Connecting Pedestrians with Disabilities to Adaptive Signal Control for Safe Intersection Crossing and Enhanced Mobility

2019 Field Test and Evaluation Plan

August 2019
Publication Number: FHWA-JPO-19-753

U.S. Department of Transportation

Produced by Carnegie Mellon University, with support from Diyunu and Booz Allen Hamilton.
(Cover page figure source: US Department of Transportation)

U.S. Department of Transportation
Intelligent Transportation Systems (ITS) Joint Program Office

Notice

Quality Assurance Statement

The Federal Highway Administration provides high quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-19-753		

4. Title and Subtitle	5. Report Date
Connecting Pedestrians with Disabilities to Adaptive Signal Control for Safe Intersection Crossing and Enhanced Mobility: 2019 Field Test and Evaluation Plan	Aug 2019
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Stephen Smith, Zachary Rubinstein, Bernadine Dias, Jim Marousek, Sara Sarkhili, Huthaifa Ashqar, Maurice Farber, Diego Lodato, Corey Harper	Task 1.3 Report

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Carnegie Mellon University 5000 Forbes Avenue Pittsburgh PA 15213	
	11. Contract or Grant No. DTFH6117C00014

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation ITS Joint Program Office 1200 New Jersey Avenue, SE Washington, DC 20590	Year 2 Field Test Evaluation Plan
	14. Sponsoring Agency Code

15. Supplementary Notes

Govind Vadakpat (COR);

16. Abstract

PedPal is a prototype mobile (smartphone) app designed to assist pedestrians with disabilities when crossing the street at signalized intersections. *PedPal* interacts directly with the traffic signal system controlling the intersection to communicate both crossing intent (eliminating the need to seek out and push a pedestrian call button) and personalized crossing constraints (ensuring sufficient time is allocated for the pedestrian to cross). Future versions of *PedPal* will incorporate the ability to monitor crossing progress and to dynamically extend the crossing time in situations where more time is needed to safely get across, as well as provide enhanced capabilities aimed at improving crossing efficiency and general mobility.

In this test plan, we outline and describe a set of user evaluation tests that will be conducted with the Year 2 *PedPal* mobile app.

17. Keywords	18. Distribution Statement
pedestrians with disabilities, safe intersection crossing, smartphone app	

19. Security Classify. (of this report)	20. Security Classify. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	40	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Table of Contents

CHAPTER 1 OVERVIEW 1

CHAPTER 2 SAFE INTERSECTION CROSSING 3

2.1 YEAR 2 PEDESTRIAN DEVICE 4
2.2 PEDPAL MOBILE APP 5

CHAPTER 3 FIELD TEST DESIGN 8

3.1 TEST OBJECTIVES 8
3.2 TEST PARTICIPANTS 9
3.3 TEST LOCATION 9
3.4 TEST ROUTES 12
3.5 TEST PROTOCOL 12
3.5.1 Introduction 14
3.5.2 Obtain Consent Form 14
3.5.3 Conduct Pre-Test Survey 15
3.5.4 Configure Test Device 17
3.5.5 PedPal Mobile App Training 17
3.5.6 Conduct Live Test Session 18
3.5.7 Post-Test Survey 19
3.5.8 Data Download and Labeling 21
3.6 DATA COLLECTION METHODOLOGY 21
3.6.1 Observational Data 21
3.6.2 Video Recordings 21
3.6.3 Phone Data Logs 22

APPENDIX A RECRUITMENT FLYER 23

APPENDIX B PRE-TEST SURVEY FORM 25

APPENDIX C POST-TEST SURVEY FORM 29

APPENDIX D DATA COLLECTION SHEET 31

List of Tables

Table 3-1: Test Personnel Roles 13
Table 3-2: User Test Protocol Timeline 15

List of Figures

Figure 2-1: Components of the Safe Intersection Crossing System 4
Figure 2-2: Year 2 Device to Be Used for User Testing 5
Figure 2-3: Current *PedPal* Mobile App Settings 6
Figure 2-4: Snapshot of the *PedPal* Mobile App User Interface 7
Figure 3-1: Test Location with Example Route 10
Figure 3-2: Overview of Field Test Protocol 13

Chapter 1 Overview

Transportation and mobility are crucial for living today. However, people with disabilities (mobility, vision, hearing, and cognitive) often do not have equal access to transportation, which hinders their ability to experience a full life. The Accessible Transportation Technology Research Initiative (ATTRI) of the U.S Department of Transportation's (USDOT) Intelligent Transportation Systems Joint Program Office (ITS-JPO) aims at improving the mobility of travelers with disabilities through research, development, and implementation of transformative technologies, applications, or systems for people of all abilities to effectively plan their personal and independent travel. ATTRI research focuses on the needs of three stakeholder groups: persons with disabilities, older adults, and veterans with disabilities.

The ATTRI Broad Agency Announcement focuses on transformational changes and revolutionary advances in accessible transportation, personal mobility, and independent travel for all travelers that lead to offering a totally new travel experience in intermodal surface transportation in the United States. This involves research and development in three key application areas:

1. Smart Wayfinding and Navigation Systems
2. Pre-trip Concierge and Virtualization, and
3. Safe Intersection Crossing

This document is developed as a part of the Safe Intersection Crossing application area. It presents the plan for the conducting test and evaluation activities of a mobile application (app) called *PedPal* that has been developed over the past two years for this application area. The *PedPal* mobile app is a prototype smartphone application designed to assist pedestrians with disabilities when crossing the street at signalized intersections. The *PedPal* mobile app interacts directly with the traffic signal system controlling the intersection to communicate both crossing intent (eliminating the need to seek out and push a pedestrian call button) and personalized crossing constraints (ensuring sufficient time is allocated for the pedestrian to cross). The current version of the *PedPal* mobile app will incorporate the ability to monitor crossing progress and to dynamically extend the crossing time in situations where more time is needed to safely get across, as well as provide enhanced capabilities aimed at improving crossing efficiency and general mobility.

1. In this test plan, we outline the device to be tested, the test objectives, test participants, test team roles, and the test protocol which will be used to conduct user testing of the Year 2 *PedPal* mobile app.
2. During the Year 2 user field tests, the project team intends to follow the general testing approach that was adopted for the Year 1 user field test; and will perform similar tests again in Year 2. For Year 2, testing will also be revised to incorporate

testing for the updated and additional features in the *PedPal* mobile app, listed below:

- 3G/4G wireless communication between the *PedPal* mobile app and the SURTRAC, rather than Dedicated Short Range Communications (DSRC).
- The use pre-planned route information.

3. The Year 2 user field test evaluation will again emphasize the qualitative strengths and weaknesses that are observed and reported by participants during testing, but will also capture data to provide quantitative evidence or justification where feasible.

The remainder of this report is organized as follows.

- Chapter 2 first summarizes the Year 2 prototype version of the *PedPal* mobile app that will be tested by prospective participants.
- Chapter 3 then presents the design of the user field test, including descriptions of the field test location, the testing protocols that have been adopted, and the data collection plan.

Chapter 2 Safe Intersection Crossing

The *Safe Intersection Crossing* project is intended to develop and demonstrate assistive services that promote safe passage of injured veterans, older adults, and other persons with blindness, low vision, cognitive, or mobility related disabilities when crossing signalized intersections, and leverage smart traffic signal infrastructure to further provide these persons with significant mobility enhancements.

In Year 1, these prototype services were accessible to participants via smartphones that were equipped with both the Y1 *PedPal* mobile app and with Dedicated Short-Range Communication (DSRC) capability. In Year 2, these prototype services will be available to participants via smartphones that will be equipped with both the enhanced Y2 *PedPal* mobile app and 3G/4G data plans; which will again allow them to (1) access real-time information from traffic signal infrastructure and nearby vehicles and (2) actively influence traffic signal control decisions and vehicle movements at the intersection. More specifically, the *PedPal* mobile app will provide accessible interfaces that allow pedestrians to:

- Communicate personalized intersection crossing constraints (e.g., crossing direction, crossing time needed) to the signal system and
- Receive sufficient crossing time, and necessary information (e.g., geometric information about the intersection) to facilitate safe crossing.

Real-time monitoring of crossing performance by the *PedPal* mobile app will be used to automatically request an extension to the green time in real-time when appropriate. The *PedPal* mobile app will also enable participants to provide pre-planned pedestrian route and destination information (e.g., walking path) to the traffic signal infrastructure, which can be used in conjunction with other real-time information to adapt signal phase timings preemptively as the pedestrian approaches the intersection, leading to shorter and more reliable pedestrian travel times, and more efficient travel connections.

The technical approach taken to provide these capabilities combines pedestrian-to-infrastructure communication with recent advances in real-time, adaptive traffic signal control, embodied in the *SURTRAC* traffic signal control system (http://www.surtrac.net). *SURTRAC* combines artificial intelligence with traffic theory to provide, for the first time, real-time optimization of traffic flows in complex urban road networks, where (in contrast to suburban corridors) there are multiple, competing dominant traffic flows that change through the day. *SURTRAC* takes a decentralized, collaborative online planning approach to signal control. Each intersection independently senses its locally approaching traffic and generates in real-time a signal timing plan that moves sensed traffic through the intersection to minimize cumulative wait time. Intersections then share their plans with

downstream neighbors to achieve coordinated behavior at the network level. In the field, *SURTRAC* shows reductions of 25% in vehicle travel times, 30% in number of stops and 40% in vehicle wait times. In the current context, *SURTRAC* provides the ability to adjust signal timing plans on a second by second basis. As such, the *PedPal* mobile app should yield compound benefits in areas with large concentrations of disadvantaged pedestrians (e.g., near elder care facilities, retirement homes, schools for persons with disabilities, etc.).

Figure 2-1 identifies the principal components of the safe intersection crossing system.

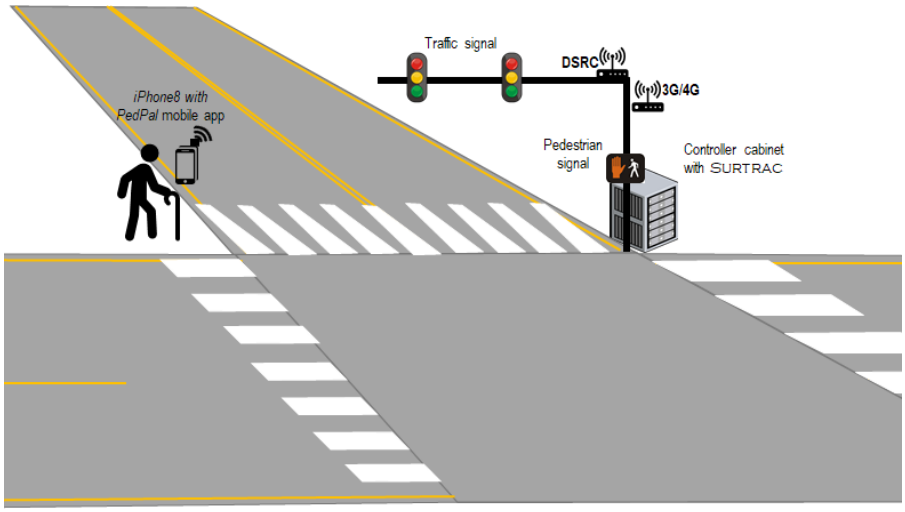


Figure 2-1: Components of the Safe Intersection Crossing System

2.1 Year 2 Pedestrian Device

The Pedestrian Device for the Year 2 *PedPal* mobile app prototype is shown in Figure 2-2 below. It consists of an iPhone 8 smartphone running the *PedPal* mobile app. For Year 2, the iPhone will not use DSRC connectivity as done for the Year 1 evaluation but will instead use 3G/4G cellular communications.

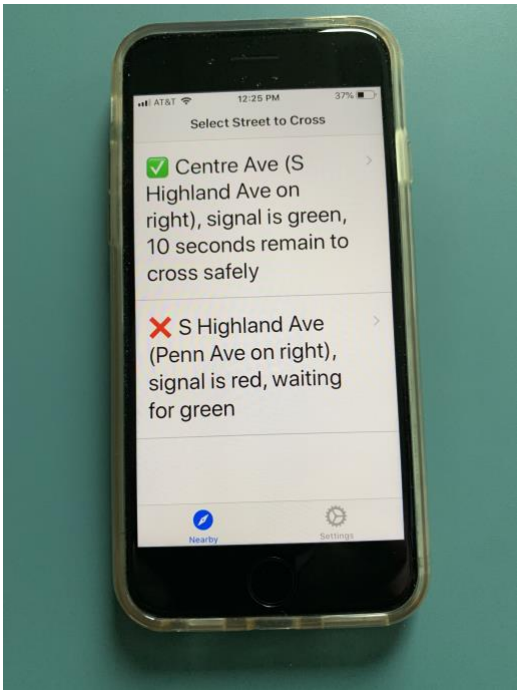


Figure 2-2: Year 2 Device to Be Used for User Testing

2.2 *PedPal* Mobile App

The *PedPal* prototype mobile app is designed to assist the user in crossing the intersection. The *PedPal* mobile app is customizable by the user and will use the user's personalized crossing constraints. It allows the user to communicate crossing intent (eliminating the need for a pedestrian call button) along with the time that is required for safe crossing. If the request is made in advance of the green in the crossing direction, then an extension to crossing time will always be granted by the traffic control system. If the request is made when the signal is already green in the crossing direction, the traffic control system will determine whether there is enough time remaining to permit crossing and grant a time extension or if the pedestrian should wait until the next green cycle.

As shown in Figure 2-3, configuration of the *PedPal* mobile app currently includes of several user-preference settings, including:

- Traveler Type – white cane user, guide dog user, wheelchair users, deaf, etc. This setting establishes the default baseline crossing speed for the user.
- Street Crossing Speed – crossing speed can be further tuned relative to the default speed using this setting.
- Show Diagonal Crossings – specifies whether diagonal crossings should be considered.

- Re-Sort Corners After Crossing – impacts user preference when using two crossings to accomplish a diagonal crossing
- Countdown Frequency (V0) – When operating with voice over on, this setting controls the verbosity of the spoken countdown.
- Device Orientation – fixed or dynamic

Figure 2-3: Current *PedPal* Mobile App Settings

The *PedPal* mobile app supports all of the native accessibility features of the iPhone, including voice-over, zoom, font enlarging, etc. These features are configured from the iPhone's Settings control.

Figure 2-4 below illustrates the process of selecting the street to cross, which triggers sending of a Signal Request Message (SRM) to request that sufficient crossing time be allocated to the next green phase in the selected crossing direction. Receipt of MapData (MAP) and Signal Phase and Time (SPaT) messages enable generation of the screen on the left, and once the user selects the street to cross, an SRM is sent to the intersection. The intersection will subsequently send a Signal Status Message (SSM) back to the app, indicating whether or not the extension has been granted. In the example, given in Figure 2-4, the extended crossing duration has been granted but by the time Centre Ave was selected it was no longer green. Hence the user is told "Don't Cross", and once the time until green reaches 5 seconds, a countdown down from 5 is shown to alert the user that crossing time is near (middle screen). When the crossing phase becomes active, the app tells the user it is "OK To Cross" and the app counts down the time remaining (right screen).

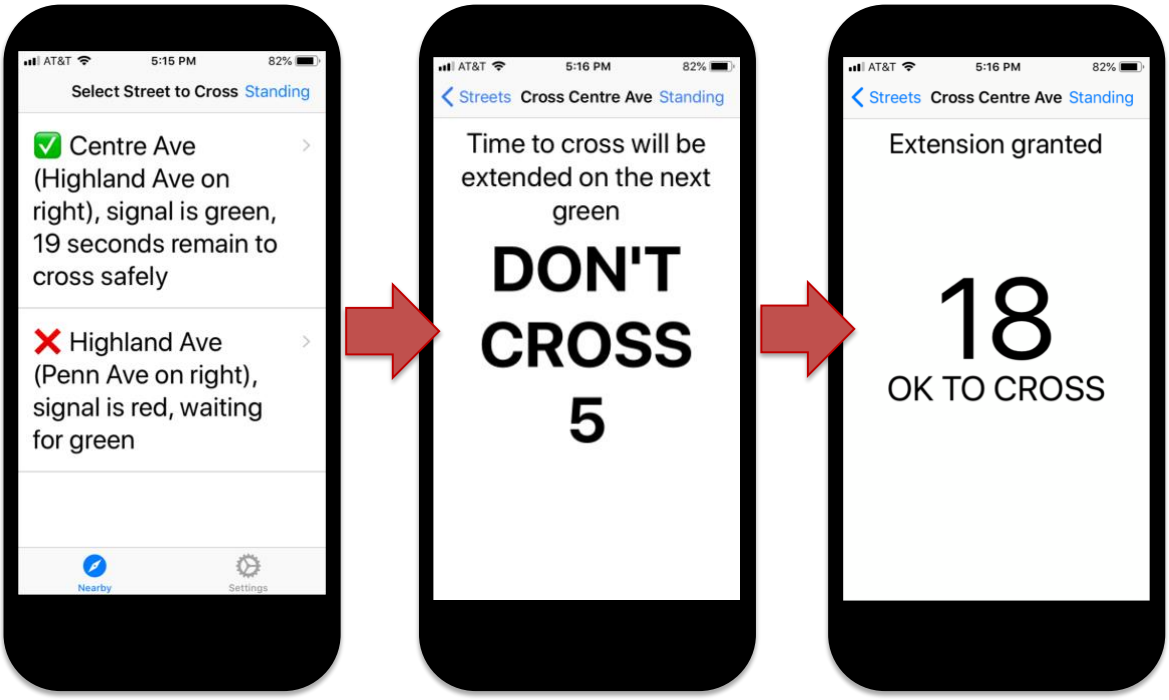


Figure 2-4: Snapshot of the *PedPal* Mobile App User Interface

Chapter 3 Field Test Design

This chapter describes the overall design of Year 2 field test that will be undertaken to evaluate the *PedPal* mobile application. This initial field test will be carried out during the period from August 12 to August 23, 2019 and will involve user testing conducted by 15-20 volunteers recruited from the local disability community. It is intended that recruited participants will include individuals with a range of disabilities, spanning visually impaired people (most prevalent), wheelchair users, and elderly persons with mobility challenges.

Each volunteer will be individually engaged for a 1-hour to 2-hour session, during which the prospective user will first be asked to complete an information gathering pre-test survey, and then will introduced to the *PedPal* mobile app running against an intersection traffic signal simulator. Once training activities are complete, the user will be transported to the nearby field site. At the selected intersections, a series of crossing tours through a route consisting of several adjacent intersections will be performed, both with the assistance of the *PedPal* and without it (as the individual would normally cross the street). For test purposes, the route information will have been previously generated and pre-loaded onto the test devices.

During these crossing tours, data and observations will be collected on crossing times, cycles required to cross, trajectory anomalies, *PedPal* mobile app message traffic, impacts to vehicular traffic and other notable events. Following the testing of the device, the session will conclude by conducting a post-test survey, where each participant will be given the opportunity to comment on the potential of the *PedPal* mobile app, what they liked and did not like, and to provide any suggestions they might have for improvement.

In the following subsections, we summarize the basic objectives of the field study, the physical intersection where the testing will take place, the overall testing protocols that will be adopted, and the methodology for collecting test data.

3.1 Test Objectives

The primary objective in conducting the field test is to assess the extent to which the *PedPal mobile app* is performing as intended and to gauge its usefulness (or potential usefulness) to pedestrians with disabilities. More specifically, the field test is designed to answer the following types of questions:

1. Does the application improve or hold the potential to improve (a) the safety of crossing the intersection, (b) the stress associated with crossing the intersection, and (c) the time required to cross the intersection?

2. Does the application work consistently for all users during their acts of intersection crossing (i.e., is it robust and error free)?
3. What are the application's strengths and weaknesses with respect to user acceptance?
4. For what types of potential users is the application likely to be most useful (e.g., we might expect the app to be less useful for a motorized wheelchair user than for a user with a walker (or a manual wheelchair user)?
5. What is the impact of the application's use on vehicular and transit traffic flows? It is expected that there could be some adverse effect on vehicle movement due to longer wait times.

3.2 Test Participants

Evaluating the usefulness and potential of the *PedPal* mobile app will be greatly reinforced through test evaluation results collected from a diverse pool of test participants. As with the Year 1 User Test, the project team hopes and expects to achieve a reasonable amount of diversity in the types of disabilities covered by participants, although our principal focus will remain on attracting individuals who are vision impaired, or have mobility challenges (e.g., wheel chair users, older individuals that move with a walker or cane). As with the Year 1 user evaluation, the project team has decided to explicitly exclude consideration of individuals with cognitive disabilities in the Year 2 evaluation, recognizing that this is perhaps the most challenging user group.

Potential participants will again be recruited via contacts that were developed during the initial user stakeholder meeting held in October 2017 at the outset of the project, and through other prior contacts known to the project team. Recruitment of new participants will be facilitated though the introduction of a Recruitment Flyer, shown in Appendix A. The project team has also invited the participants from the Year 1 User Test to participate again in the Year 2 User Test. We currently have 15 individuals who have agreed to participate, including 9 from our Year 1 user test. These participants include 9 vision impaired individuals, 3 wheelchair users, 2 mobility limited users walking with a cane or walker, and 5 older individuals (with some categories overlapping). We have explicitly excluded recruiting persons with cognitive disabilities and persons younger than 21.

3.3 Test Location

The target location for the field test is a set of four intersections, listed below, in the vicinity of University of Pittsburg Medical Center's (UPMC) Shadyside Hospital and Henry Hillman Cancer Center complex in the East End of Pittsburgh PA.

1. Baum Boulevard and Cypress Street
2. Baum Boulevard and Liberty Avenue
3. Center Avenue and Aiken Avenue

4. Centre Avenue and Cypress Street

These intersections have been chosen for the following combination of reasons: (1) because the SURTRAC adaptive signal control system and a DSRC message processing capability are installed and operational at each of these intersections, (2) because of the relatively large volume of pedestrian traffic crossing these intersections, and (3) because of the intention to test users' ability to travel routes through sequences of consecutive intersections instead of just conducting tours around a single intersection as in Year 1. Since theses intersections are controlled by the SURTRAC adaptive signal control system, the green phase in any direction can (and will) vary from cycle to cycle, depending on the actual vehicle traffic on the road at any given moment. A bird's eye photograph of the area encompassing these intersections are shown in Figure 3-1: Test Location.

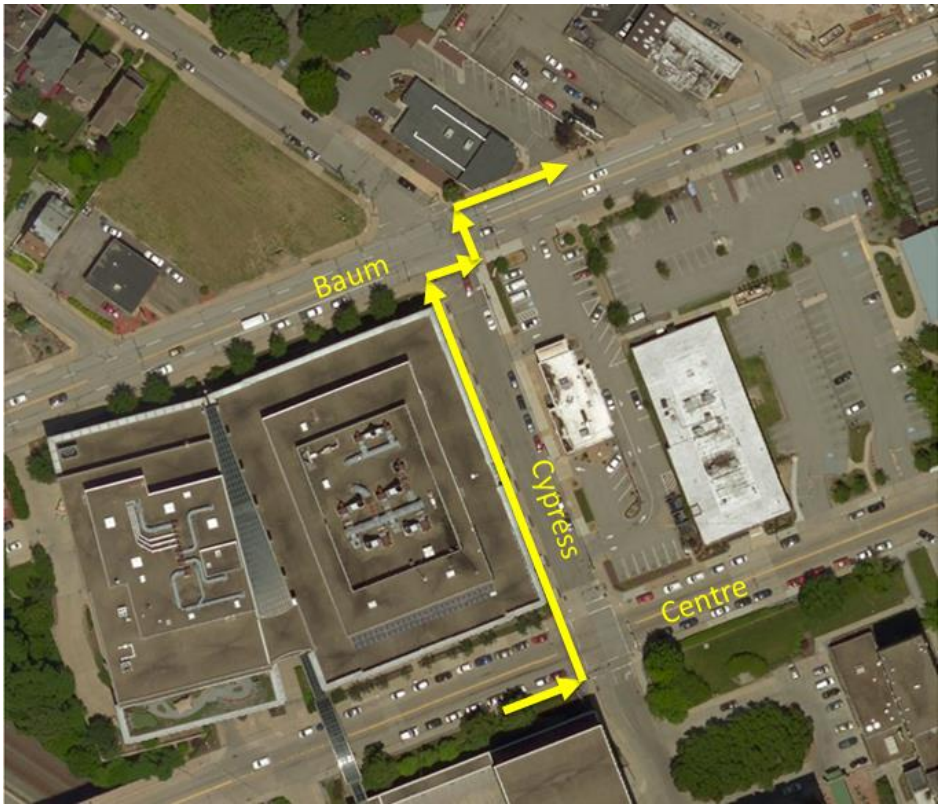


Figure 3-1: Test Location with Example Route

More specifically, testing will involve crossing some subset of the following 4 intersections:

1. *Centre Avenue and Cypress Street* is a basic four-way intersection that consists of one travel lane in both the east/west and north/south travel directions. It is a simple two-phase intersection (i.e., no dedicated left turn phases) with the signal just cycling between east/west and north/south phases. The intersection design has a single curb cut at each corner rather than curb cuts directly interfacing with the

crosswalks and, although there are pedestrian countdown signals, there are no audible pedestrian signals nor pedestrian push buttons available. The lack of audibles, corner curb cut design, and the changing amount of green time in a given direction over time, make this an extremely challenging intersection to cross for blind pedestrians. This intersection was the focus of the Year 1 user field test experiments.

2. *Baum Boulevard and Cypress Street* is a basic four-way intersection one block north of Centre/Cypress. It consists of two travel lanes in the east/west direction and a single travel lane in the north/south travel direction. Traffic in the east/west direction on Baum Boulevard is heavier than that on Centre during certain periods of the day, and that plus the width of the roadway (4 lanes) likely presents a more significant crossing challenge than does crossing Centre Avenue (2 lanes). Like the Centre/Cypress intersection, there are no audibles, no pedestrian call buttons, and curb cuts interface directly with the crosswalks.

3. *Center Avenue and Aiken Avenue* is a technically also a simple 4 way intersection with 1 travel lane in the east/west direction and 2 travel lanes in the north/south direction, located one block east from Centre/Cypress. However, just past the intersection going north is a Y of sorts, where the two sets of north/south travel lanes veer northwest to become Liberty Avenue, and a third one way travel lane veers northeast and continues Aiken Avenue. Hence in some crossing directions the pedestrian must navigate more than one crossing in the same direction. Like the Centre/Cypress intersection, there are no audibles, no pedestrian call buttons, and curb cuts interface directly with the crosswalks.

4. *Baum Boulevard and Liberty Avenue* is essentially a 5 way intersection crossing and the most complex intersection to cross of the four potential test intersections. It is one block east of Baum/Cypress and one block northwest of Centre/Aiken. The intersection has two travel lanes both the east/west and north/south directions, making it the highest volume intersection from a vehicle perspective, and additionally, has a fifth one way exit in the northeast direction along South Atlantic Avenue. Whereas the above three intersections are all simple two phase intersections, Baum/Liberty also has 2 “protected left” turning phases in addition to the basic east/west and north/south phases, to facilitate left turns from Baum traveling eastbound onto Liberty or South Atlantic traveling north, and from Liberty traveling south onto Baum traveling east. Like the three other intersections, there are no audibles, and curb cuts interface directly with the crosswalks. Pedestrian call buttons do exist.

3.4 Test Routes

The Year 2 test protocol will include testing over several pre-planned travel routes each covering 2-3 crossing intersections. Each test route will require the participant to traverse roughly a city block along different adjacent streets each covering 2-3 SURTRAC controlled crossing intersections. For test control purposes, the routing information will have been generated in advance and preloaded into each participant's PedPal mobile app, prior the start of the user field testing.

The route will begin at starting location and will involve walking a short distance (no more than 20 minutes in total), and which will include crossing several different traffic intersections to reach a specified destination. The start location will be the intersection of Cypress Street and Centre Avenue which is one of the intersections with SURTRAC controlled traffic lights.

An example of one of the planned test routes, depicted in Figure 3-1 above, is described below.

1. The Test Route starts on the right-hand side of Centre Avenue, with the Test Participant heading east, towards the intersection with Cypress Street.
2. After arriving at the southwest corner of the Centre Avenue and Cypress Street intersection, the participant will cross Centre Street to the northwest corner of the intersection.
3. The participant will proceed north on the left side of Cypress Street heading towards Baum Boulevard.
4. After arriving at the southwest corner of the intersection of Cypress Street and Baum Boulevard, the participant will cross Cypress Street to the southeast corner of the intersection.
5. The participant will then cross Baum Boulevard to the northeast corner of the intersection.
6. The participant will proceed east on the left side of Baum Boulevard heading towards Liberty Avenue until the final destination is reached.

3.5 Test Protocol

The field-testing protocol will consist of three phases, as shown below in Figure 3-2. During the first of the three Phases, the Pre-Test Phase, initial information will be obtained from the participant and he/she will be introduced to the *PedPal* mobile app and given training in its use. This first Phase will be carried out at Carnegie Mellon University (CMU), due to its relative proximity to the field test site and the availability of conference rooms and training area. During the second phase, the Test Phase, the participant will be transported to the field test site, and a series of intersection crossings will be performed both with and without the assistance of the *PedPal* mobile app. After test activities are complete, the test

participant will be transported back to CMU for the third Phase, the Post-Test Phase, of the test protocol, where the participant will be asked to complete a post-test survey and any captured data will be downloaded to a secure server. All test activities and data handling will be carried out in compliance with the Institutional Review Board (IRB) standards and associated protocols of CMU.

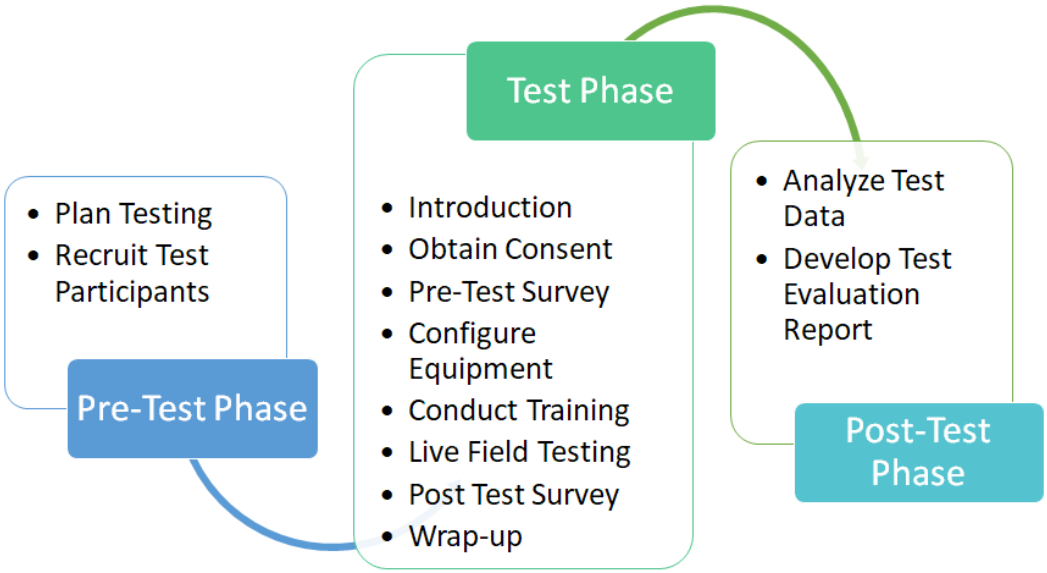


Figure 3-2: Overview of Field Test Protocol

Table 3-1 identifies and describes the test personnel roles required during user testing. The field test team will consist of at least 6 IRB-approved individuals, and the test team will be cross-trained in several test roles shown in Table 3-1 below, and team members may fulfill more than one test role during testing activities, Assignments will be distributed across the test team to accommodate training, and respective schedules. .

Table 3-1: Test Personnel Roles

Role	Description
Test Manager	The test manager is responsible for the overall test execution. The test administrator ensures that the field test conditions meet the necessary requirements and the data collection is up to standards. The test manager confirms that the field test covers all aspects of the application to be demonstrated and gives official approval to kick-off the proceedings for the conduct of the field test. The test manager also ensures that all the necessary equipment for recording the test and collecting test data is available on the day of testing.

Role	Description
Researcher	The researcher will support different test activities including (1) survey preparation, collection and processing (2) test equipment preparation and configuration and (3) data downloading and labeling, and (4) general support.
Application Trainer	The application trainer is responsible for training each test participant on how to use the application, informing them of the test procedure and best practices and guidelines for safe application usage. The application trainer will log all questions, errors, and difficulties encountered during the training session.
Safety Person	The safety person will be responsible for ensuring the participant's safety by coordinating with other vehicles and other personnel. The safety personnel will follow the participants in close proximity during the test session and will only interact with the participant if a safety intervention is needed to keep the participant safe.
Observer	The field test observer(s) is responsible for collecting related field test data such as Participant's progress in time and space, participant's fatigue, observable traffic conditions, and any errors made by participant. Once the test session is complete, the field test observer is responsible for providing an event log to the data analyst for further analysis of the test results. Note that both the system and data collectors will be responsible for recording data during the test session.
Videographer	Additional test observers will video record the crossings (contingent on participant consent) to provide collaborating or clarifying analysis test results.

Table 3-2 summarizes the user test protocol and identifies the field test personnel roles required to execute each test step. Each step of the protocol is described in more detail in the subsections below.

3.5.1 Introduction

The Test Manager will greet the test participants and the introduce the ATTRI Safe Intersection Crossing program, and provide an introduction and overview the *PedPal* mobile app. This will be followed by an overview of testing protocol and the schedule of test activities and conclude with an introduction to the test team.

3.5.2 Obtain Consent Form

One of the Researchers will review the participant consent form with the assembled test participants and answer any questions. The Researcher will then supervise the distribution and collection of signed consent forms from test participants. Only those participants providing their written consent will be allowed to participate in the field test. To streamline

the testing we will also give participants the opportunity to review and sign consent forms in advance of the test date.

Table 3-2: User Test Protocol Timeline

Phase	Test Activity	Time (mins)	Test Personnel/Role
1	Introduction (**Error! Reference source not found.**)	5-10	Test Manager
	Obtain Consent Form (**Error! Reference source not found.**)	5-10	Researcher-1
	Conduct Pre-Test Survey (3.5.3)	15	Researcher-1
	Configure Test Equipment (3.5.4)	10	Researcher-2
	Conduct *PedPal* Mobile App Training (3.5.5)	20	App Trainer
2	Conduct Live Test Session (3.5.6)	30	Safety Person Observer Videographer
3	Conduct Post-Test Survey (3.5.7)	15	Researcher-1
	Data Download and Labeling ()	30	Researcher-2
	Wrap up	5	Test Manager

3.5.3 Conduct Pre-Test Survey

The pre-test survey will be focused on collecting base information on each participant's level of ability and experience in crossing different intersections, user's level of experience with smartphone technology, frequency of traffic intersection crossing, desired features of the mobile app, current challenges crossing traffic intersections, guidance tools used (wheelchair, cane, dog, etc.), and demographic information (gender, age range, disability, and ethnicity). This information will be used to inform the *PedPal* mobile app training session (Section 3.3.2) and the configuration of the *PedPal* mobile app for the field test, as well as to provide a basis for better understanding the potential utility of the app. The goals and construct of the Pre-Test Survey is provided below, and a prototype of the form that will be used is provided in Appendix B.

1. Determine whether the participant supported the previous year's user testing for the Year 1 *PedPal* mobile app prototype.

2. For participants who also supported the Year 1 user testing of the *PedPal* mobile app, determine their recollection about their experience using *PedPal*. There will be a request to be specific, and the extent feasible, detailed and comprehensive.

3. Determine what tools the participant typically uses for guidance when traveling. A checkbox list will be provided, and the participant will additionally be allowed to list any other mode of assistance that they employ. Finally, the participant will be allowed to provide optional comments regarding tool usage.

4. Determine what technology, if any, does the Participant typically use to assist with their travel? (e.g. GPS device, smartphone, smartphone map apps such as Apple Maps or Google Maps, or other apps such as BlindSquare, etc.). A checkbox list will be provided, and the participant will also be allowed to list any other technology that they employ. Finally, the participant will be allowed to provide optional comments regarding technology usage.

5. Determine the level on a scale of 1 (least) to 5 (most) at which the participant rates their proficiency with respect to their use of a smartphone.

6. For those participants familiar with the voiceover features on a smartphone, determine how many years the Participant has been using this voiceover technology.

7. Determine the level on a scale of 1 (least) to 5 (most) at which the participant rates their proficiency with respect to their use of the voiceover capabilities on a smartphone.

8. Determine the frequency with which the test participant crosses intersections. A checkbox list will be provided, and additionally, the participant will be allowed to provide optional comments regarding their intersection crossing habits.

9. Determine what challenges, if any, does the participant face when crossing traffic intersections. There will be a request to be specific, and the extent feasible, detailed and comprehensive.

10. Determine what features/characteristics the participant think will be important in a mobile app such as the *PedPal* mobile app. There will be a request to be specific, and the extent feasible, detailed and comprehensive.

11. Gather demographic information on the test participant including the following:
    - Determine the gender(s) that the test participant identifies. A checkbox list of genders will be provided, including an option to indicate that they prefer not to answer this question.
    - Determine the age range of the test participant. A checkbox list of age brackets will be provided, including an option to indicate that they prefer not to answer this question.
    - Determine which, if any, ATTRI target populations the participant identifies with. A checkbox list of target populations will be provided, including an option to indicate that they prefer not to answer this question.

- Determine which, if any, ATTRI disability types the participant identifies with. A checkbox list of disability categories will be provided, including an option to indicate that they prefer not to answer this question.
- Determine which, if any, ethnicities the participant identifies with. There will be an option to indicate that they prefer not to answer this question.

Finally, the participant will be allowed to provide optional comments regarding their demographic information.

12. Determine if the participant has additional observations or comments that they believe is of importance, concern or interest.

3.5.4 Configure Test Device

One of the Researchers, will verify the operational status of all iPhones and their respective installed *PedPal* mobile app. The Researcher will also ensure that the default settings are applied to the *PedPal* mobile app. Once operational status is verified, the Researcher will work with each test participant to customize the mobile app settings on the iPhone 8 and ancillary devices (e.g., bone conducting headphones) provided to that test participant to meet their unique needs.

3.5.5 *PedPal* Mobile App Training

During the initial part of each training session, which will be held indoors at CMU, the participant will be introduced to the *PedPal* technology solution and given a chance to become familiar with its use. The iPhone 8 smartphone and *PedPal* mobile app interface will be introduced to the participant in an accessible manner (which naturally will be varied according to each user's needs and preferences).

After all the participant's questions about its use are addressed, the participant will be guided through a few exercises using a traffic intersection simulator that was developed for this purpose. The participant will be then asked to independently use the *PedPal* mobile app to assist in crossing the (simulated) intersection, while being observed. For blind participants, the voice-over capabilities provided by the *PedPal* mobile app and instructions on how to adjust relevant settings will also be explained. After initial simulator tests are conducted indoors at the CMU facility, the participant will be invited to continue practicing, again with the simulator, outdoors at a mock intersection setup at a safe location at the CMU facility. All questions, errors, and difficulties encountered in each training session will be documented to inform future testing sessions.

Once the training session is complete and if the participant feels comfortable to move on to the testing phase, the participant will be invited to transition to the user test session. Also, if the participant has previously participated in *PedPal* user test sessions, the trainer will take note of how well the participant recalls how to use the *PedPal* mobile app from the previous experience. At the conclusion of the training session, and prior to conducting the live test

session described in Section 3.5.6 below, one of the Researcher will again confirm the operational status and custom configuration of each participant's iPhone, as described in Section 3.5.4 above.

3.5.6 Conduct Live Test Session

After the training session is complete, the participants will transition to an observation and testing session where Researchers will transport the participants to the field test site and test the use of the *PedPal* mobile app, as well as observe the participant while they cross intersections without assistance from the app. In order to minimize the effect of route familiarity on results, the ordering of testing vs. observation of traversal without the app will be randomized for the participants. Therefore, some participants will first do the observation phase and then do the testing phase, while others will first do the testing phase and then do the observation phase.

As described in Section 3.4 earlier, participants will be asked to traverse a route that should take no more than 20 minutes and includes traversing various adjacent streets through several SURTRAC controlled intersections to reach a specified destination. The start location will be the intersection of Cypress Street and Centre Avenue which is one of the intersections with SURTRAC controlled traffic lights.

Prior to arriving at the field test site, each participant will have been provided with an iPhone 8 smartphone hosting the installed *PedPal* mobile app. The operational status and individual participant's preferred configuration will have been verified before and after the training session described in Section 3.5.5 above.

Three researchers will walk with the participant throughout the route. One researcher will be focused on ensuring the safety of the participant, while another researcher will be focused on documenting observations and questions about how the participant navigates the route and the crossings using their regular methodology. A third researcher will focus on video recording of the session if permission is granted by the participant. Observations will be therefore recorded using a combination of checking tabulated categories, taking notes, photos, audio, and video recordings as appropriate. Researchers will only intervene or interact with the participant during this route traversal to prevent an unsafe situation for the participant or to answer any questions the participant has.

The participant will be instructed to traverse the route using his/her usual methodology and to assume that they are traveling alone. The participant will be free to abandon the route and exit the test at any time if they do not feel they can accomplish the route safely and independently. After the participant has completed or exited a test, the researchers will clarify any questions that were documented during the observation session. The participant will also be offered access to restrooms and to light refreshments.

As with the test sessions, the observation sessions will include three researchers and one participant for each test. One researcher will always be focused on participant safety and

the other two on recording observations via observation sheets and video (if permission is granted by the participant). Observations will be recorded using a combination of checking tabulated categories, taking notes, photos, audio, and video recordings as applicable.

The participant will be given similar (but not necessarily identical) routes for both the observation session and the testing session. The participant may also be asked to cross the traffic intersections more than once to gain additional insight into how participant behavior can vary, and we may also toggle the intersection's SURTRAC component on and off to evaluate the impact of that component of the solution. Once again, the safety-focused researcher will follow the participant in close proximity and only interact with the participant if an intervention is needed to keep the participant safe. The other researchers will document a variety of factors including any errors encountered, localization accuracy, any confusion on the part of the participant, weather and traffic conditions, unexpected occurrences of any kind, participant fatigue and observable stress, and participant use of app.

The *PedPal* mobile app will also record a variety of data including crossing times, button presses, GPS logs, etc. Some participants may also elect to participate in the training and test sessions on different dates. The participant will be offered access to restrooms and to light refreshments after the test session is complete.

3.5.7 Post-Test Survey

Finally, after each test session, the participant will be asked to complete a post-test survey. This survey will seek to record the participant's view of his/her experience using the *PedPal* mobile app and participating in the user test. As with the pre-test survey, the test team will plan, conduct, monitor, collect, and subsequently analyze the post-test survey data,

The survey will be conducted after the test participants have been escorted back to the Courtyard Marriot conference room. The survey will include questions about user-friendliness, impact on user confidence, useful features, training session effectiveness, and areas for improvement. The post-survey questions are listed below. The post-survey questions are listed below. Participants will be given the option of completing this survey via interview or via written response.

The goals and general construct of the Post-Test Survey is provided below, and a prototype of the form that will be used is provided in Appendix B.

1. Determine which features of the *PedPal* mobile app the participant found to be the most useful or promising. There will be a request to be specific, and the extent feasible, detailed and comprehensive.

2. For those participants who tested the *PedPal* mobile app at a previous session, determine what changes were most notable to them during this test session, and if they found those changes useful. There will be a request to be specific, and the extent feasible, detailed and comprehensive.

3. Determine the level on a scale of 1 (least) to 5 (most) at which the participant rates the user-friendliness of the *PedPal* mobile app interface.

4. Determine the extent that the test participant felt that solutions such as the *PedPal* mobile app could increase safety and confidence when independently crossing an intersection. There will be a request to be specific, and the extent feasible, detailed and comprehensive.

5. Determine the level on a scale of 1 (least) to 5 (most) at which the participant rates the ability of the *PedPal* mobile app to increase their safety when traveling independently.

6. Determine the level on a scale of 1 (least) to 5 (most) at which the participant rates the ability of the *PedPal* mobile app to increase their confidence when traveling independently.

7. Determine the level on a scale of 1 (least) to 5 (most) at which the participant rates the ability of the *PedPal* mobile app to increase their efficiency when traveling independently.

8. Determine what enhancements, if any, the test participant might suggest for improving the *PedPal* mobile app. There will be a request to be specific, and the extent feasible, detailed and comprehensive.

9. Determine whether the test participant's has interest in learning about future versions of this technology.

10. Determine if there is anything else, in general, the participant would like to relate about their experience during this project.

The data collected from the survey responses will be used to develop summary statistics to assess the reliability and performance of the system from the participant's perspective. The statistics will help the project team assess how many participants perceived the *PedPal* mobile appl to be useful when crossing the intersection, what components or features need to be improved, what features could be added to improve user experience, and how these factors differ by age, gender, type of disability, etc. This statistical information will also be used to derive conclusions on participant's perception of adequate green time required to cross intersection as well as the reliability of the system.

3.5.8 Data Download and Labeling

At the conclusion of each participant's test activities, a Researcher will transfer and label the phone data log files, as well as the video recordings of the test session to permanent storage. The Researcher will also ensure that all written surveys and written observation notes are collected for subsequent electronic scanning. All data is to be stored in a private hard drive and stored in the project PI's office, in accordance with IRB approved privacy procedures.

3.6 Data Collection Methodology

3.6.1 Observational Data

A primary source of test data will be the written observational data and notes that will be recorded by the *Observer* (see Section 3.3.3). At the outset of each user test, basic test environmental conditions will be recorded, including weather conditions (sunny, cloudy, raining, etc.), traffic conditions (time of day, free flow, congested, etc.) and assistive crossing tools (guide dog, white cane, walker, wheelchair, etc.). Then, for each crossing loop around the intersection undertaken by the participant (both with and without the app), the following basic set of data will be recorded:

- Direction of each cross
- Start time of each cross
- End time of each cross
- Number of green cycles missed before making the next cross
- Whether or not the app was being used
- Level of observed confusion (1 to 5)
- Level of observed fatigue (1 to 5)
- Level of observed frustration (1 to 5)
- Number of safety interventions
- Other notable events that were observed.

The information sheet developed to facilitate this data collection is shown Appendix C.

3.6.2 Video Recordings

A secondary source of test data will be the video-recordings of the street crossings will be captured by the *Videographer*, for those participants that give videotaping consent. This will serve as a backup for verifying various aspects of the written observational data to be collected by the *Observer*.

3.6.3 Phone Data Logs

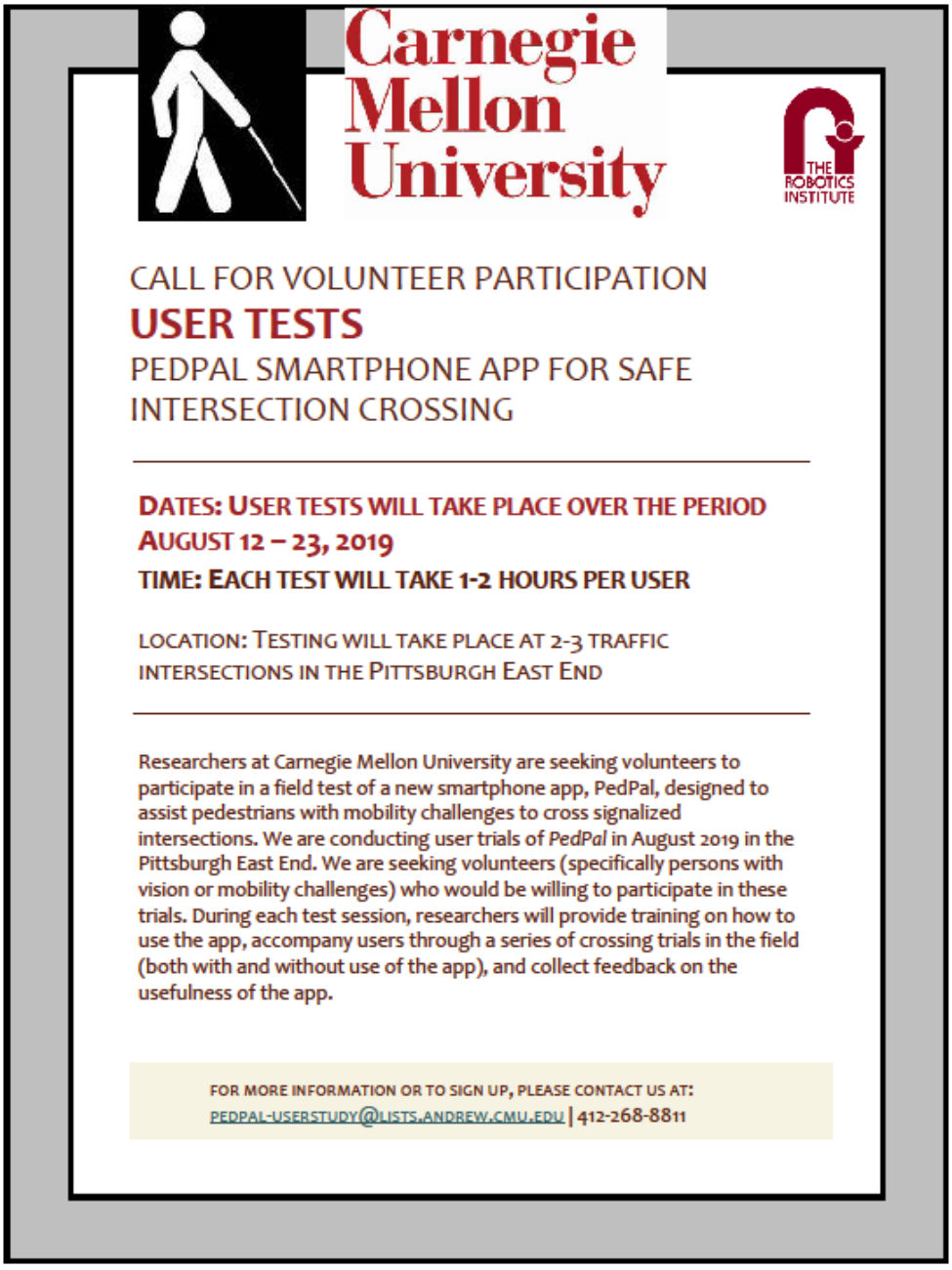
Finally, for each participant's crossing, phone data log files will be collected and stored to supplement the observation log files. This will provide the test evaluators a more detailed understanding of the app-to-infrastructure communication behavior, the efficacy of the *PedPal* mobile app's user interface, and the overall performance of *PedPal* mobile app. A JSON data logging structure has been developed to record the following event information:

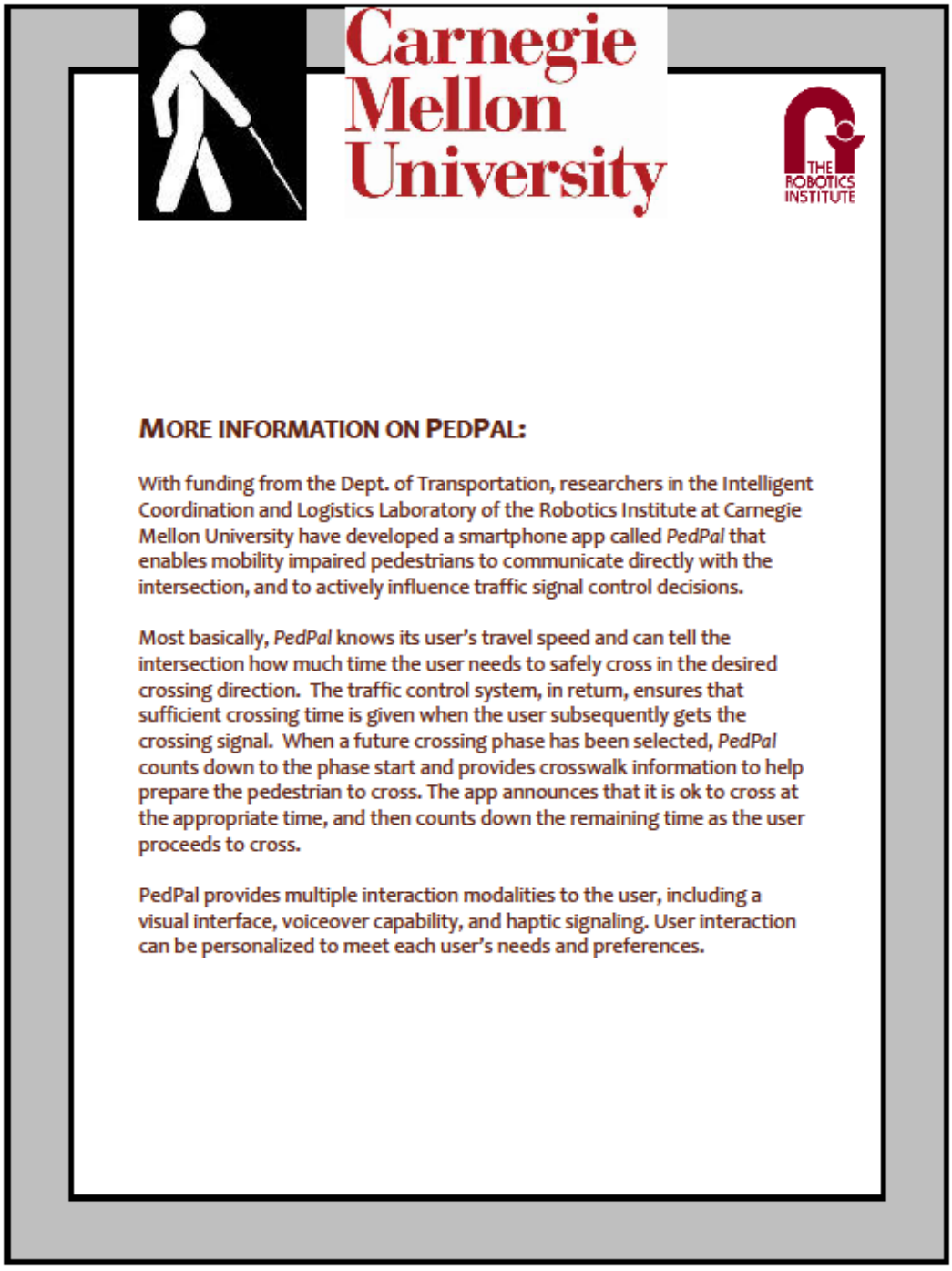
- The receipt of every MAP message, SPaT message, and Signal Status Message (SSM) by *PedPal* mobile app, including the time received, the message ID, and other relevant content information (i.e., the time-remaining value from SPaT messages, the status value for SSMs)
- The transmission of every SRM sent by the *PedPal* mobile app to the intersection, including the time sent, the message ID, and the crossing duration requested.
- Location readings at predefined time intervals
- Simulated localization readings[1]

The capture of transmission and receipt of messages provides a basis for assessing the performance characteristics of the *PedPal* mobile app, including round-trip times for crossing requests, levels of dropped messages, etc.

[1] Actual localization values needed by the mobile app during the field tests will be provided manually via a live remote connection to the iPhone8 devices. This workaround is in place to compensate for the lack of adequate localization accuracy provided by the iPhone 8. Our plan for overcoming this shortcoming is to utilize top-tier Bluetooth beacons at the intersection to sufficiently boost localization accuracy. However, due to problems in the shipping of the identified beacons (which are manufactured in Prague and are currently lost in transit), it is now clear that they will not arrive in time to adequately test and install. Hence our manual simulation approach to providing this capability for the field test. Test participants will be informed of this situation prior to the start of field testing. We will now plan to test the Beacon solution independently in September 2019.

Appendix A Recruitment Flyer




Carnegie
Mellon
University
THE
ROBOTICS
INSTITUTE
MORE INFORMATION ON PEDPAL:
With funding from the Dept. of Transportation, researchers in the Intelligent Coordination and Logistics Laboratory of the Robotics Institute at Carnegie Mellon University have developed a smartphone app called PedPal that enables mobility impaired pedestrians to communicate directly with the intersection, and to actively influence traffic signal control decisions.
Most basically, PedPal knows its user's travel speed and can tell the intersection how much time the user needs to safely cross in the desired crossing direction. The traffic control system, in return, ensures that sufficient crossing time is given when the user subsequently gets the crossing signal. When a future crossing phase has been selected, PedPal counts down to the phase start and provides crosswalk information to help prepare the pedestrian to cross. The app announces that it is ok to cross at the appropriate time, and then counts down the remaining time as the user proceeds to cross.
PedPal provides multiple interaction modalities to the user, including a visual interface, voiceover capability, and haptic signaling. User interaction can be personalized to meet each user's needs and preferences.

Appendix B Pre-Test Survey Form

PedPal User Study: Pre-Test Survey

Prior to carrying out the user test, we would like to learn more about you and your preferences, habits, strategies and experiences when traveling around the city. We appreciate your time and effort answering the following questions.

1. Did you participate in the previous user testing for the *PedPal* mobile app?
   - ○ Yes
   - ○ No

2. If you participated in previous user testing for the *PedPal* mobile app, what are your recollections about the experience of using *PedPal*?

3. What tools, if any, do you use for guidance when traveling? Please select all that apply.
   - ○ Guide dog
   - ○ Cane
   - ○ Walker
   - ○ Wheelchair
     - ○ Motorized
     - ○ Manual
   - ○ Other (please list all tools you use)

   Optional comments on your tool use:

4. What technology if any do you use to assist you with travel? Please select all that apply.
    - ○ GPS
    - ○ Smartphone
    - ○ Google maps
    - ○ Other (please list all tools you use)

    Optional comments on your technology assistance:

5. How would you rate your proficiency at using smartphones on a scale of 1 to 5 where 5 is highly proficient (expert) and 1 is not at all proficient (novice)?

6. Do you use voiceover features on a smartphone? If yes, how many years have you been using voiceover technology?

7. If you use voiceover technology, how would you rate your proficiency at using voiceover features on smartphones on a scale of 1 to 5 where 5 is highly proficient (expert) and 1 is not at all proficient (novice)?

8. How often do you cross the road independently? Please select the one answer that best describes your regular habits.
    - ○ Daily
    - ○ A couple of times a week
    - ○ Once a week
    - ○ Once every few weeks
    - ○ Rarely
    - ○ Never

    Optional comments on your independent road crossings:

9. What challenges, if any, do you face when crossing traffic intersections?

10. What features/characteristics do you think are important in a smartphone app that assists you to cross the street?

11. Demographic information:

Gender

- ○ Male
- ○ Female
- ○ Other (please specify)
- ○ Prefer not to answer

Age Range

- ○ Below 18
- ○ 18-25
- ○ 26-45
- ○ 46-65
- ○ Above 65
- ○ Prefer not to answer

Do you identify as part of any of the following ATTRI (Accessible Transportation Technology Research Initiative by the U.S. Department of Transportation) target populations? Please select all that apply.

- ○ Persons with disabilities
- ○ Veterans with disabilities
- ○ Older adults
- ○ Prefer not to answer

Do you consider yourself a person with any of the following disabilities targeted by ATTRI (Accessible Transportation Technology Research Initiative by the U.S. Department of Transportation)? Please select all that apply.

- ○ Vision
- ○ Mobility
- ○ Hearing
- ○ Cognitive
- ○ Prefer not to answer

Ethnicity

- ○ Please list all ethnic groups with which you identify

- ○ Prefer not to answer

Please provide any optional comments about your demographic information

12. Please provide any optional comments on anything further you wish to tell us?

Appendix C Post-Test Survey Form

PedPal User Study: Post-Test Survey

Now that you've tried out the *PedPal* intersection crossing app, we are interested to get your impressions of its potential usefulness if it were to be further developed into a publicly available product, and also any suggestions and thoughts you might have about how the mobile app could be improved.

1. What features of the *PedPal* solution did you find the most promising or helpful? Please explain your answer and provide as much detail as possible.

2. If you evaluated the *PedPal* mobile app during a previous test session, what changes were most notable to you in this test session? Do you find these changes useful? Please elaborate as much as possible.

3. How would you rate the user-friendliness of the *PedPal* mobile app interface on a scale of 1 to 5 with 1 being extremely difficult to use, and 5 being highly user friendly?

4. How would you rate the likelihood of *PedPal* to increase your safety when traveling independently? Please use a scale of 1 to 5 where 1 is highly unlikely, and 5 is highly likely.

5. How would you rate the likelihood of *PedPal* to increase your confidence when traveling independently? Please use a scale of 1 to 5 where 1 is highly unlikely, and 5 is highly likely.

6. How would you rate the likelihood of *PedPal* to increase your efficiency when traveling independently? Please use a scale of 1 to 5 where 1 is highly unlikely, and 5 is highly likely.

7. What enhancements would you suggest for *PedPal*?

8. Would you be interested in testing future versions of this technology?
   - ○ Yes
   - ○ No

9. Is there anything else you would like to tell us about your experience during this test or about this project in general?

Appendix D Data Collection Sheet

ATTRI *PedPal* Crossing Test Information Sheet

Participant #:	**Date:**
Arrival Time:	**Departure Time:**
Weather Condition: ☐ Sunny ☐ Cloudy ☐ Rainy ☐ Other, specify	**Traffic Condition:** ☐ Rush hour traffic ☐ Free flow ☐ Accident ☐ Congested ☐ Other, Specify
Assistive Crossing Tools: ☐ Guide dog ☐ Cane ☐ Walker ☐ Wheelchair ☐ Other, specify ☐ None	

Simulation Trial #:	
Simulation Trial Start:	**Simulation Trial End:**

Test Notes

1 How many times does the user need assistance?
☐ None ☐ 1 ☐ 2 ☐ 3 ☐ Other, specify

2 What types of assistance does the user need?

3 What questions does the user ask?

4 How many and what mistakes does the user make?
☐ None ☐ 1 ☐ 2 ☐ 3 ☐ Other, specify

5 What is the % completion rate of assignments by the user?
☐ None ☐ 20% ☐ 50% ☐ 100% ☐ Other, specify

6 What is the observed frustration level of the user when completing the assignments?
(on a scale of 1-5, 1: no frustration, and 5: completely frustrated)
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

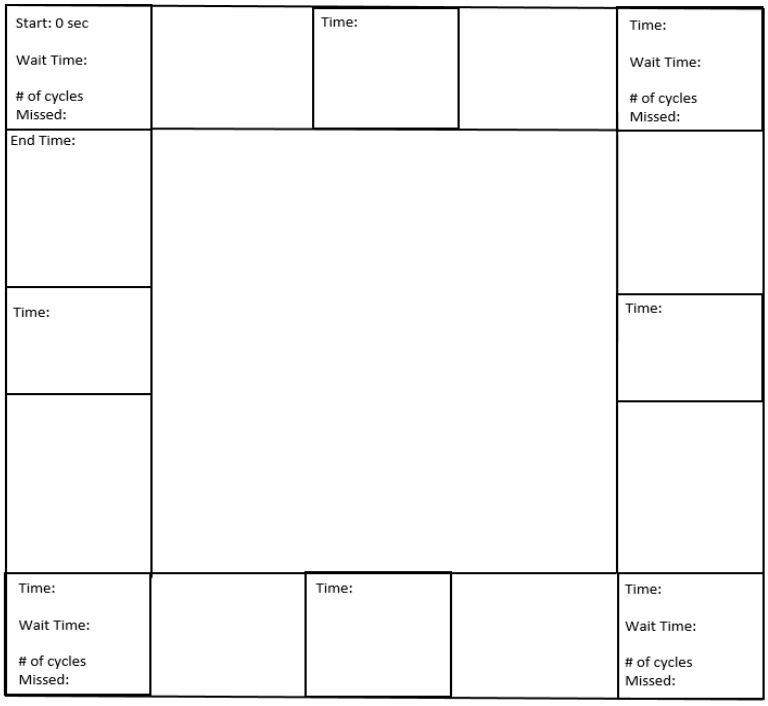
7 Observed confusion (on a scale of 1-5, 1: no confusion, and 5: completely confused)
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

8 Observed fatigue (on a scale of 1-5, 1: no fatigue, and 5: completely fatigued)
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

9 Did the user agree to do the road test?
☐ Yes ☐ No

10 Any other relevant observations?

Crossing Trial #:	**App Usage:** ☐ No App ☐ Using App
Start Time:	**End Time:**



Notes:

1. Observed confusion (on a scale of 1-5, 1: no confusion, and 5: completely confused)
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
2. Observed fatigue (on a scale of 1-5, 1: no fatigue, and 5: completely fatigued)
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
3. Observed frustration (on a scale of 1-5, 1: no frustration, and 5: completely frustrated)
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
4. Number of safety interventions by safety personnel:
   ☐ None ☐ 1 ☐ 2 ☐ 3 ☐ Other, specify
5. Number of green phases missed before pedestrian crosses:
   ☐ None ☐ 1 ☐ 2 ☐ 3 ☐ Other, specify

6. Other Observations

U.S. Department of Transportation
ITS Joint Program Office – HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free “Help Line” 866-367-7487

www.its.dot.gov

FHWA-JPO-19-753

U.S. Department of Transportation