents are somewhat unlikely (28.9%) or very unlikely (24.4%) to use the app after the study. 26.7% are somewhat likely to use the app. Only 4.4% of respondents are very likely to use the app. The data indicates overall low enthusiasm toward continued use of the app after the study.

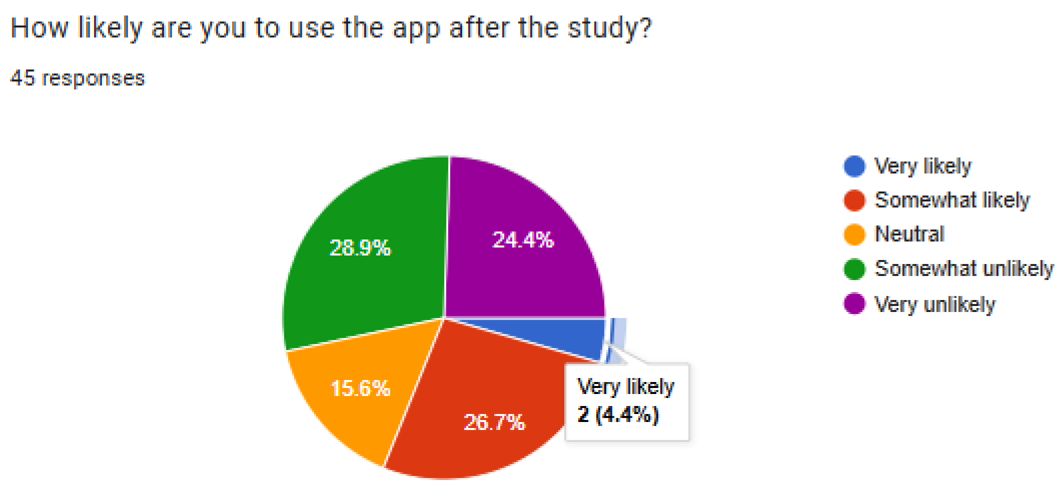


Figure G-7 - How likely participants are to use the app after the study

<u>Overall experience with the app</u>

Level of satisfaction

Figure G-9 shows the level of satisfaction with the app. The satisfaction levels are categorized into five groups:

- Very satisfied (blue): 2.2% (1 respondent)
- Somewhat satisfied (red): 40% (18 respondents)
- Neutral (orange): 26.7% (12 respondents)
- Somewhat dissatisfied (green): 28.9% (13 respondents)
- Very dissatisfied (purple): 2.2% (1 respondent)

The highest percentage of respondents, 40%, are somewhat satisfied with the app. 28.9% of respondents are somewhat dissatisfied. 26.7% of respondents are neutral. Only 2.2% of respondents are very dissatisfied, and 2.2% of respondents are very satisfied. Overall, the app has mixed satisfaction levels, with many users expressing moderate satisfaction.

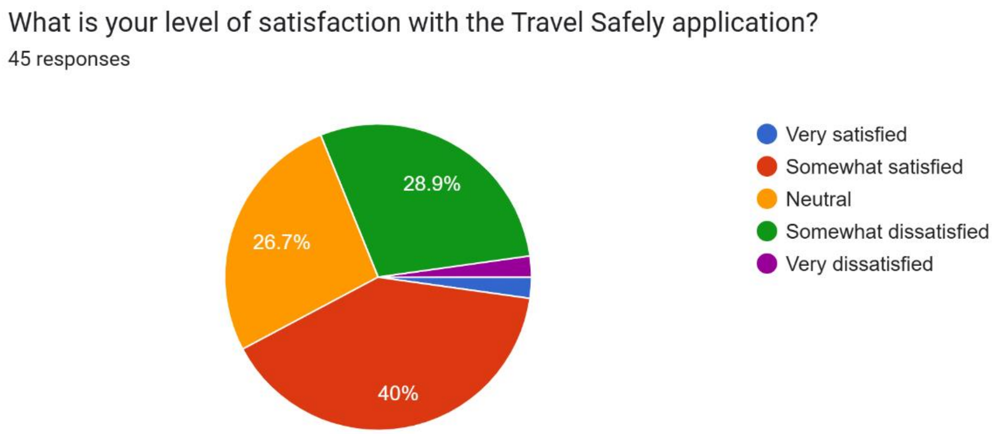


Figure G-8 – Overall level of satisfaction with the app

Advantages and disadvantages of using the app:

To assess the advantages of the app, participants were provided with predefined options along with an open-ended response option to gather additional feedback. Participants were allowed to select several answers. The results are as follows:

- Increased safety: 30 responses (66.7%)
- Timely alerts: 20 responses (44.4%)
- Convenience: 8 responses (17.8%)
- Better navigation: 7 responses (15.6%)

Other:

- Traffic light countdown: 2 responses (4.4%)
- None: 1 response, the participant did not see any advantages for using the app. (2.2%)

For the disadvantages, participants selected from predefined options and had the opportunity to provide additional feedback through an open-ended response. Participants were allowed to select several answers. The results are summarized below:

- Technical issues: 20 responses (44.4%)
- Inaccurate alerts: 19 responses (42.2%)
- Battery consumption: 15 responses (33.3%)
- User interface difficulties: 10 responses (22.2%)

Other:

- Inaccurate and untimely alerts, for example, the app issued an alert about a speeding car even when the participant was far from the sidewalk inside a building.
- Not practical or useful.
- Not particularly helpful for navigation.

- Inconvenient and unnecessary, especially for pedestrians and cyclists.
- Ineffective while biking; phone vibrations on the handlebar were difficult to feel.
- Limited number of users.
- Not available at enough crosswalks and stoplights.
- Decreased safety due to distractions.
- Alerts warning drivers about green lights could encourage dangerous driving.
- Excessive data consumption.
- Lack of integration with other apps, such as Google Maps.
- On Samsung phones, the app closes in the background despite being excluded from the "deep sleep" setting.
- The app displayed a message that the app is not available in the participant's area.

Distraction

Figure G-10 illustrates responses to the question "Do you find the app distracting?". The results are:

- Yes (blue): 44.4% (20 respondents)
- No (red): 55.6% (25 respondents)

The results indicate that while a majority do not consider the app distracting, a significant portion of users still experience distraction when using it.

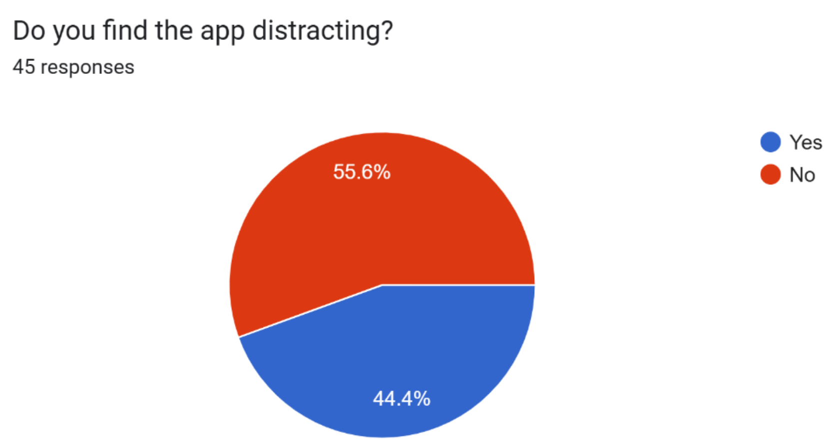


Figure G-9 – User responses on whether the app is distracting or not

In summary, the app was found to be distracting in the following ways:

- App malfunctions, including frequent and unexpected mode changes (e.g., walking vs. driving), required participants to troubleshoot while on the move. This was disruptive and felt unsafe, particularly when biking or walking, as it further increased distractions.

- Participants reported that the app sometimes led them to focus more on their phones than their surroundings, decreasing situational awareness. This was especially concerning while driving, as the app pulled attention away from the road, raising safety concerns.
- Flashing alerts and random notifications created significant distractions, particularly for bikers and pedestrians, diverting attention from the surrounding environment.
- Late alerts and phone vibrations often caused participants to look at their phones, pulling their focus away from the road or their surroundings, which contributed to increased distraction.

Safety

Impact of the app on unsafe behaviors, such as jaywalking, or not yielding to pedestrians as a driver.

Figure G-11 displays the perceived impact of the app on reducing unsafe behaviors, based on responses to the statement: "Using the Travel Safely app will reduce unsafe behaviors, such as jaywalking or failing to yield to pedestrians as a driver," where participants were asked to indicate their level of agreement or disagreement.

Opinions are split, with 13 participants disagreeing and 14 participants agreeing with the statement. A significant number of respondents remain neutral (11 responses), indicating uncertainty about the app's impact. Very few participants strongly agreed (1 response), while strongly disagreed responses account for 6 responses. Overall, the responses are mixed, with a slight leaning toward disagreement regarding the app's ability to reduce unsafe behaviors. However, a substantial portion remains unconvinced or uncertain about its effectiveness.

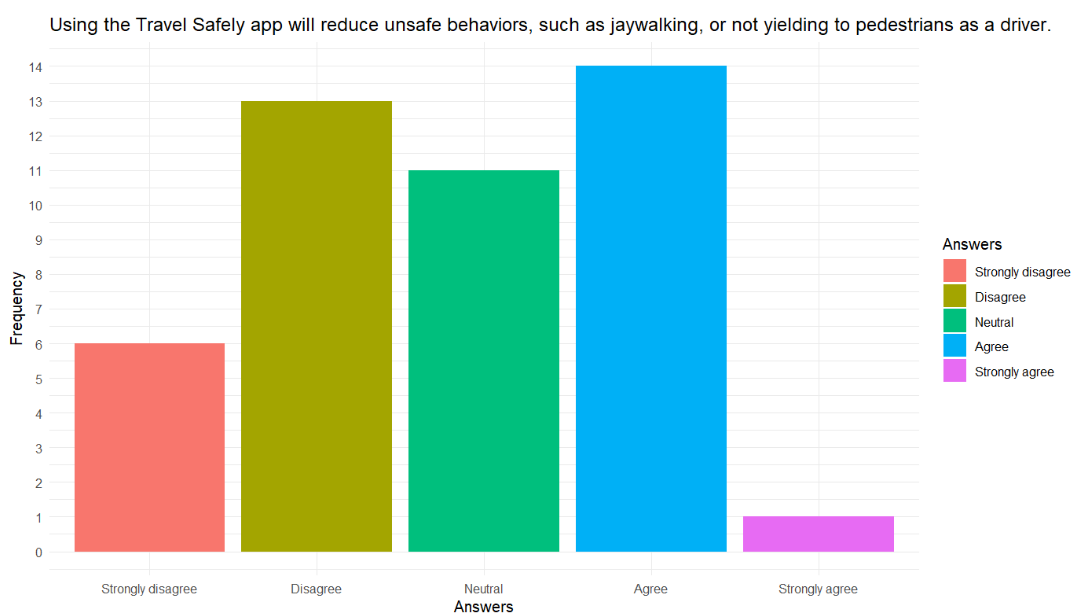


Figure G-10 – Impact of the app on unsafe behaviors, such as jaywalking, or not yielding to pedestrians as a driver.

Jaywalking

Figure G-12 shows responses to the question "Do you jaywalk or follow other pedestrians when they jaywalk?". The responses are distributed as follows:

- Yes (blue): 57.8% (26 respondents)
- No (red): 26.7% (12 respondents)
- Maybe (orange): 15.6% (7 respondents)

This indicates that jaywalking is relatively common among the respondents.

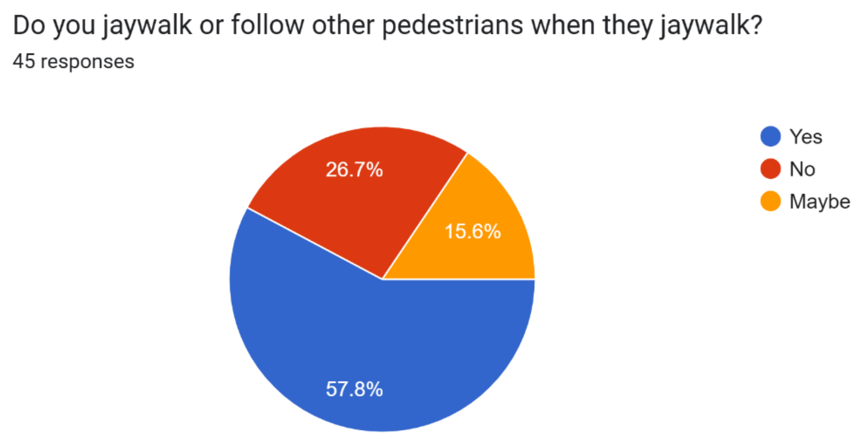


Figure G-11 – Jaywalking or following others who jaywalk

User compliance with walk/don't walk signals at intersections and midblock crossings

Figure G-13 shows how often respondents comply with walk/don't walk signal indications at intersections and midblock crossings. The responses are as follows:

Intersections:

- Always: 19 respondents.
- Often: 17 respondents.
- Sometimes: 7 respondents.
- Rarely: 2 respondents.
- Never: No respondents.

Midblock Crossings:

- Always: 13 respondents.
- Often: 19 respondents.
- Sometimes: 8 respondents.
- Rarely: 5 respondents.
- Never: No respondents.

Compliance is generally higher at intersections than at midblock crossings. The majority of respondents either always or often comply with signals at both locations. A slightly higher number of respondents reported rarely complying at midblock crossings compared to intersections.

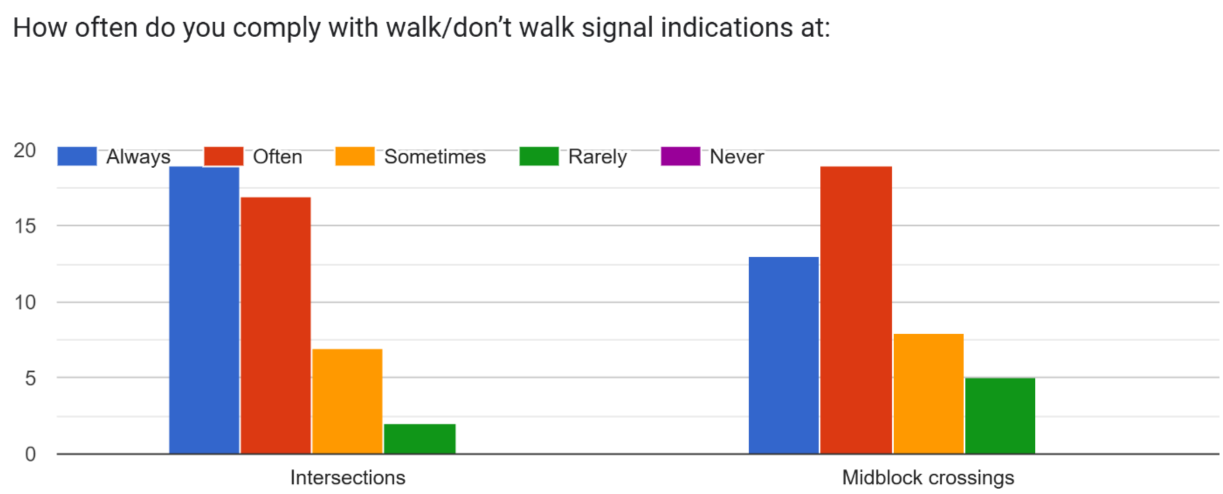


Figure G-12 – User compliance with walk/don't walk signals at intersections and midblock crossings

Impact of the app on compliance with walk/don't walk signs

Figure G-14 illustrates how the app affected respondents' level of compliance with walk/don't walk signs. The responses are categorized into five groups:

- Strongly increase compliance (blue): 4.4% (2 respondents)
- Somewhat increase compliance (red): 15.6% (7 respondents)
- No effect on compliance (orange): 80% (36 respondents)
- Somewhat decrease compliance (green): 0%
- Strongly decrease compliance (purple): 0%

Overall, the app had minimal influence on improving compliance with walk/don't walk signs for most respondents.

Figure G-13 – Impact of the app on compliance with walk/don't walk signs

Perception of safety at midblock crosswalks with flashing beacons

Figure G-15 displays how midblock crosswalks with flashing beacons affect respondents' perception of safety. The responses are categorized into five groups:

- I feel much safer (blue): 22.2% (10 respondents)
- I feel somewhat safer (red): 62.2% (28 respondents)
- No difference (orange): 15.6% (7 respondents)
- I feel less safe (green): 0%
- I do not feel safe (purple): 0%

Overall, most participants feel safer using midblock crosswalks equipped with flashing beacons.

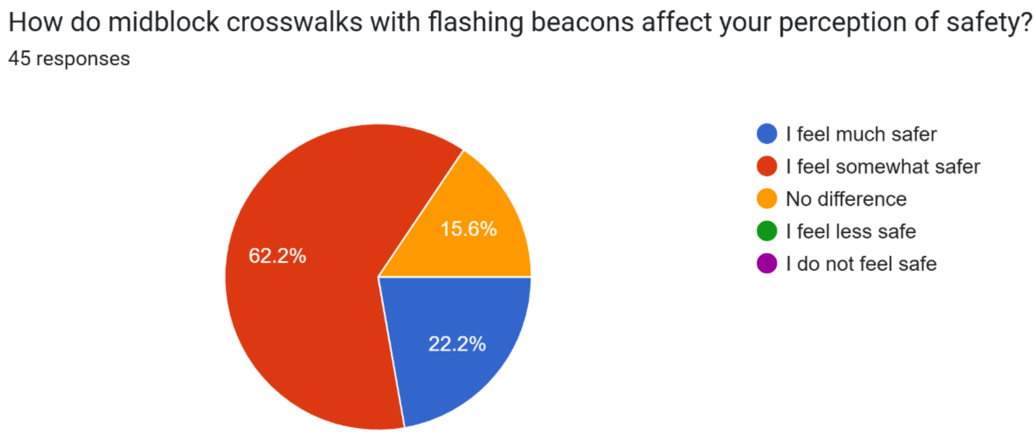


Figure G-14 – Perception of safety at midblock crosswalks with flashing beacons

Perception of the effectiveness of traffic safety technologies in improving pedestrian and cyclist safety

Figure G-16 shows the perception of the effectiveness of three traffic safety technologies in improving pedestrian and cyclist safety. The technologies assessed are:

- Smartphone apps (like Travel Safely)
- Rectangular Rapid Flash Beacons (RRFB)
- Traditional traffic signals with push buttons for pedestrians

Results:

Smartphone Apps (like Travel Safely):

- Very Ineffective (blue): 6 respondents.
- Ineffective (red): 13 respondents.
- Neutral (orange): 12 respondents.
- Effective (green): 13 respondents.
- Very Effective (purple): Minimal responses (1 respondent).

Rectangular Rapid Flash Beacons (RRFB):

- Very Ineffective (blue): Very few respondents (2).
- Ineffective (red): Zero responses.
- Neutral (orange): 7 respondents.
- Effective (green): The majority (22 respondents).
- Very Effective (purple): 14 respondents.

Traditional Traffic Signals with Push Buttons for Pedestrians:

- Very Ineffective (blue): 3 respondents.
- Ineffective (red): 4 respondents.
- Neutral (orange): 4 respondents.
- Effective (green): A significant portion (18 respondents).
- Very Effective (purple): A significant portion (16 respondents).

Summary:

- RRFBs are perceived as the most effective technology, with the majority finding them Effective or Very Effective.
- Traditional traffic signals are also rated positively by many respondents.
- Smartphone apps receive mixed responses, with significant numbers rating them as Ineffective or Neutral.

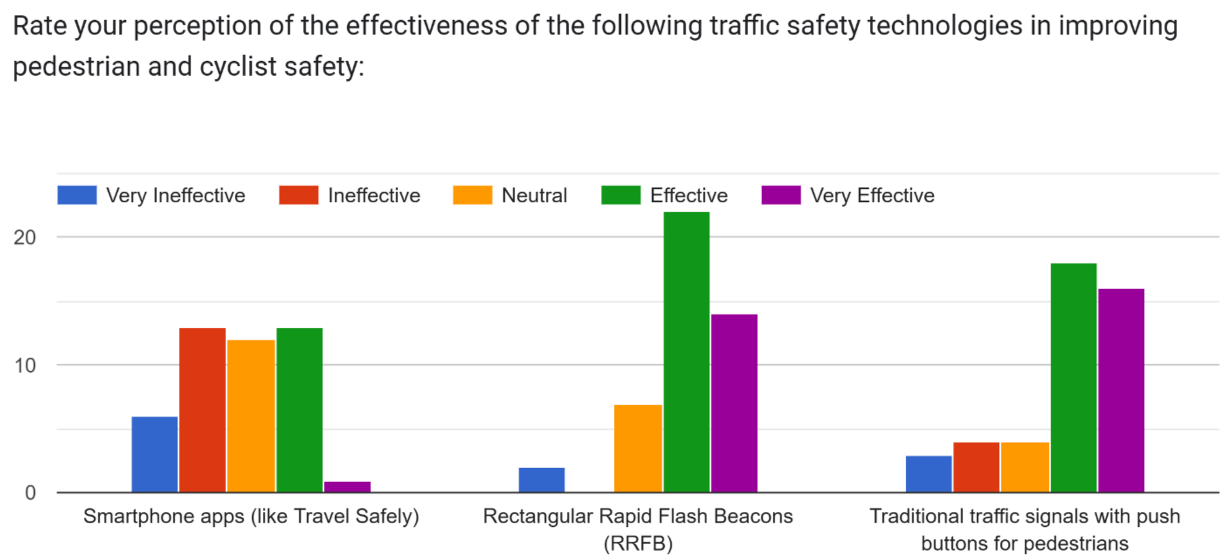


Figure G-15 – Perception of the effectiveness of traffic safety technologies in improving pedestrian and cyclist safety

<u>Other comments</u>

App functionality and performance issues:

- Alerts didn't show up when the app was in the background, and there was no record of receiving them.
- The app didn't activate flashing beacons in some instances and failed to notify when a car sped through a crosswalk.
- The app malfunctioned, switching modes (e.g., walking to driving) without user input, causing further disruption and distractions.
- The app didn't detect pedestrians accurately if they were slightly away from the road, reducing its effectiveness.

Suggestions for improvement:

- Flashing crosswalks should be automatically activated when a person is detected, without relying on the app.
- The app should be able to function in the background with push notifications instead of requiring the app to stay open.
- Data collection for cities to inform where new flashing beacon crosswalks should be added.
- Cyclists suggested incorporating speed sensors or cameras to estimate car velocity to warn pedestrians and cyclists.

Challenges for specific users:

- The app was difficult to use while cycling due to phone placement and inability to feel vibrations or easily check the phone.
- For drivers, the app seemed unnecessary and potentially distracting, especially in areas with heavy pedestrian and cyclist traffic.
- App performance was inconsistent, and participants reported it often switched modes automatically or didn't trigger alerts when they should have.
- The app's interface was confusing, with too many buttons and unclear functionality.

Effectiveness and usability:

- The app was found to be more effective in certain settings (e.g., flashing beacons at crosswalks), but its coverage was limited.
- Some participants found it unhelpful to walk, especially with the lack of alerts or inaccurate detection.
- The app's performance was worse at night and in areas with little traffic, where it became confusing to use.

Appendix H– Users' Safety Perception Survey

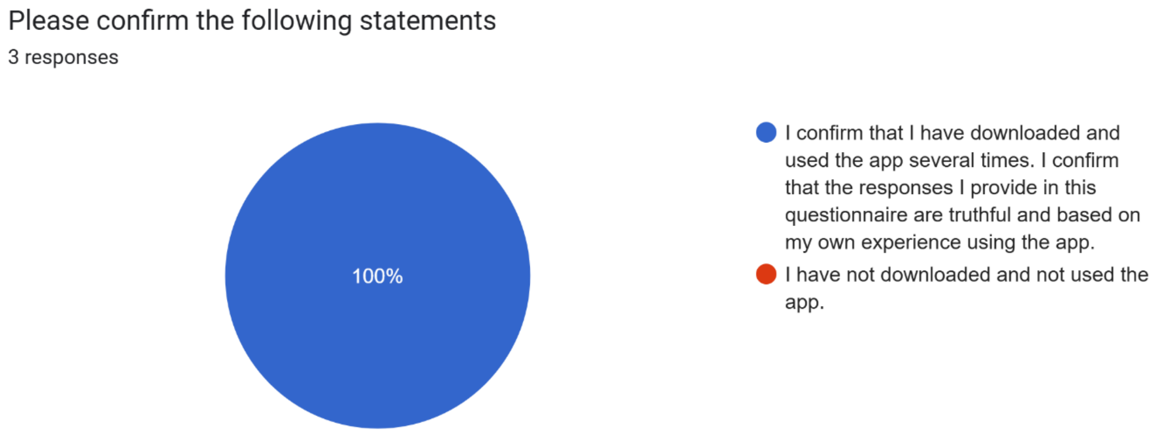


Figure H-1 – Result from question 1 from the user survey conducted via Google Forms "Pedestrian and bicyclist safety survey"

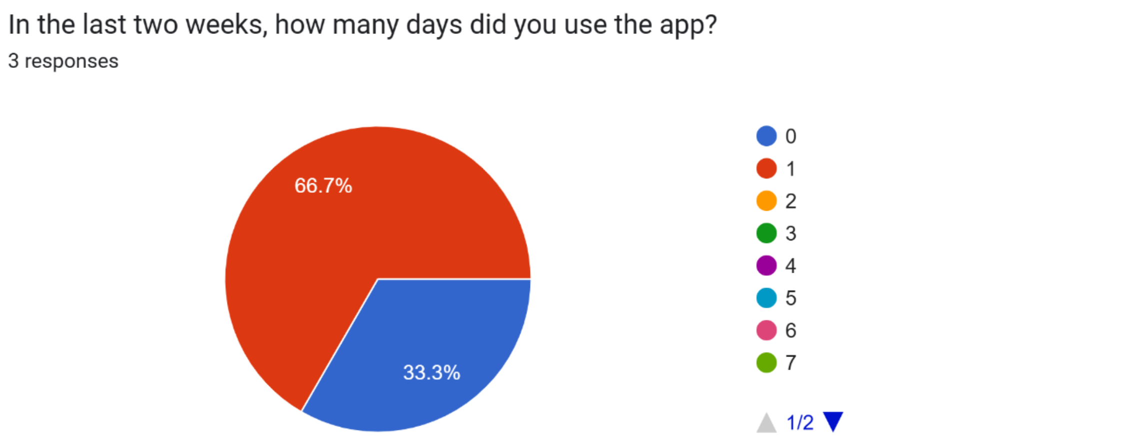


Figure H-2 – Result from question 2 from the user survey conducted via Google Forms "Pedestrian and bicyclist safety survey"

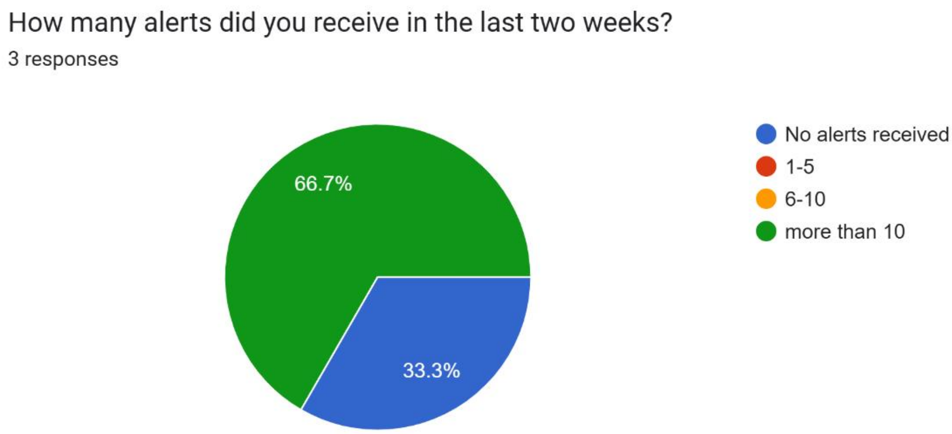


Figure H-3 – Result from question 3 from the user survey conducted via Google Forms “Pedestrian and bicyclist safety survey”

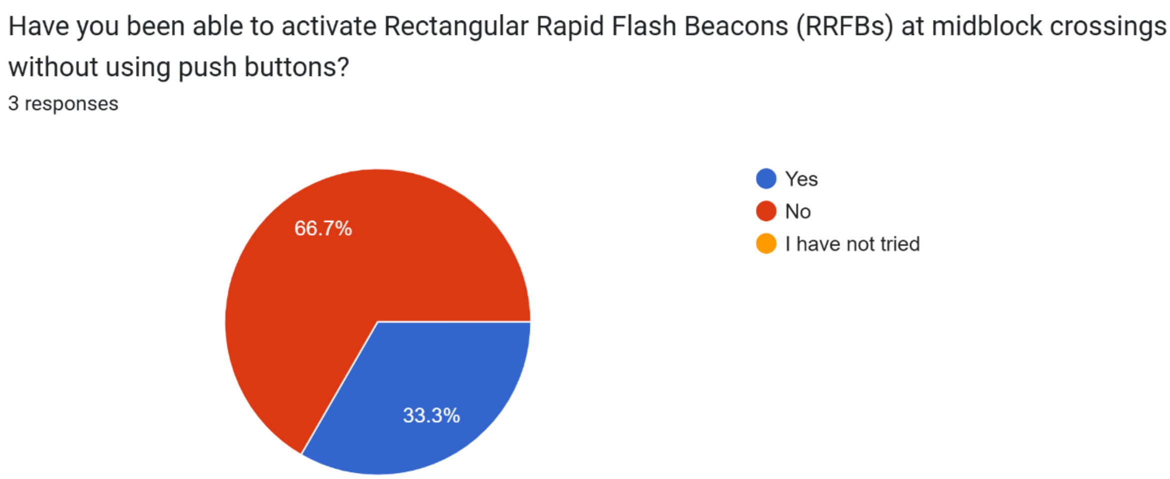


Figure H-4 – Result from question 4 from the user survey conducted via Google Forms “Pedestrian and bicyclist safety survey”

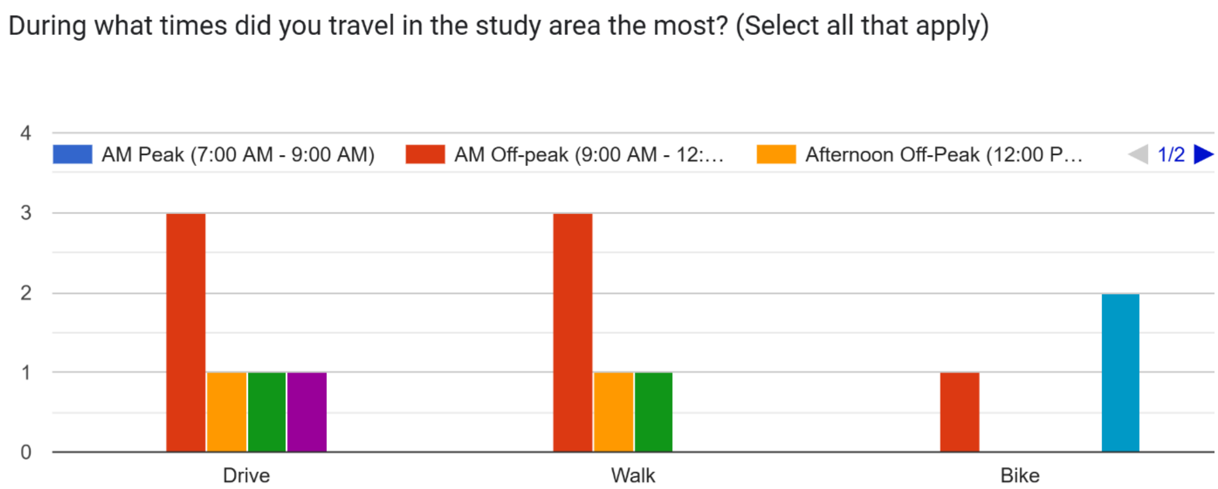


Figure H-5 – Result from question 5 from the user survey conducted via Google Forms "Pedestrian and bicyclist safety survey"

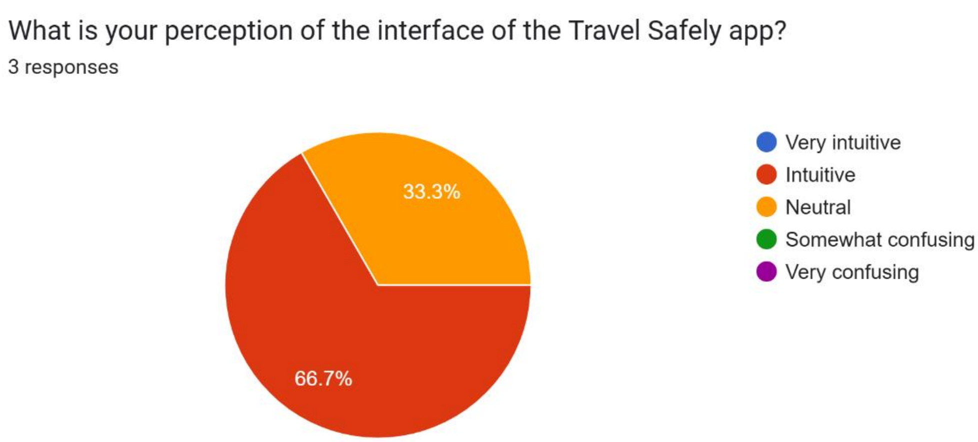


Figure H-6 – Question 6 from the user survey conducted via Google Forms "Pedestrian and bicyclist safety survey"

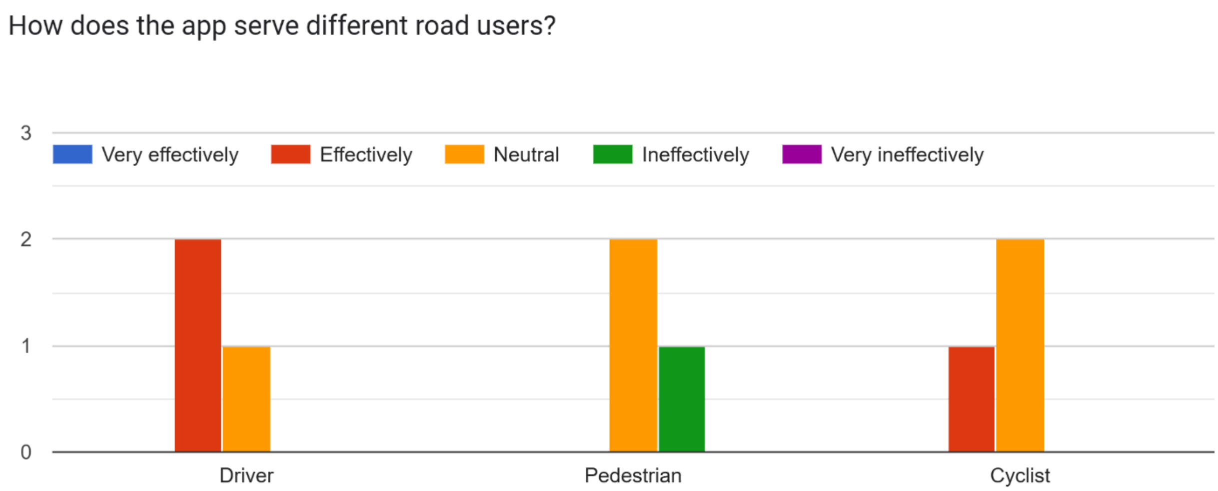


Figure H-7 – Question 7 from the user survey conducted via Google Forms "Pedestrian and bicyclist safety survey"

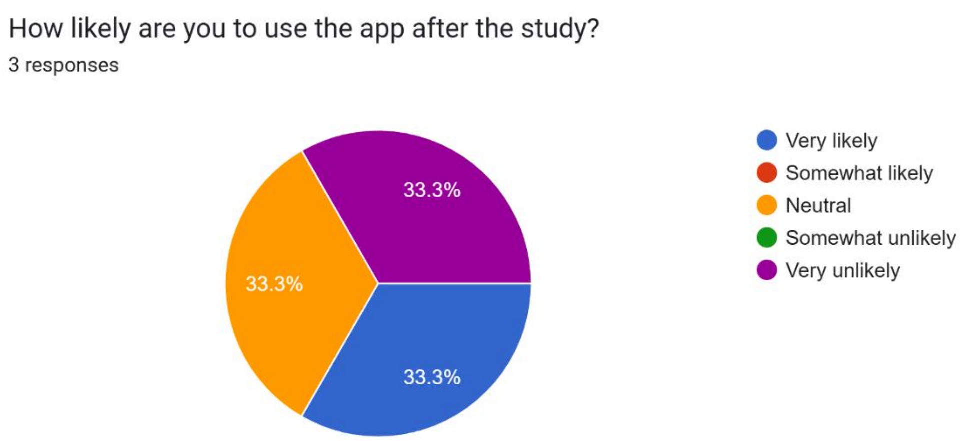


Figure H-8 – Question 8 from the user survey conducted via Google Forms "Pedestrian and bicyclist safety survey"

Figure H-9 – Question 9 from the user survey conducted via Google Forms “Pedestrian and bicyclist safety survey”

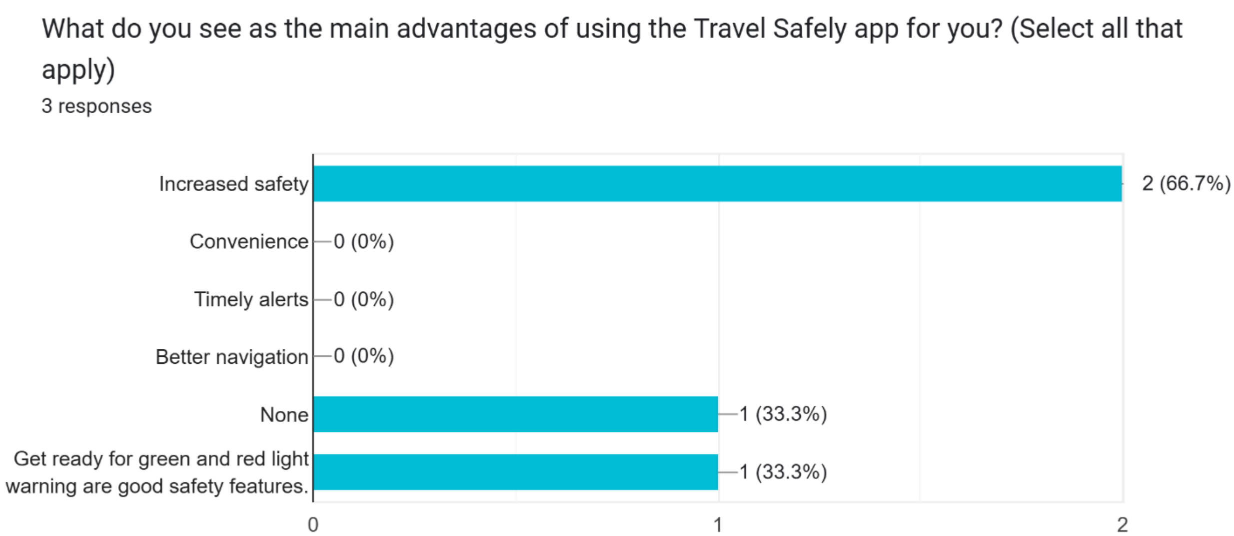


Figure H-10 – Question 10 from the user survey conducted via Google Forms “Pedestrian and bicyclist safety survey”

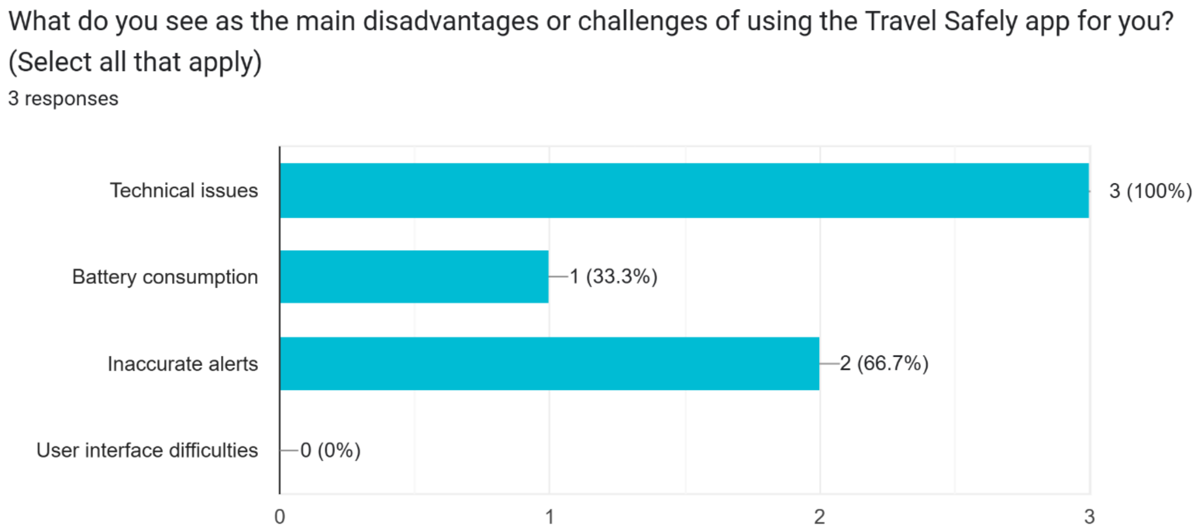


Figure H-11 – Question 11 from the user survey conducted via Google Forms "Pedestrian and bicyclist safety survey"

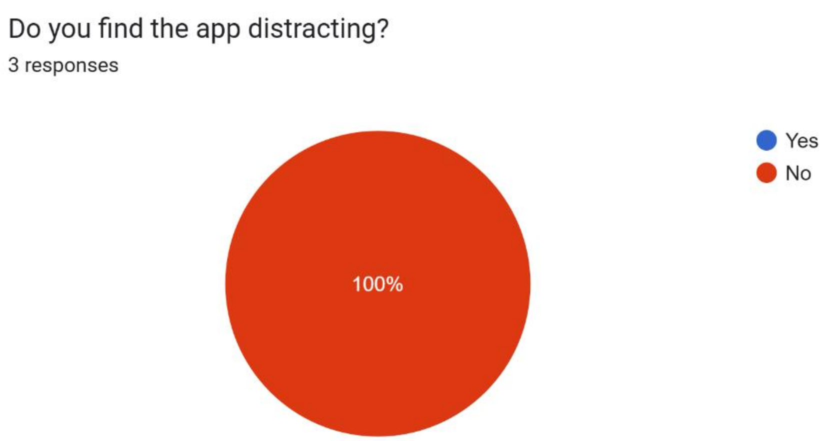


Figure H-12 – Question 12 from the user survey conducted via Google Forms "Pedestrian and bicyclist safety survey"

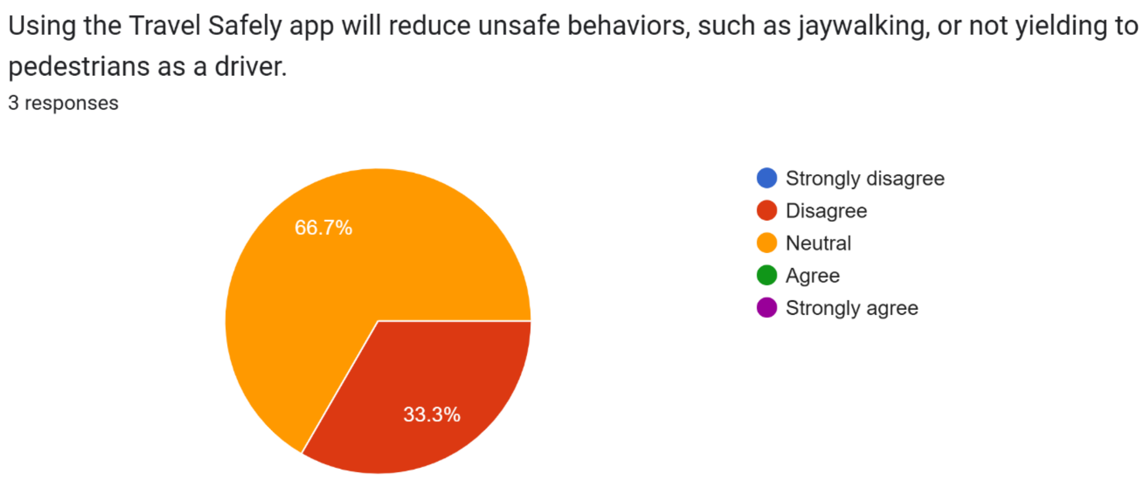


Figure H-13 – Question 13 from the user survey conducted via Google Forms “Pedestrian and bicyclist safety survey”

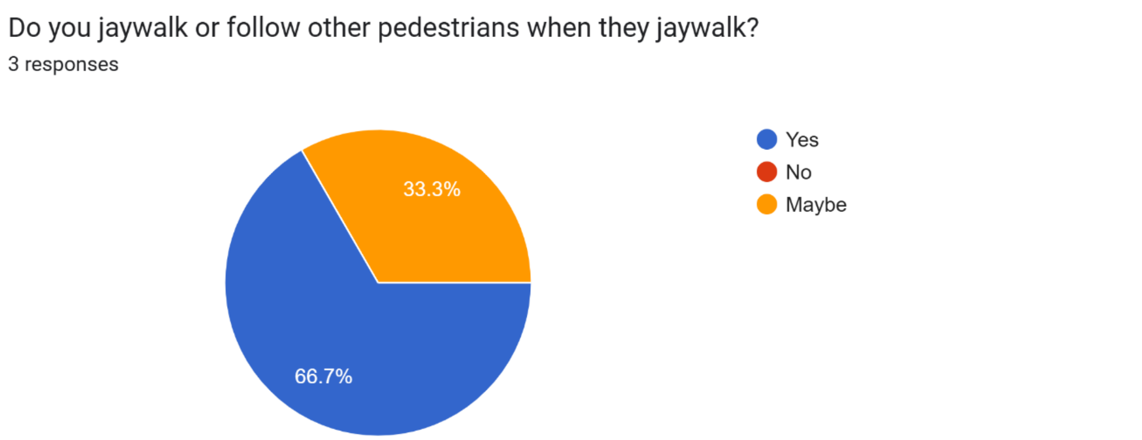


Figure H-14 – Question 14 from the user survey conducted via Google Forms “Pedestrian and bicyclist safety survey”

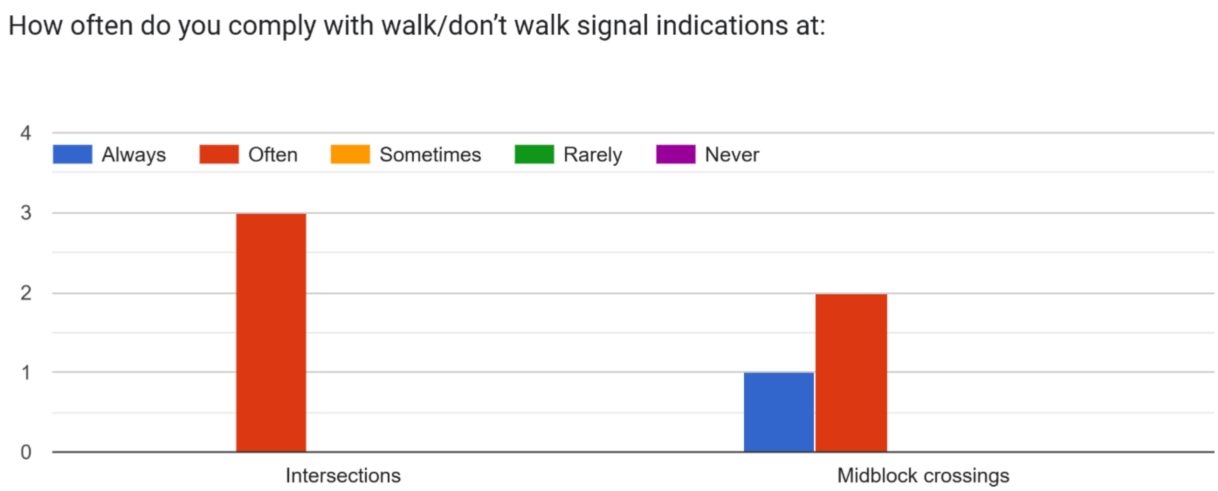


Figure H-15 – Question 15 from the user survey conducted via Google Forms "Pedestrian and bicyclist safety survey"

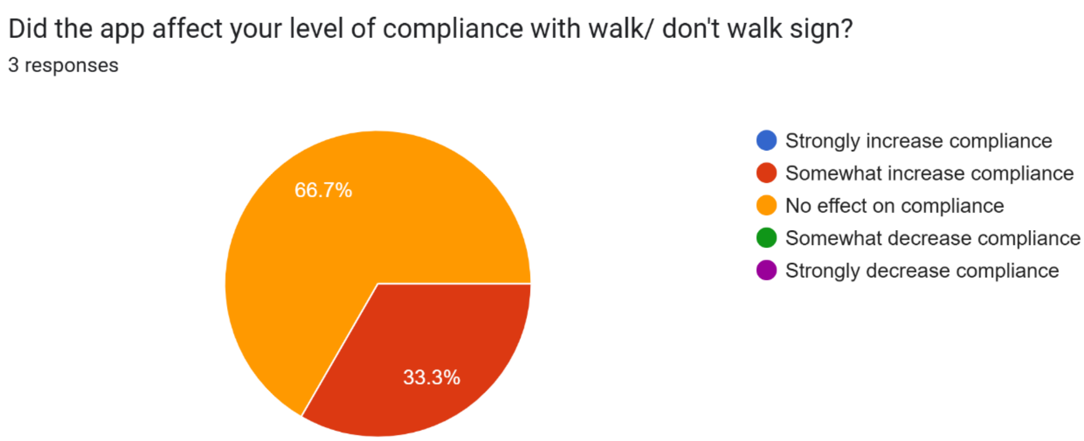


Figure H-16 – Question 16 from the user survey conducted via Google Forms "Pedestrian and bicyclist safety survey"

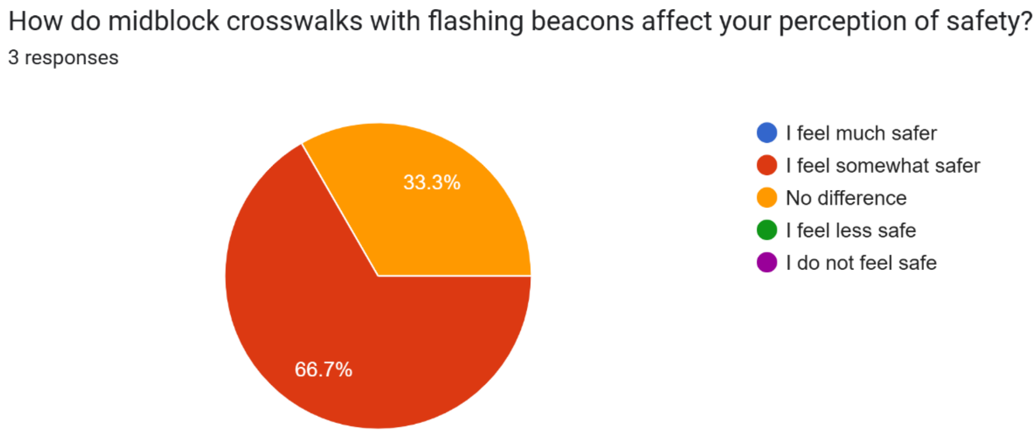


Figure H-17 – Question 17 from the user survey conducted via Google Forms “Pedestrian and bicyclist safety survey”

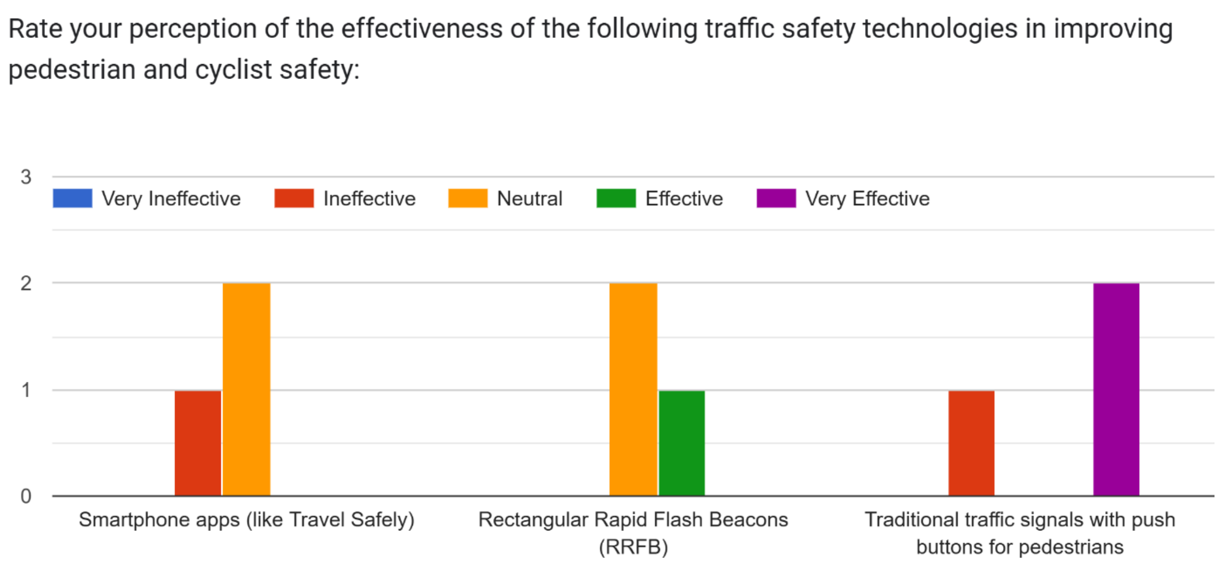


Figure H-18 – Question 18 from the user survey conducted via Google Forms “Pedestrian and bicyclist safety survey”

Appendix I– Field observations of the signalized intersections in the study network

S3:

Figure I-1- Intersection of W Univ. Ave. & 18^{th} St. (labeled as S3 in Figure 1)

- NW 18th St and Fletcher Dr are one-way towards West University Ave. and have bicycle lanes.
- The intersection has a bike signal, which increases the waiting time for pedestrians crossing NW 18th St.

S4:

Figure I-2 - Intersection of W Univ. Ave. & 17th St

- The intersection has a bike signal.
- NW 17th St is one-way from West University Ave., and it includes bicycle lanes.

S12:

Figure I-3 – Intersection at Museum Rd. & Center Dr

- Some trash bins are located next to the push button, which can cause pedestrians not to push the buttons because of accessibility or bad smell.

S13:

Counting down for pedestrian crossing Museum Rd.

S14 (NW 19th St & West University Ave.):

Figure I-4 – Intersection at NW 19th St & West University Ave

- This intersection was not reported in the previous project.
- It is a 3-legged intersection.
- There is a bus stop before the intersection heading WB.
- The EB has a speed bump after crossing the intersection, and the WB has a speed bump before the intersection.
- Traffic spillback was observed.

S15 (NW 16th St & West University Ave.):

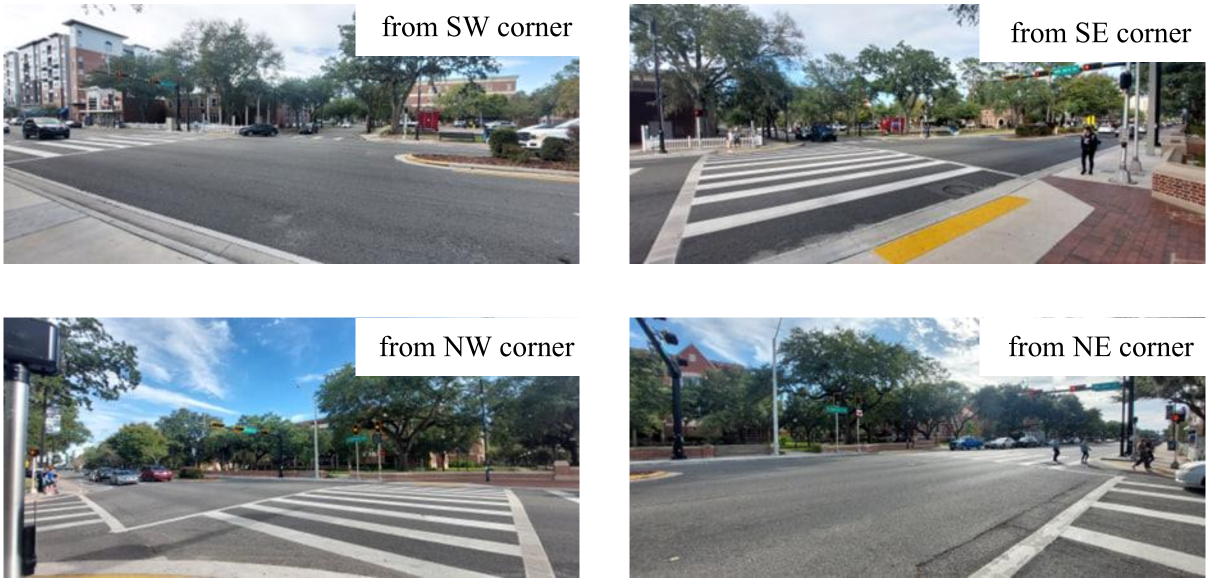


Figure I-5 – Intersection at NW 16th St & West University Ave.

- This intersection was not reported in the previous project.
- It is a 3-legged intersection.
- There is a bus stop before the intersection heading WB.
- The EB has a speed bump after crossing the intersection, and the WB has a speed bump before the intersection.
- The east side of the intersection does not have a pedestrian crossing, but the west side pedestrian crossing is wide.
- Push buttons are available and beeping, and they have a voice to say the available crossing street name.

S16 (Museum Rd. & Reitz Union Dr.):

Figure I-6 – Intersection at Museum Rd. & Reitz Union Dr

- This intersection was reported as a Midblock crossing (C6) in the previous project.
- The orange sign “Vehicles must stop for pedestrians in crosswalk” is observed toward EB before the intersection.
- Pedestrian crossing time and diagonal crossing are available.
- Construction site toward SB (Sweetwater Drive).

Appendix J– Field observations of the midblock crossings in the study network

C1:

Figure J-1 – Intersection between signals at Gale Lemerand Dr

- Yellow and orange signs indicating that “vehicles must stop for pedestrians in crosswalk” are observed toward NB.
- Jaywalking has
- Rectangular “stop for pedestrian within a crosswalk” sign in traffic separator (pedestrian island).

C2:

Figure J-2 – Intersection between signals at Gale Lemerand Dr

- Yellow “pedestrian ahead” sign before the crossing.
- Yellow pedestrian crossing warning signs and flashing beacons have been installed.

C3:

view from the north

view from the south

Figure J-3 – Intersection between signals at Gale Lemerand Dr

- Rectangular “stop for pedestrian within a crosswalk” sign between yellow lines.
- Yellow pedestrian crossing warning signs and flashing beacons have been installed.
- Pedestrian detection and flashing beacons work.

C4:

view from the north

Figure J-4 – Intersection between signals at Gale Lemerand Dr

- The orange sign “vehicles must stop for pedestrians in crosswalk” is observed toward SB.

C5:

Figure J-5 – Intersection between signals at Museum Rd

- Yellow “pedestrian ahead” sign before the crossing.
- The orange sign “vehicles must stop for pedestrians in crosswalk” with a red beacon on top is observed toward EB.
- Rectangular “stop for pedestrian within a crosswalk” sign in traffic separator (pedestrian island).
- Yellow pedestrian crossing signs were observed, but one of them was inside the construction site.

C7:

Figure J-6 – Intersection between signals at Museum Rd

- The pushbutton for crossing toward the south is not working.
- Vehicles drive faster and do not pay much attention to pedestrians because they are located after the intersection.

C8:

Figure J-7 – Intersection at between signals at Museum Rd

- Yellow signs with flashing beacons have been installed.

C9:

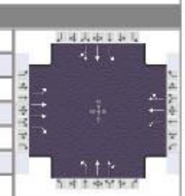
Figure J-8 – Intersection at between signals at Gale Lemerand Dr.

- Orange “pedestrian ahead” sign before the crossing toward SB.
- Rectangular “stop for pedestrian within a crosswalk” sign in traffic separator (pedestrian island).
- Bus stop locating before crossing in both directions.
- Pedestrian detection and flashing beacons work.
- Medium pedestrian traffic crossing observed.

Appendix K– Traffic operational analysis data and reports

HCS Signalized Intersection Input Data

General Information				Intersection Information	
Agency	UF			Duration, h	0.250
Analyst		Analysis Date	Oct 17, 2024	Area Type	CBD
Jurisdiction		Time Period		PHF	1.00
Urban Street	13th St	Analysis Year	2024	Analysis Period	1> 12:00
Intersection	W Univ Ave @ 13th St	File Name	W Uni Ave @ 13th Oct_17_2024 St - PEAK.xus		
Project Description					



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (v), veh/h	104	352	84	300	228	76	180	428	68	156	536	60

Signal Information			
Cycle, s	133.3	Reference Phase	2
Offset, s	0	Reference Point	End
Uncoordinated	Yes	Simult. Gap E/W	On
Force Mode	Fixed	Simult. Gap N/S	On

Green	14.0	2.2	30.4	10.2	9.1	30.7
Yellow	3.8	0.0	3.8	3.7	3.7	3.7
Red	2.0	0.0	2.0	2.0	2.0	2.0

Traffic Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (v), veh/h	104	352	84	300	228	76	180	428	68	156	536	60
Initial Queue (Q_b), veh/h	5	8	3	7	3	1	1	4	8	0	7	9
Base Saturation Flow Rate (s_o), veh/h	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Parking (N_m), man/h		None		0	L			None			None	
Heavy Vehicles (P_{HV}), %	5	3	5	4	2		2	1		0	3	
Ped / Bike / RTOR, /h	308	0	0	88	0	0	184	4	0	196	8	0
Buses (N_b), buses/h	0	0	0	0	0	0	0	0	0	0	0	0
Arrival Type (AT)	3	3	3	3	3	3	3	3	3	3	3	3
Upstream Filtering (I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Lane Width (W), ft	11.0	11.0	11.0	11.0	11.0		11.0	11.0		11.0	11.0	
Turn Bay Length, ft	450	690	240	240	605		310	545		470	590	
Grade (P_g), %		0			0			0			0	
Speed Limit, mi/h	25	25	25	25	25	25	30	30	30	30	30	30

Phase Information	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Maximum Green (G_{max}) or Phase Split, s	25.0	45.0	25.0	45.0	30.0	70.0	25.0	55.0
Yellow Change Interval (Y), s	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.8
Red Clearance Interval (R_c), s	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Minimum Green (G_{min}), s	7	12	7	12	7	12	7	12
Start-Up Lost Time (lt), s	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Extension of Effective Green (e), s	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Passage (PT), s	3.0	3.5	3.0	3.5	3.0	3.5	2.5	3.5
Recall Mode	Off	Off	Off	Off	Off	Off	Off	Off
Dual Entry	No	Yes	No	Yes	No	Yes	No	Yes
Walk ($Walk$), s		7.0		7.0		7.0		7.0
Pedestrian Clearance Time (PC), s		24.0		22.0		22.0		23.0

Multimodal Information	EB			WB			NB			SB		
85th % Speed / Rest in Walk / Corner Radius	30.0	No	30.0	30.0	No	30.0	30.0	No	35.0	30.0	No	20.0
Walkway / Crosswalk Width / Length, ft	10.0	10.0	70.0	10.0	10.0	70.0	10.0	10.0	75.0	10.0	10.0	70.0
Street Width / Island / Curb, ft	0.0	0	No	0.0	0	No	0.0	0	No	0.0	0	No
Width Outside / Bike Lane / Shoulder, ft	12.0	5.0	2.0	12.0	5.0	2.0	12.0	5.0	2.0	12.0	5.0	2.0
Pedestrian Signal / Occupied Parking	Yes		0.50	Yes		0.50	Yes		0.50	Yes		0.50

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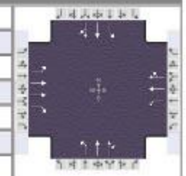
Figure K-1– Traffic and phase timing input data for the intersection at Univ Ave & 13th St

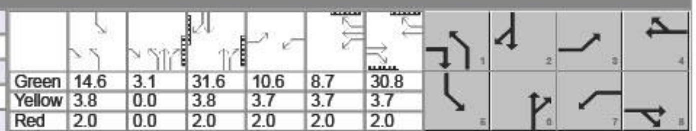
HCS Signalized Intersection Results Summary

General Information				Intersection Information	
Agency	UF			Duration, h	0.250
Analyst		Analysis Date	Oct 17, 2024	Area Type	CBD
Jurisdiction		Time Period		PHF	1.00
Urban Street	13th St	Analysis Year	2024	Analysis Period	1> 12:00
Intersection	W Univ Ave @ 13th St	File Name	W Uni Ave @ 13th Oct_17_2024 St - PEAK.xus		
Project Description					



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h	104	352	84	300	228	76	180	428	68	156	536	60

Signal Information										
Cycle, s	136.1	Reference Phase	2							
Offset, s	0	Reference Point	End							
Uncoordinated	Yes	Simult. Gap E/W	On	Green	14.6	3.1	31.6	10.6	8.7	30.8
Force Mode	Fixed	Simult. Gap N/S	On	Yellow	3.8	0.0	3.8	3.7	3.7	3.7
				Red	2.0	0.0	2.0	2.0	2.0	2.0



Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase	3	8	7	4	1	6	5	2
Case Number	2.0	3.0	2.0	4.0	2.0	4.0	2.0	4.0
Phase Duration, s	18.4	38.6	30.7	50.9	25.3	45.6	21.2	41.5
Change Period, ($Y+R_c$), s	5.7	5.7	5.7	5.7	5.8	5.8	5.8	5.8
Max Allow Headway (*MAH*), s	4.3	4.9	4.3	4.9	4.2	4.7	3.7	4.7
Queue Clearance Time (g_s), s	10.6	14.5	26.6	11.3	17.3	21.4	14.4	25.5
Green Extension Time (g_e), s	0.2	4.3	0.0	4.4	0.5	6.3	0.3	6.0
Phase Call Probability	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Max Out Probability	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.04

Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement	3	8	18	7	4	14	1	6	16	5	2	12
Adjusted Flow Rate (*v*), veh/h	104	352	84	300	158	146	180	261	235	156	313	283
Adjusted Saturation Flow Rate (*s*), veh/h/ln	1520	1544	924	1558	1662	1454	1477	1564	1366	1583	1622	1447
Queue Service Time (g_s), s	8.6	12.5	8.0	24.6	8.7	9.3	15.3	18.7	19.4	12.4	23.1	23.5
Cycle Queue Clearance Time (g_c), s	8.6	12.5	8.0	24.6	8.7	9.3	15.3	18.7	19.4	12.4	23.1	23.5
Green Ratio (*g/C*)	0.08	0.24	0.38	0.20	0.35	0.35	0.14	0.27	0.27	0.11	0.25	0.25
Capacity (*c*), veh/h	142	744	412	213	582	510	207	428	375	180	408	366
Volume-to-Capacity Ratio (*X*)	0.734	0.473	0.204	1.410	0.271	0.287	0.869	0.610	0.627	0.869	0.766	0.775
Back of Queue (*Q*), ft/ln (50 th percentile)	162	156	65	762	101	94	173	201	182	144	280	253
Back of Queue (*Q*), veh/ln (50 th percentile)	6.2	6.1	2.5	29.5	4.0	3.8	6.8	8.0	7.3	5.8	10.9	10.1
Queue Storage Ratio (*RQ*) (50 th percentile)	0.36	0.23	0.27	3.18	0.17	0.16	0.56	0.37	0.34	0.31	0.47	0.44
Uniform Delay (d_1), s/veh	61.9	43.9	28.1	79.0	30.6	30.9	55.6	41.3	41.5	59.4	46.1	46.3
Incremental Delay (d_2), s/veh	7.1	0.6	0.3	209.5	0.3	0.4	11.9	1.7	2.1	9.6	3.6	4.2
Initial Queue Delay (d_3), s/veh	33.7	1.6	0.5	118.4	0.1	0.1	1.3	0.4	0.6	0.0	2.3	2.9
Control Delay (*d*), s/veh	102.8	46.0	28.8	406.9	31.0	31.3	68.8	43.4	44.2	69.0	52.1	53.4
Level of Service (LOS)	F	D	C	F	C	C	E	D	D	E	D	D
Approach Delay, s/veh / LOS	54.3	D		217.8	F		50.4	D		56.1	E	
Intersection Delay, s/veh / LOS	92.2						F					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS	2.63	C	2.58	C	2.55	C	2.63	C
Bicycle LOS Score / LOS	0.93	A	0.99	A	1.05	A	1.11	A

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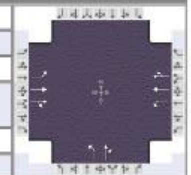
Figure K-2 – Report results for LOS and delay analyses for the intersection at 13th St

HCS Signalized Intersection Input Data

General Information				Intersection Information	
Agency	UF			Duration, h	0.250
Analyst		Analysis Date	Apr 3, 2025	Area Type	Other
Jurisdiction	Gainesville	Time Period	AM Peak: 7 am - 8 am	PHF	1.00
Urban Street	West University Ave	Analysis Year	2025	Analysis Period	1> 7:15
Intersection	WUA @ 17th St	File Name	WUA@17thSt April_03_2025 - PEAK.xus		
Project Description					



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h	44	516	36	36	452	32	24	8	32			

Signal Information				
Cycle, s	59.3	Reference Phase	2	
Offset, s	0	Reference Point	Begin	
Uncoordinated	Yes	Simult. Gap E/W	On	
Force Mode	Fixed	Simult. Gap N/S	On	

Green	2.2	1.5	19.3	19.4	0.0	0.0
Yellow	2.5	0.0	3.4	3.4	0.0	0.0
Red	2.0	0.0	2.4	2.4	0.0	0.0

Traffic Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h	44	516	36	36	452	32	24	8	32			
Initial Queue (Q_b), veh/h	0	2	0	0	3	0	0	1	0			
Base Saturation Flow Rate (s_o), veh/h	1900	1900	1900	1900	1900	1900	1900	1900	1900			
Parking (N_m), man/h		None			R	0	0	L + R	0			
Heavy Vehicles (P_{HV}), %	0	2		1	2		0	13				
Ped / Bike / RTOR, /h	96	12	24	76	0	6	156	0	8	36	8	
Buses (N_b), buses/h	0	0	0	0	0	0	0	0	0			
Arrival Type (*AT*)	3	3	3	3	3	3	3	3	3			
Upstream Filtering (*I*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			
Lane Width (*W*), ft	11.0	11.0		11.0	11.0		11.0	11.0				
Turn Bay Length, ft	130	410		130	860		130	320				
Grade (*Pg*), %		0			0			0			0	
Speed Limit, mi/h	25	25	25	25	25	25	25	25	25			

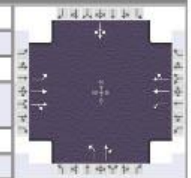
Phase Information	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Maximum Green (G_{max}) or Phase Split, s	25.0	45.0	25.0	60.0		55.0		
Yellow Change Interval (*Y*), s	3.7	3.5	2.5	3.4		3.4		
Red Clearance Interval (R_c), s	2.0	2.0	2.0	2.4		2.4		
Minimum Green (G_{min}), s	5	12	5	12		3		
Start-Up Lost Time (*lt*), s	2.0	2.0	2.0	2.0	2.0	2.0		
Extension of Effective Green (*e*), s	2.0	2.0	2.0	2.0	2.0	2.0		
Passage (*PT*), s	2.5	3.5	2.5	3.5		3.0		
Recall Mode	Off	Min	Off	Min		Off		
Dual Entry	No	Yes	No	Yes		Yes		
Walk (*Walk*), s		7.0				7.0		5.0
Pedestrian Clearance Time (*PC*), s		13.0				19.0		10.0

Multimodal Information	EB			WB			NB			SB		
85th % Speed / Rest in Walk / Corner Radius	30.0	No	15.0				20.0	No	20.0	20.0	No	20.0
Walkway / Crosswalk Width / Length, ft	10.0	10.0	64.0				10.0	10.0	52.0	10.0	10.0	52.0
Street Width / Island / Curb, ft	0.0	0	No	0.0		No	0.0	0	No		0	
Width Outside / Bike Lane / Shoulder, ft	12.0	5.0	2.0	12.0	5.0	2.0	12.0	5.0	2.0			
Pedestrian Signal / Occupied Parking	Yes	0.50			0.50		Yes	0.50		Yes		

Figure K-3 – Traffic and phase timing input data for the intersection at Univ Ave & 17th St

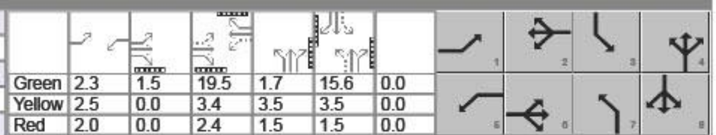
HCS Signalized Intersection Results Summary

General Information				Intersection Information	
Agency	UF			Duration, h	0.250
Analyst		Analysis Date	Apr 3, 2025	Area Type	Other
Jurisdiction	Gainesville	Time Period	AM Peak: 7 am - 8 am	PHF	1.00
Urban Street	West University Ave	Analysis Year	2025	Analysis Period	1> 7:15
Intersection	WUA @ 17th St	File Name	WUA@17thSt April_03_2025 - PEAK.xus		
Project Description					



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h	44	516	36	36	452	32	24	8	32	4	4	4

Signal Information										
Cycle, s	61.5	Reference Phase	2							
Offset, s	0	Reference Point	Begin	Green	2.3	1.5	19.5	1.7	15.6	0.0
Uncoordinated	Yes	Simult. Gap E/W	On	Yellow	2.5	0.0	3.4	3.5	3.5	0.0
Force Mode	Fixed	Simult. Gap N/S	On	Red	2.0	0.0	2.4	1.5	1.5	0.0



Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase	1	6	5	2	7	4	3	8
Case Number	1.1	4.0	1.1	4.0	1.1	4.0	0.0	14.0
Phase Duration, s	8.3	27.2	6.8	25.6	6.7	27.5	0.0	20.8
Change Period, ($Y+R_c$), s	5.7	5.8	4.5	5.8	5.0	5.8	4.0	5.8
Max Allow Headway (*MAH*), s	3.8	4.7	3.8	4.7	3.3	4.4	0.0	4.4
Queue Clearance Time (g_s), s	3.0	8.6	2.8	8.6	2.6	3.0		2.2
Green Extension Time (g_e), s	0.1	5.5	0.1	5.6	0.0	0.1	0.0	0.1
Phase Call Probability	0.52	1.00	0.46	1.00	0.33	0.66		0.49
Max Out Probability	0.00	0.01	0.00	0.00	0.00	0.00		0.00

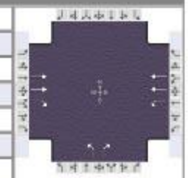
Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement	1	6	16	5	2	12	7	4	14	3	8	18
Adjusted Flow Rate (*v*), veh/h	44	266	262	36	255	223	24	32			8	
Adjusted Saturation Flow Rate (*s*), veh/h/ln	1810	1870	1835	1795	1870	1619	1810	1344			267	
Queue Service Time (g_s), s	1.0	6.6	6.6	0.8	6.5	6.6	0.6	1.0			0.2	
Cycle Queue Clearance Time (g_c), s	1.0	6.6	6.6	0.8	6.5	6.6	0.6	1.0			0.2	
Green Ratio (*g/C*)	0.36	0.35	0.35	0.36	0.32	0.32	0.30	0.35			0.24	
Capacity (*c*), veh/h	391	647	635	363	601	521	509	475			153	
Volume-to-Capacity Ratio (*X*)	0.112	0.411	0.412	0.099	0.424	0.428	0.047	0.067			0.052	
Back of Queue (*Q*), ft/ln (50 th percentile)	9	73	71	8	76	66	6	12			2	
Back of Queue (*Q*), veh/ln (50 th percentile)	0.4	2.9	2.8	0.3	3.0	2.7	0.2	0.4			0.1	
Queue Storage Ratio (*RQ*) (50 th percentile)	0.07	0.18	0.18	0.06	0.09	0.08	0.04	0.04			0.01	
Uniform Delay (d_1), s/veh	13.2	15.4	15.4	13.4	16.5	16.6	15.2	13.2			19.3	
Incremental Delay (d_2), s/veh	0.1	0.5	0.5	0.1	0.6	0.7	0.0	0.1			0.1	
Initial Queue Delay (d_3), s/veh	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0			0.0	
Control Delay (*d*), s/veh	13.3	15.9	15.9	13.5	17.2	17.4	15.2	13.3			19.3	
Level of Service (LOS)	B	B	B	B	B	B	B	B			B	
Approach Delay, s/veh / LOS	15.7		B	17.0		B	14.1		B	19.3		B
Intersection Delay, s/veh / LOS	16.2						B					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS	1.97	B	1.76	B	2.52	C	2.54	C
Bicycle LOS Score / LOS	0.96	A	0.91	A	0.58	A	0.50	A

Figure K-4 – Report results for LOS and delay analyses for the intersection at 17th St

HCS Signalized Intersection Input Data

General Information				Intersection Information	
Agency				Duration, h	0.250
Analyst		Analysis Date	Apr 3, 2025	Area Type	Other
Jurisdiction		Time Period		PHF	1.00
Urban Street	West University Avenue	Analysis Year	2025	Analysis Period	1> 12:00
Intersection	Gale Lamerand	File Name	W Uni Ave @ GL April_03_2025 - PEAK.xus		
Project Description	13th of March				



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h		580	72	128	544		72		116			

Signal Information									
Cycle, s	46.6	Reference Phase	2						
Offset, s	0	Reference Point	End	Green	5.3	14.4	7.3	0.0	0.0	0.0
Uncoordinated	Yes	Simult. Gap E/W	On	Yellow	3.7	3.7	3.4	0.0	0.0	0.0
Force Mode	Fixed	Simult. Gap N/S	On	Red	2.0	2.0	3.2	0.0	0.0	0.0

Traffic Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h		580	72	128	544		72		116			
Initial Queue (Q_b), veh/h		5	0	1	3		3		0			
Base Saturation Flow Rate (s_o), veh/h		1900	1900	1900	1900		1900		1900			
Parking (N_m), man/h		None			None			None				
Heavy Vehicles (P_{HV}), %		1	1	2	2		5		5			
Ped / Bike / RTOR, /h	16	4	0	16	0		16	8		4	0	
Buses (N_b), buses/h	0	0	0	0	0	0	0	0	0			
Arrival Type (*AT*)		3	3	3	3		3		3			
Upstream Filtering (*I*)		1.00	1.00	1.00	1.00		1.00		1.00			
Lane Width (*W*), ft		11.0	11.0	11.0	11.0		11.0		11.0			
Turn Bay Length, ft		290	300	340	520		110		100			
Grade (P_g), %		0			0			0			0	
Speed Limit, mi/h		25	25	25	25		30		30			

Phase Information	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Maximum Green (G_{max}) or Phase Split, s		45.0	25.0	65.0		35.0		
Yellow Change Interval (*Y*), s		3.7	3.7	3.7		3.4		
Red Clearance Interval (R_c), s		2.0	2.0	2.0		3.2		
Minimum Green (G_{min}), s		12	5	12		4		
Start-Up Lost Time (l_t), s		2.0	2.0	2.0	2.0			
Extension of Effective Green (*e*), s		2.0	2.0	2.0	2.0			
Passage (*PT*), s		2.0	2.0	2.0		2.0		
Recall Mode		Min	Min	Off		Off		
Dual Entry		Yes	No	Yes		No		
Walk (*Walk*), s		7.0				7.0		0.0
Pedestrian Clearance Time (*PC*), s		18.0				21.0		0.0

Multimodal Information	EB			WB			NB			SB		
85th % Speed / Rest in Walk / Corner Radius	30.0	No	30.0				30.0	No	30.0	30.0	No	30.0
Walkway / Crosswalk Width / Length, ft	6.0	11.0	60.0				10.0	11.0	65.0	10.0	11.0	65.0
Street Width / Island / Curb, ft	0.0	0	No	0.0		No	0.0	0	No		0	
Width Outside / Bike Lane / Shoulder, ft	12.0	5.0	2.0	12.0	5.0	2.0	12.0	5.0	2.0			
Pedestrian Signal / Occupied Parking	Yes	0.50			0.50		Yes	0.50		Yes		

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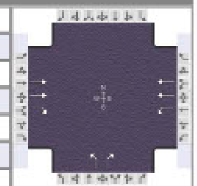
Figure K-5 – Traffic and phase timing data for the intersection at Univ Ave & Gale Lemerand Dr

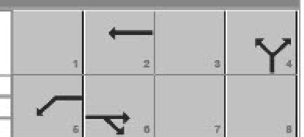
HCS Signalized Intersection Results Summary

General Information				Intersection Information	
Agency				Duration, h	0.250
Analyst		Analysis Date	Apr 3, 2025	Area Type	Other
Jurisdiction		Time Period		PHF	1.00
Urban Street	West University Avenue	Analysis Year	2025	Analysis Period	1> 12:00
Intersection	Gale Lamerand	File Name	W Uni Ave @ GL April_03_2025 - PEAK.xus		
Project Description	13th of March				



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h		580	72	128	544		72		116			

Signal Information										
Cycle, s	46.6	Reference Phase	2							
Offset, s	0	Reference Point	End	Green	5.3	14.4	7.3	0.0	0.0	0.0
Uncoordinated	Yes	Simult. Gap E/W	On	Yellow	3.7	3.7	3.4	0.0	0.0	0.0
Force Mode	Fixed	Simult. Gap N/S	On	Red	2.0	2.0	3.2	0.0	0.0	0.0



Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase		6	5	2		4		
Case Number		7.3	2.0	4.0		9.0		
Phase Duration, s		20.7	11.4	32.1		14.5		
Change Period, (*Y+R c*), s		5.7	5.7	5.7		6.6		
Max Allow Headway (*MAH*), s		3.2	3.3	3.2		3.4		
Queue Clearance Time (*g s*), s		7.9	5.1	5.5		5.2		
Green Extension Time (*g e*), s		3.3	0.2	3.3		0.4		
Phase Call Probability		1.00	1.00	1.00		0.91		
Max Out Probability		0.00	0.00	0.00		0.00		

Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement		6	16	5	2		7		14			
Adjusted Flow Rate (*v*), veh/h		580	72	128	544		72		116			
Adjusted Saturation Flow Rate (*s*), veh/h/ln		1795	1519	1781	1781		1726		1468			
Queue Service Time (*g s*), s		5.9	1.5	3.1	3.5		1.6		3.2			
Cycle Queue Clearance Time (*g c*), s		5.9	1.5	3.1	3.5		1.6		3.2			
Green Ratio (*g/C*)		0.32	0.32	0.12	0.56		0.16		0.16			
Capacity (*c*), veh/h		1152	487	212	2010		288		243			
Volume-to-Capacity Ratio (*X*)		0.503	0.148	0.603	0.271		0.250		0.477			
Back of Queue (*Q*), ft/ln (50 th percentile)		65	12	36	28		28		27			
Back of Queue (*Q*), veh/ln (50 th percentile)		2.6	0.5	1.4	1.1		1.1		1.0			
Queue Storage Ratio (*RQ*) (50 th percentile)		0.22	0.04	0.11	0.05		0.25		0.27			
Uniform Delay (*d 1*), s/veh		13.2	11.3	19.4	5.2		17.3		17.5			
Incremental Delay (*d 2*), s/veh		0.1	0.1	1.0	0.0		0.2		0.5			
Initial Queue Delay (*d 3*), s/veh		0.3	0.0	0.4	0.0		1.0		0.0			
Control Delay (*d*), s/veh		13.6	11.3	20.9	5.2		18.5		18.0			
Level of Service (LOS)		B	B	C	A		B		B			
Approach Delay, s/veh / LOS	13.3		B	8.2		A	18.2		B	0.0		
Intersection Delay, s/veh / LOS	11.7						B					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS	2.03	B	0.66	A	2.26	B	2.52	C
Bicycle LOS Score / LOS	1.03	A	1.04	A		F		

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Figure K-6 – Report results for LOS, and delay analysis for the intersection at Gale Lemerand Dr