RESEARCH

UDOT Keeping Utah Moving

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4501 South 2700 West - P.O. Box 148410 - SLC,UT 84114-8410

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DEVELOPING THE CONCEPT OF OPERATIONS FOR A MOBILE APPLICATION TO INTERFACE WITH A CENTRAL TRAFFIC SIGNAL SYSTEM

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16. Abstract

This report summarizes tasks performed toward the development of a Concept of Operations (ConOps) for a mobile/smartphone application designed to assist pedestrians with disabilities when crossing the street at signalized intersections. This app, if developed and rolled out, will interact 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). This report also discussed the phased approach in the development and release of the app. Along with the features to be included in the initial release of the app, the ConOps also documented what possible future versions of the app will incorporate to improve crossing efficiency and general mobility.

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TABLE OF CONTENTS

LIST OF TABLES ... vi
LIST OF FIGURES ... vii
LIST OF ACRONYMS ... viii
EXECUTIVE SUMMARY ... 1
1.0 INTRODUCTION ... 2
1.1 Problem Statement ... 2
1.2 Objective and Scope ... 3
1.3 Outline of Report ... 3
2.0 RESEARCH METHODS ... 5
2.1 Overview ... 5
2.2 Concept of Operations ... 5
2.3 Current State of Practice (Mobile Applications) ... 7
2.4 Stakeholders and User Needs for Mobile App ... 9
2.5 System Requirements ... 11
2.5.1 Advanced Traffic Management System ... 11
2.5.2 Existing Mobile Apps ... 12
2.6 Summary ... 15
3.0 CON/OPS DEVELOPMENT PLAN ... 16
3.1 Overview ... 16
3.2 Methodology ... 16
3.2.1 Develop Core Steering Committee ... 16
3.2.2 Identify Stakeholders ... 17
3.2.3 Hold Initial Stakeholder Meetings ... 17
3.2.4 Segment and Prioritize Stakeholder Brainstorm Ideas ... 18
3.2.5 Hold Follow-Up Stakeholder Meetings ... 19
3.2.6 Develop Filtering Criteria and Consolidate Initial ConOps ... 19
3.2.7 Meet with Core Steering Committee ... 19
3.2.8 Hold Final Stakeholders Meeting ... 20
3.2.9 Finalize ConOps ... 20
3.3 Core Groups ... 20

3.4 Summary..23
4.0 RANKING METHODOLOGY..24
4.1 Overview..24
4.2 Phased Approach for App Development..24
4.3 Filtering Criteria..24
4.4 Ranking..25
4.5 Phasing and Filtering..27
4.6 Summary..31
5.0 RESULTS: THE CONCEPT OF OPERATIONS..32
5.1 Overview..32
5.2 User-Oriented Operational Description..32
5.2.1 Overview of the System..32
5.2.2 User Groups..35
5.3 Operational Needs..38
5.3.1 Justification for Development of an App..38
5.3.2 Description of Features..39
5.4 System Overview..42
5.4.1 App Architecture..44
5.4.2 Central Signal System..45
5.4.3 Server Communication..46
5.4.4 System Layers / Organizational Interfaces..47
5.5 Operational and Support Environments..48
5.5.1 Facilities..48
5.5.2 Equipment (Phase I)..48
5.5.3 Hardware..48
5.5.4 Software..49
5.5.5 Personnel..49
5.5.6 Legal Support..50
5.5.7 Operational Procedures..50
5.5.8 Support Necessary..50
5.5.9 Phasing..51

5.6 Operational Scenarios 51
5.6.1 Phase I Scenarios 52
5.6.2 Phase II Scenarios 55
5.6.3 Scenarios with Possible Additional Features 59
6.0 RISKS FOR APPLICATION DEVELOPMENT 61
6.1 Overview 61
6.2 Mobile App Risk Assessment 62
6.2.1 Business Case 63
6.2.2 Operational Development 65
6.3 Summary 67
7.0 CONCLUSION 68
7.1 Summary 68
REFERENCES 69
APPENDIX A: KICKOFF MEETING SUMMARY 71
APPENDIX B: INITIAL STAKEHOLDER MEETING SUMMARY: CUSTOMER STAKEHOLDERS 73
APPENDIX C: INITIAL STAKEHOLDER MEETING SUMMARY: OPERATORS STAKEHOLDERS 80
APPENDIX D: INITIAL STAKEHOLDER MEETING SUMMARY: MANAGERS STAKEHOLDERS 84
APPENDIX E: FOLLOW-UP STAKEHOLDER MEETING SUMMARY 95
APPENDIX F: MOBILE APP CONCEPT OF OPERATIONS RATINGS SURVEY SHEET 98

LIST OF TABLES

Table 3.1 Technical Advisory Committee Members and Responsibilities....................................21
Table 3.2 Stakeholder Groups and Subgroups..22
Table 3.3 UDOT Stakeholder Delegates for Customers, Operators, and Managers Groups.........22
Table 4.1 Example Ranking Spreadsheet for the Scope Section of ConOps................................26
Table 4.2 Critical Goals and Features of the App...26
Table 4.3 Phasing Results: Scope 27
Table 4.4 Phasing Results: User-Oriented Operations 28
Table 4.5 Phasing Results: Operational Needs – System Function 28
Table 4.6 Phasing Results: Operational Needs – Organization Needs 29
Table 4.7 Phasing Results: Operational Needs – Data 29
Table 4.8 Phasing Results: System Overview 30
Table 4.9 Phasing Results: Operational & Support Environments...30
Table 4.10 Phasing Results: Operational Scenarios 31

LIST OF FIGURES

Figure 2.1 The Systems Engineering “Vee” - Figure used in FHWA training courses..................6
Figure 2.2 MAPS System Diagram 14
Figure 5.1 Organization of User Groups...35
Figure 5.2 System Overview Diagram for an App Integrated with the Central Traffic System (High Level)...42
Figure 5.3 Key Components of System Overview 44
Figure 5.4 High-Level System Architecture of the Mobile Application 45
Figure 5.5 Internal and External Server Communication for the Mobile Application 46
Figure 5.6 Organizational Interfaces...47
Figure 6.1 Project Organization...62

LIST OF ACRONYMS

APS	Accessible Pedestrian Signal
ASC	Advanced System Controller
ATMS	Advanced Traffic Management System
ATSPM	Automated Traffic Signal Performance Measure
CAV	Connected Autonomous System
ConOps	Concept of Operations
DMS	Dynamic Messaging System
DOT	Department of Transportation
DTS	Division of Technology Services
FHWA	Federal Highway Administration
HTTP	Hypertext Transfer Protocol
IRIS	Intelligent Roadway Information System
ITS	Intelligent Transportation System
KITS	Kimley-Horn Integrated Transportation System
MAPS	Mobile Accessible Pedestrian Signals
MQTT	Message Queuing Telemetry Transport
TAC	Technical Advisory Committee
UDOT	Utah Department of Transportation

EXECUTIVE SUMMARY

The Utah Department of Transportation (UDOT) is intending to develop an open-source smartphone application that integrates with the central signal system. With over 96% of the signals in Utah being connected to one central traffic management system there is an opportunity to connect each of the signals directly to the user through the smartphone devices they already own (81% of adult Americans have a smartphone). This application, when developed, will help place pedestrian calls on signals through a user's smartphone. Initially, the target audience will be pedestrians with additional needs i.e., pedestrians with mobility, visual or hearing impairments. In later phases of development, the app will be able to accommodate other modes of transportation as well. With the application being open-source, other jurisdictions outside of Utah utilizing the same traffic signal management system as UDOT will receive the same benefit to safety. In addition, others will be able to further enhance the app for improved safety and operations.

This document presents the method for developing the Concept of Operations (ConOps) for the potential mobile application. A Concept of Operations is a high-level description of what the major system capabilities will be, and it describes system characteristics for a proposed system from the user's viewpoint. The ConOps for the app was developed through an intense process of stakeholder engagement, and it will be the guiding document for subsequent planning activities in the initial release of the app. In general, the ConOps followed the template recommended by the Federal Highway Administration (FHWA) as per report number FHWA-HOP-07-001. The research report contains all the steps followed throughout the project including the formation of core groups and stakeholder groups and ranking of the ideas generated by the stakeholder groups. At the end, the report concludes with a qualitative risk assessment as a recommendation for next steps moving forward.

1.0 INTRODUCTION

1.1 Problem Statement

Accommodating pedestrians with extra needs has been a subject of concern in UDOT for some time. Pedestrians with mobility impairments can struggle to cross the street in the time that is given through signal timing. Visually impaired pedestrians have unique difficulties in their experience with crossing the street at intersections, from locating and pressing the pedestrian button to being able to identify when their crossing phase begins or where the appropriate crosswalk is located. Current methods for addressing these concerns can be costly and take years to rollout on a wide scale with the need to install audible warnings and other equipment at each intersection. With over 96% of the signals in Utah being connected to one central traffic management system, there is an opportunity to connect each of the signals directly to the user through the smartphone devices they already own (85% of adult Americans have a smartphone (Pew Research Center)).

While the initial motivation for the investigation of this opportunity is to provide much needed aid to pedestrians with extra needs, connecting the central traffic system with a mobile app creates additional opportunities for the everyday pedestrian or bicyclist. There is ample interest within UDOT that if an app can provide a safer crossing experience for visually impaired pedestrians, why stop there? Why not provide tools for pedestrians of all abilities, or even bicyclists? While the primary purpose of the development of such an app would be to address those with additional needs, an app available to all pedestrians can also provide a better intersection crossing experience without changing any physical equipment at the signals.

The development of such an app and its integration within the connected traffic signal is no small task. For that reason, Concept of Operations (ConOps) framework from the Federal Highway Administration (FHWA) was used to assess the feasibility of the proposed concept and to develop it into an actionable plan that can be assessed by technical personnel for application in the field.

1.2 Objective and Scope

The objective of this research was to create a ConOps for the development of a cellphone application to be integrated with the UDOT central signal system. The scope for the development of this app was established through meeting with UDOT representative stakeholders of several groups, customers, operators, and managers, and developing a plan for implementing a system that would meet the needs of each of these stakeholder groups. As part of this process, a ConOps, a development plan, a risk and feasibility assessment, and a literature review were developed as deliverables. The ConOps has identified:

- The purpose of the project.
- Who will use the system and what it will be used for.
- How and when the system will be used.
- In what environment, the system will be used.
- Who will maintain the system and how it will be maintained.
- The roles and responsibilities of the various parties using the system.
- How the effectiveness of the system will be measured.
- How the new system will impact stakeholder operations.

1.3 Outline of Report

The report is organized in the following sections:

- Chapter 1 includes the scope and primary objective of this research project.
- Chapter 2 reviews the literature on the structure of the ConOps document according to FHWA and reviews similar cell phone applications that are developed or are being developed.
- Chapter 3 discusses the detailed work plan for the final deliverable of the project, which is the ConOps for the cell phone app. This plan includes meetings with the Technical Advisory Committee (TAC) and the stakeholder groups, idea generation approaches, and a discussion on different core groups.
- Chapter 4 includes the ranking criteria used in prioritizing different features of the

cell phone app. A final table including all the features ranked based on priorities is also added here.

- Chapter 5 presents the ConOps document. It has been adapted to fit in this report and modified to avoid repeating large sections presented separately in the report.
- Chapter 6 discusses the risk assessment for future steps in the project.
- Chapter 7 summarizes the conclusions of the research.
- References and appendices follow the main chapters.

2.0 RESEARCH METHODS

2.1 Overview

The project involved a review of the methodology for the development of a ConOps, a review of similar systems involving the implementation of apps to aid pedestrians with disabilities, and advanced traffic management systems.

2.2 Concept of Operations

The Concept of Operations (ConOps) is meant to communicate, at the highest possible level, the needs and wants of the client, users, and other stakeholders for a system. It is a critical element in product development and the successful rollout of a new product. An Intelligent Transportation System (ITS) project development using Federal Highway Administration (FHWA) funding requires a systems engineering analysis per Title 23 CFR 940.11 ((FHWA), 2007) . The winged “V” (or “Vee”) model as shown in Figure 2.1 is frequently used by FHWA to represent the systems engineering process. Preparing a ConOps is the very first step of the “V” model.

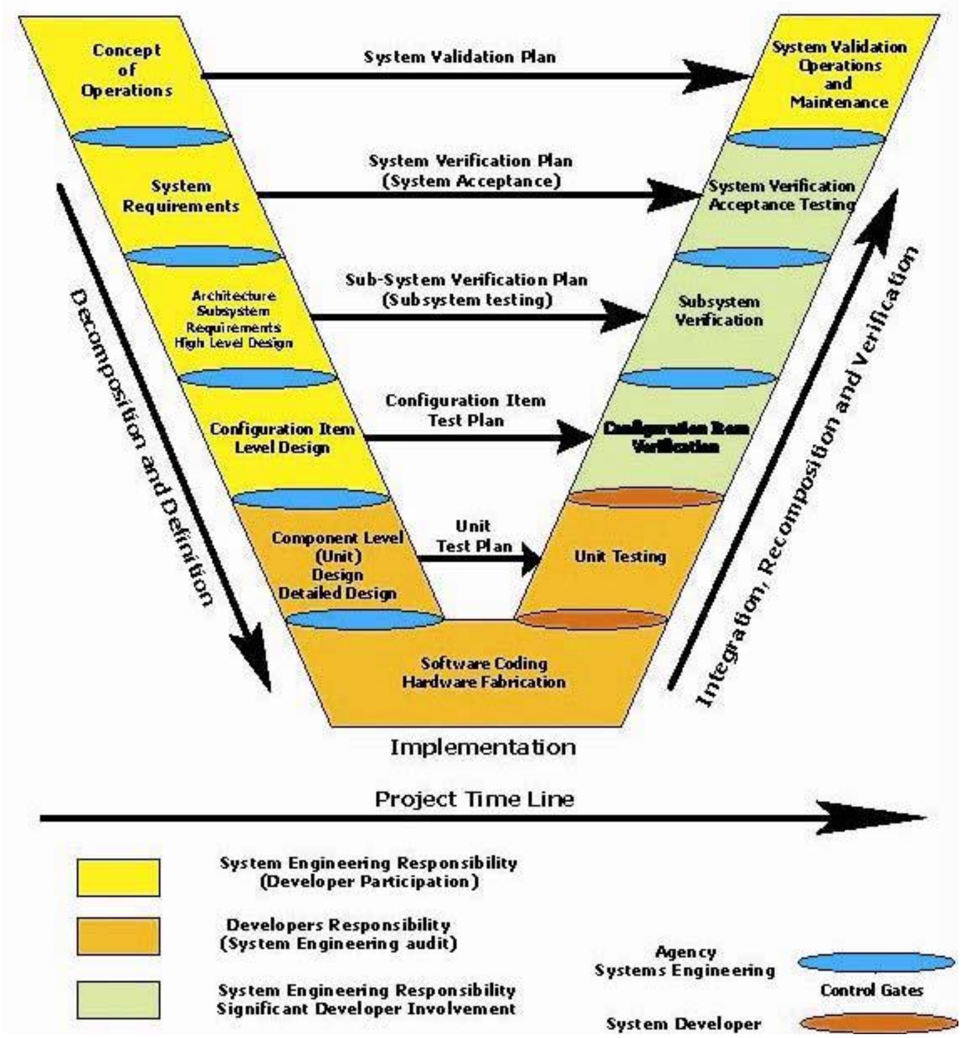

Figure 2.1 The Systems Engineering "Vee" - Figure used in FHWA training courses (Smith, 2005)

The primary motivations for a ConOps include the identification of system stakeholders, the assurance of a common communication forum, the formulation and documentation of a high-level system definition, and the definition of all major user groups and activities (Smith, 2005). To achieve this, a ConOps should include scope, references, user-oriented description, operational needs, system overview, operational and support environment, and operational scenarios. This source (Smith, 2005) also includes a sample outline to illustrate the construction of a ConOps, which includes the following:

1. Scope
2. Referenced Documents

3. User-Oriented Operational Description
4. Operational Needs
5. System Overview
6. Operational Environment and Support Environment
7. Operational Scenarios

Scope: Outlines the contents of the document, sets the scope of the system, describes the purpose of the system, highlights the goals and objectives for the system, identifies the intended audience of the system, and conveys a vision for the system.

Referenced Documents: Includes documents that will be beneficial in developing a ConOps, i.e., example ConOps documents, requirements documents, organizational studies and planning documents, and minutes from meetings concerning system development.

User-Oriented Operational Description: Explains the operations of all aspects of the system, including personnel activities, operational processes, user classes, and any other system interaction.

Operational Needs: Ties system function to organizational needs to align the goals and vision of the system with those of the organization.

System Overview: Summarizes the system in the most effective way.

Operational and Support Environments: Describes the world in which the system operates, and includes information about the facilities, equipment, and supporting staff the system needs to function.

Operational Scenarios: Uses a wide variety of user classes and system functionality to give the reader a more realistic view of the how the system will work.

2.3 Current State of Practice (Mobile Applications)

Developing a ConOps requires identifying prior similar research efforts and conducting a thorough review. There has already been work done to date on using mobile apps to facilitate individuals with disabilities at intersections. One such effort, the Mobile Accessible Pedestrian Signals (MAPS), is being spearheaded at the University of Minnesota in several phases (Liao, 2013; Liao, et al., 2011; Liao, 2014; Liao & Davis, 2020). Initial work focused on identifying stakeholders and learning what potential users with visual disabilities would need from a mobile pedestrian app (Liao, et al., 2011) and testing a prototype of the app by individuals with visual disabilities (Liao, 2013). The first implementation of the app was for special cases of navigation of visually impaired pedestrians through work zones (Liao, 2014), with recent implementation being a version of the app that pedestrians can use to request a pedestrian phase from the signal and receive real-time geometrics, signal timing, and phasing information in an accessible manner. The steps taken in the development and testing of this app included:

1. User Need Analysis
2. Development of Prototype App
3. App Development
4. Field Experiment

Overall, participants reported that the MAPS system, which has been connected to ASC3 (Advanced System Controller 3) intersections with SmartLink from Miovision, provided helpful geometry information (82%) and helpful signal information (59%).

Another similar effort, PedPal, is being developed at Carnegie Melon in connection with SURTRAC signals in Pittsburgh, Pennsylvania (Smith, et al., 2018; Smith, et al., 2019). This effort began with a ConOps that was intended to communicate the needs and wants of end users during early design stages to ensure that their needs and the rationale behind them were clearly understood. Feedback was solicited from those with visual impairment and mobility disabilities and other stakeholders to identify desired aspects of the system before the development of the app and the system. This project also included a Systems Requirements Traceability Matrix that listed the needs of each stakeholder.

Crosswatch, an app developed by Ivanchenko, Coughlan, and Shen (2009) at Smith-Kettlewell Eye Research Institute in San Francisco, uses computer vision software running on a mobile phone to aid visually impaired pedestrians in orienting themselves in a crosswalk. This is to ensure safe crossing within the intersection. With this system, the user takes an image of the intersection with a standard mobile camera phone, which is analyzed in real time by software run on the phone, and the output of the software is communicated to the user with synthesized speech or acoustic cues. The software uses a computer vision approach for acquiring information about one's surroundings that does not require any infrastructure beyond the smartphone and what is already provided for sighted people – namely, street signs, traffic lights, and painted street markings.

2.4 Stakeholders and User Needs for Mobile App

Identification of stakeholders and the needs of potential end users of the system is a critical component of the ConOps. Liao et al. (2011) revealed in their user needs analysis that many visually impaired persons use a cane to get around and thus preferred an experience that allowed them to keep one or both hands free to use the cane. They also identified that visually impaired persons identified that knowing when to cross the street was the most important piece of information a system could provide, with other important information being knowing the orientation of the crosswalk, knowing when they were reaching the opposite curb, and knowing where the signal-button was located. Liao (2013) later interviewed ten blind and low-vision participants ranging from ages 19 to 59 to gain a high-level understanding of the user needs and potential user interface issues with navigating and orienting. Interviews allowed the design team to begin designing the MAPS system description to meet the needs of visually impaired users, while future efforts will include actual usability testing. Participants were asked questions relating to six categories of dependent variables - vision background, navigation and mobility, questions pertaining to intersection crossing, technology self-ratings, proposed MAPS system description, and demographic information. Liao (2013) summarizes additional recommendations from these interviews: signal timing information should be provided, auditory messages should be brief and clear, tactile feedback should be used for warning, the push-button should be activated automatically or from a mobile device, and the support system should not interfere with the user's wayfinding ability. That work also found that half of anticipated users owned a smartphone, though the percentage has likely risen in recent years. Liao's surveys and field tests also revealed that users could take around 8 seconds to find Accessible Pedestrian Signal (APS) push-buttons and over 25 seconds to locate non-APS push-buttons, and that most would prefer to use a smartphone rather than locate the push-button. The app ultimately ended up providing users with feedback through text, text-to-speech, and icons (Liao and Davis, 2020). Users could interact with the app by using a single tap to prompt identification information about the crosswalk the user is currently facing, double tap to prompt signal state information for the crosswalk, or long press to prompt the user's current location.

Smith et al. (2019) worked with persons with both visual and mobility disabilities. They identified several organizations to assist them in creating a forum with the potential users of their systems, including blind and vision rehabilitation services, disability training experts, schools for the blind and deaf, and goodwill industries. Other organizations with ties to aiding those with visual or mobility disabilities were also consulted. The following desired changes and user needs were identified:

1. Interacting with the Traffic Signal Control System
2. Obtaining Real-Time Information about the Intersection
3. Assistance Crossing the Intersection
4. Locating and Recognizing the Intersection
5. Position and Orienting
6. Confirming
7. Customizable Assistance
8. Supporting Hands-Free Option
9. Interacting with Other Mobile Apps
10. Supporting Audio Communication
11. Integrating a Pre-Planned Itinerary
12. Incorporating Transit Arrivals

The ConOps was intended to communicate with the end user during early design stages to ensure that their needs and rationales were clearly understood. A total of 108 stakeholder requirements were identified in the Requirements Traceability Matrix (requirements for stakeholders), most of which were addressed by the system.

2.5 System Requirements

A review of systems requirements showed that an integrated management / control system is the prerequisite for the functionality of the mobile app. Additionally, a review was performed on existing traffic management systems that collect the necessary information.

2.5.1 Advanced Traffic Management System

Advanced traffic management system (ATMS) integrates technology primarily to improve the flow of vehicle traffic and improve safety. Some notable systems of integrated / advanced traffic management systems are: IRIS (Intelligent Roadway Information System), Georgia Navigator, SURTRAC, and Kimley-Horn Integrated Transportation System (KITS).

IRIS (Intelligent Roadway Information System) is an open-source Advanced Traffic Management System (ATMS) software project developed by the Minnesota Department of Transportation. It is used by transportation agencies to monitor and manage interstate and highway traffic. Agencies using IRIS are Minnesota Department of Transportation, California Department of Transportation, Nebraska Department of Transportation, Wyoming Department of Transportation, and the Wisconsin Department of Transportation (IRIS Homepage).

Georgia Navigator was originally conceived to address incident management, congestion management, and motorist assistance needs for the 1996 Olympic Games in Atlanta (Johnson & Thomas, 1999). Since its founding, the Navigator architecture has expanded to a statewide program providing traffic monitoring, traveler information, incident management, and traffic management services for travelers in the Atlanta metropolitan area and throughout the State of Georgia (Jeffrey & Luttrell, 2000). It is undergoing a large expansion program and currently includes traffic cameras, changeable message signs, ramp meters, and a traffic speed sensor system. Traffic signals are not yet part of the system.

Surtrac is an intelligent traffic signal control system developed by Rapid Flow Technologies which manages intersection control with the help of artificial intelligence and robotics. Surtrac's AI algorithms use data feeds from video, radar, or inductive loop detection systems to optimize the timing of traffic signals. The system is reported to yield an average of 20%+ delay improvement (Rapid Flow Technologies, 2021). Surtrac is designed to optimize for all modes of travel including pedestrians, bicycles, transit, connected travelers, and connected & autonomous vehicles (CAV).

Kimley-Horn Integrated Transportation System (KITS) is a Kimley-Horn-developed traffic management system used by Virgina DOT, City of Austin, and Los Angeles County among other agencies. Using arterial control functionality in conjunction with ITS analysis tools and devices, KITS provides support for signal and freeway devices as well as ITS functions (including transit signal priority, advanced signal timing analytics, decision support, and other communication protocols). The process for using KITS is similar to that of an advanced traffic management system: real-time traffic data flows into a centralized system where the data is integrated and processed. The information stored in the centralized system can send alerts to engineers or personnel monitoring the system, and actions can be taken within KITS to improve traffic flow, safety, and efficiency (Kimley-Horn). As an integrated system, KITS can perform the following (Kimley-Horn):

1. Assist in monitoring traffic through the use of CCTV cameras, dynamic maps, equipment monitoring, and other displays.
2. Identify unusual activity in the system including congestion, detector issues, roadway incidents, and abnormal phase timing.
3. Send user-customizable alerts and reports.
4. Aid in responding to traffic incidents, inclement weather, or other events through integrated CCTV and Dynamic Message Signs (DMS).
5. Set up ways to automatically initiate responses to specified conditions.
6. Allow the user to remotely control traffic devices and make changes off-site if needed.
7. Store and archive previous signal timing.
8. Provide additional signal timing resources including time-space diagrams, turning movement count analyses, performance metrics, and a Synchro interface.

2.5.2 Existing Mobile Apps

A review of existing similar mobile apps was performed to identify operational needs and system requirements. The MAPS app was intended to provide information in as close to real-time as possible (Liao and Davis, 2020). The original cabinet-side system in Stillwater, MN was planned to work with Hypertext Transfer Protocol (HTTP) to send information to the app. This technology was overloaded by the data requirements and suffered large latency issues, requiring the use of a more modern protocol that is more data-centric and mobile friendly than the document-centric and more commonly used HTTP. To combat this, the creators utilized Message Queuing Telemetry Transport (MQTT) to transmit information with latencies between 0.33 seconds and 1.3 seconds, with an average of 0.88 seconds and a standard deviation of 0.38 seconds, down from around 3 seconds with HTTP. The app uses information received from the traffic signal via MQTT to determine when the "walk" or "don't walk" signs are displayed for the crosswalk the phone is facing. Information regarding intersection geometry and signal phasing was correctly relayed to pedestrians 96% of the time, with the incorrect instances resulting from faulty orientation information from the user's phone, which could be distorted when in proximity with large metal objects. The creators of this system determined that the location data from the smartphone itself was considered too faulty and unreliable, and consequently added Bluetooth beacons at intersections to be used when the GPS signal is poor. The system was implemented at four signalized intersections (with ASC3 controllers) and two unsignalized intersections. Additional hardware was required at each cabinet to allow the signal information to be broadcast locally in real-time. SmartLink from Miovision data collection systems was the choice for deployment. A GUI was used to test and debug signal information transfer. The debugging GUI shows crosswalks superimposed on a satellite view to help system controllers monitor at a system level. The app was developed with the following features:

1. Wireless communication with a traffic controller and communicating real-time signal phasing and timing information as requested by the user
2. Broadcasting through Text-to-Speech warning signals such as 'Do not walk' or 'Walk phase is on, X sec left'
3. Transmission of a pedestrian call to the signal controller for registered blind, visually impaired, elderly, or disabled pedestrians when they confirm the desired direction of crossing.

The MAPS application integrates digital compass, GPS, Wi-Fi, and Text to Speech (TTS) interface to identify user location and to obtain signal information. The system diagram of MAPS data communication is illustrated in Figure 2.2.

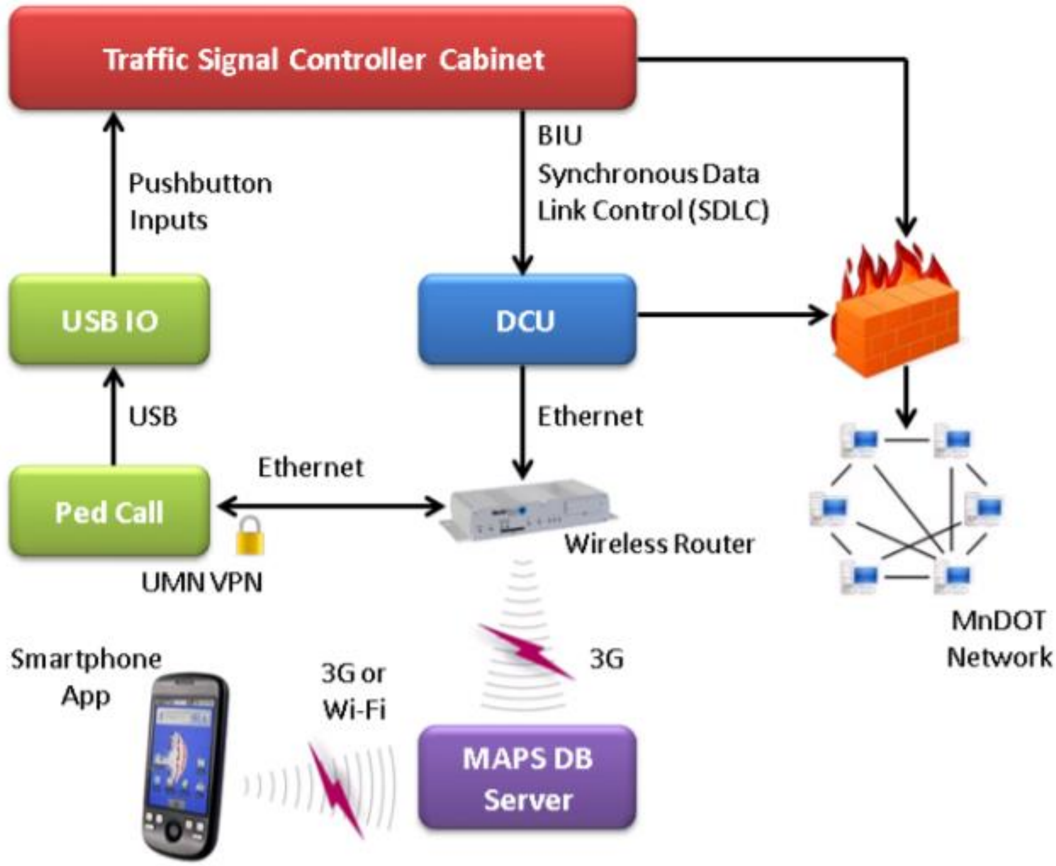

Figure 2.2 MAPS System Diagram (Liao, 2012)

Field tests were conducted to validate the use and functioning of the MAPS system in real-world situations. To serve this purpose, 2 intersections were identified, and 18 visually impaired participants were invited to participate. Participants were given a brief tutorial on how to use the smartphone app and then were asked to perform crossing tasks at the selected intersections. The researchers observed that the 15 minutes spent training on use of the app was likely not sufficient. They also noted a common issue with the app getting confused with direction if the user brought the phone closer to the ear for better listening and that some participants experienced incorrect information because the GPS receiver on the phone was not able to identify the user's correct location.

The PedPal app (Smith et al., 2018) was developed to tie into cabinets in the Pittsburgh, Pennsylvania SURTRAC real-time traffic signal system using dedicated short-range communication (DSRC) and 3G/4G. The app received signal and geometric data that it used to present crossing options and timing information. The app could also send a crossing request with a personalized crossing duration to the signal. Bluetooth beacons were positioned at each intersection to aid in corner identification and to detect when users start and complete a crossing. Testing of the system revealed technical issues resulting 5% of the time, with safety interventions being necessary 11% of the time, most commonly due to pedestrians veering outside of the crosswalk.

2.6 Summary

A literature review was conducted in preparation for the development of the Concept of Operations for the implementation of a mobile app integrated with the connected signal network in Utah. The review outlined the details behind a ConOps and the FHWA requirements including the required sections and the purpose of the ConOps. Existing similar systems were investigated, namely MAPS, developed by the University of Minnesota; PedPal, developed by Carnegie Melon; and Crosswatch, developed by Smith-Kettlewell Eye Research Institute in San Francisco. Each of these systems were primarily designed to provide pedestrians with visual / mobility impairments with additional tools for navigating the transportation system. The MAPS and PedPal systems required additional hardware at intersections to provide the high-resolution GPS data required for the apps to properly identify a user’s location and orientation, while Crosswatch relied on the phone’s camera to identify the location of the crosswalk. Both the MAPS and PedPal systems were considered successful and provided correct real-time data to the user roughly 95% of the time.

3.0 CONOPS DEVELOPMENT PLAN

3.1 Overview

This section documents the methodology followed to develop the ConOps for the mobile application. Throughout the development of the final deliverable of the project, this plan was used as a guideline and a reference document for the research team. Along with outlining the methodology, this chapter specifies the core groups that contributed to the generation of ideas for the final ConOps.

3.2 Methodology

One of the first steps for developing the ConOps was a review of FHWA resources for developing a ConOps along with similar existing systems such as MAPS and PedPal. The information from this review was summarized in Chapter 2.

The ConOps itself was developed through a multiple step process, outlined as follows:

1. Develop Core Steering Committee for the purposes of this research, primarily the Technical Advisory Committee (TAC)
2. Identify stakeholder groups / participants
3. Hold initial stakeholder meetings
4. Segment and prioritize resulting brainstormed ideas into ConOps sections
5. Hold follow-up stakeholder meetings
6. Develop filtering criteria and consolidate initial ConOps
7. Meet with Core Steering Committee
8. Hold final stakeholder meetings
9. Finalize ConOps

3.2.1 Develop Core Steering Committee

The Core Steering Committee was composed of representatives from departments throughout UDOT that are invested in the concept, who were also members of the Technical Advisory Committee (TAC) for the project. The responsibilities of the Core Steering Committee included reviewing the initial ConOps, reviewing the filtering of brainstorming ideas, and setting priority levels for each item in the ConOps. The Core Steering Committee was the group that reviewed the final products of the research and ConOps stage and decided whether to progress the concept through to the next stages.

3.2.2 Identify Stakeholders

The ConOps was initially developed by gathering ideas from the meetings with stakeholders. Stakeholders were identified based on the broad groups of people that would be affected by the proposed concept of a mobile app integrated with ATSPM (Automated Traffic Signal Performance Measure). With input and extensive participation from the UDOT TAC members and stakeholders from this preliminary list, the stakeholders list was expanded or adjusted as necessary. The primary role of each stakeholder was to participate in the various stakeholder meetings and provide input and ideas as the ConOps was being written by the research team. Each stakeholder was not necessarily intended to represent all possible interested parties at this point in the process, but rather to be a delegate to interested parties and represent their needs and wants, and to provide any basis for input from these parties. It should be noted that inclusion as a Stakeholder Delegate was voluntary, and the members were asked whether they were comfortable with their final assignments or not. As the process continued, the stakeholders' involvement and responsibilities were documented by the research team, and additional input or responsibilities of stakeholders were documented with a plan for promoting their involvement. These stakeholder groups were involved in various other stages in development of the app; the time and manner of involvement for each stakeholder are included in the ConOps.

3.2.3 Hold Initial Stakeholder Meetings

The primary purpose of the initial meeting with stakeholders was to explain the goals of the proposed concept and brainstorm initial ideas, namely:

- Who are the stakeholders involved with the system?
- What does each organization lack that the system will provide?
- What are the known elements and the high-level capabilities of the system?

- What is the time-sequence of activities that will be performed?
- What are the geographical and physical locations of the system?
- What resources are needed to design and build the system?

Although the preferred method for holding these meetings was in-person meetings with several stakeholders at a time, due to COVID-19 protocols over the course of this research these meetings were held virtually. The research team led these meetings by developing a primer presentation outlining the state of the concept to that point, including the desired outcomes and any preliminary ideas for development and implementation. Following the primer, stakeholders were asked to provide input and brainstorm potential responses to the above-mentioned questions. The research team organized these ideas into their appropriate sections within the ConOps after the meetings.

3.2.4 Segment and Prioritize Stakeholder Brainstorm Ideas

Input from the stakeholder meetings was initially segmented and prioritized by the research team following the stakeholder meetings. At this point, the input was segmented into the same categories as the sections within the ConOps, essentially creating an initial ConOps. Within each of these sections, ideas and concepts were further classified and prioritized, such as items that are "needs", "wants", or "nice to haves". The ideas were categorized/prioritized in the form of a cloud-based spreadsheet so as to receive maximum feedback and interaction from the follow-up meetings. The sections of the ConOps are the same as described in Section 2.2:

1. Scope
2. Referenced Documents
3. User-Oriented Operational Description
4. Operational Needs
5. System Overview
6. Operational Environment and Support Environment
7. Operational Scenarios

3.2.5 Hold Follow-Up Stakeholder Meetings

The second round of stakeholder meetings picked up where the first round left off. After segmentation of the initial brainstorm ideas and prioritizing the wish list items, follow-up meetings were held with the same stakeholder groups and the priority list in the cloud-based spreadsheet was presented to review current ideas, refine ideas, and develop new ideas. The discussions with the stakeholders were guided by the following basic questions:

- Which current ideas do you find most important?
- How could these ideas be implemented?
- What concerns do you have with these concepts?
- What additional ideas do you have?

3.2.6 Develop Filtering Criteria and Consolidate Initial ConOps

In this step, the filtering criteria was developed, providing recommendations on filtering ideas from the brainstorming phase into further iterations of the initial ConOps and listing options for selection. The filtering criteria were based on the following general concepts:

- Feasibility
- Importance
- Implementation
- Complexity

These concepts were used when reviewing stakeholders' comments to develop final criteria. These criteria were reviewed and approved by the Core Steering Committee and are documented later in Chapter 4 of this report.

3.2.7 Meet with Core Steering Committee

The filtered results from brainstorming with stakeholders were presented to the Core Steering Committee. The purpose of this meeting was to go over all recommendations gathered up to this point and to establish levels for each possible idea. The Core Steering Committee provided feedback on the filtering process and provided further guidance on the inclusion and priority of ideas within the ConOps. At this stage, the draft ConOps was consolidated based on ideas generated in the stakeholder meetings and prioritization of ideas.

3.2.8 Hold Final Stakeholders Meeting

After the meeting with the Core Steering Committee, finalized ideas for the ConOps and priority list were presented to the stakeholders to be reviewed. Through this second round of brainstorming session, stakeholders had a chance to provide feedback and recommendations, and the research team informed the stakeholders of their responsibilities for further steps. This meeting was used to close the feedback loop by providing stakeholders with a clear understanding of how the various ideas were ranked, filtered, and augmented as part of the draft ConOps. Stakeholder engagement summaries, as well as meeting minutes and survey results, are provided in the following appendices.

- Appendix A: Summary of kickoff meeting.
- Appendix B: Initial stakeholder meeting summary.
- Appendix C: Initial stakeholder meeting summary: Customer Stakeholders.
- Appendix D: Initial stakeholder meeting summary: Operator Stakeholders.
- Appendix E: Initial stakeholder meeting summary: Manager Stakeholders.

3.2.9 Finalize ConOps

After the stakeholder meetings and Core Steering Committee meetings, the research team concentrated on finalizing the ConOps. This involved combining all feedback received in prior steps and responding to any remaining recommendations or requests. At the end of this step, the research team submitted the initial ConOps to the Core Steering Committee for review. The final version of the ConOps after the Core Steering Committee’s review and approval is added in Appendix F: Final ConOps.

3.3 Core Groups

The ConOps was primarily developed by contributions from three core groups:

1. The Technical Advisory Committee, led by Glenn Blackwelder and Mark Taylor from UDOT, was responsible for aiding the research team and providing the overall vision of UDOT. The Core Steering Committee, which was largely made up of TAC members, also supported the research team. Members of the TAC and their responsibilities are listed in Table 3.1.

Table 3.1 Technical Advisory Committee Members and Responsibilities

Team Member	Position	Responsibility in TAC
Glenn Blackwelder	Traffic Operations Engineer, UDOT	Co-Chair
Mark Taylor	Traffic Signal Operations Engineer, UDOT	Co-Chair
Bob Chamberlin	UDOT Project Manager (Consultant)	Project Manager
Rudy Zamora	Division of Technology Services (DTS) IT Manager	Member
Michael Blanchette	Statewide Signal Engineer, UDOT	Member
Stephanie Tomlin	Transportation Planner, UDOT	Member
Travis Evans	Active Transportation Safety Program Manager, UDOT	Member
Trevor Egan	Traffic Design Engineer, UDOT Central Traffic and Safety (ADA)	Member
Christopher Siavrakas	Project Manager, Intelligent Transportation Systems, UDOT	Member

2. The research team from Avenue Consultants was primarily responsible for creating the ConOps. During the process, the team prepared a development plan, conducted literature review, prepared a list of stakeholders, held initial and follow-up meetings with the TAC and stakeholder groups, and prepared deliverables. This team was led by David Bassett and assisted by Nuzhat Azra, Camille Lunt, Shawn Larson, and Shaunna Burbidge.

3. Stakeholder Groups, whose primary role was participating in various stakeholder meetings and providing input and ideas as the ConOps was created by the research team. The initial stakeholder groups and subgroups associated with the system/project are presented in Table 3.2.

Table 3.2 Stakeholder Groups and Subgroups

Stakeholder Group	Subgroup
Information Consumers	TOC ATSPM Data User Info
UDOT Customers	ADA (UDOT Needs) Traffic & Safety Planning (Active Transportation)
Maintenance	ATSPM Interface and Maintenance
Target Operators	Limited Mobility Active Transportation ADA (User Needs)
UDOT Operators	TOC (Signal Operations) Product Rollout Testers
UDOT	Legal (Privacy/Data) ADA Compliant (AG Office) TOC App Management DTS (Access)

For discussion purposes, these delegates were split into 3 groups: Customers, Operators, and Managers. The identified individuals are presented in Table 3.3.

Table 3.3 UDOT Stakeholder Delegates for Customers, Operators, and Managers Groups

Customers	Operators	Managers
Ivana Vladisavljevic, *UDOT Traffic & Safety*	Angelo Papastamos, *UDOT Planning and Travel Demand*	Rudy Zamora, *DTS*
Travis Evans, *UDOT Active Transportation Safety PM*	Heidi Goedhart, *UDOT Planning (Bike/Ped Safety)*	Jim Palmer *(AG Office, Legal)*
Trevor Egan, *UDOT Central Traffic and Safety (ADA)*	Trevor Egan, *UDOT Central Traffic and Safety (ADA)*	Shane Johnson, *Intelight*

Derek Lowe, *DTS* Michael Blanchette, *UDOT Statewide Signals* Stephanie Tomlin, *UDOT Planning and Travel Demand*		Tom Stiles, *Intelight* Derek Lowe, *DTS*

3.4 Summary

The steps mentioned in this chapter extended throughout the duration of the project (1 year). Ideas which later helped build the final ConOps were generated in the meetings and follow-up meetings held with the groups discussed in this chapter.

4.0 RANKING METHODOLOGY

4.1 Overview

The data evaluation in this research project takes the form of filtering and consolidation of the data (ideas and input from stakeholders) in preparation for the ConOps. The concepts of feasibility, importance, implementation, and complexity were used when reviewing comments from the stakeholders to develop the final criteria documented in this section. Through this process, the wide range of ideas received from the brainstorming phases were focused in on the ones with the most practical application for the proposed concept.

To gather ideas on different features, requirements, and limitations of a mobile app for the central system, three stakeholder groups were identified and consulted. After meeting with stakeholder groups and obtaining a list of desired features and concepts for the app, the research team divided the list into groups that corresponded to each section of the ConOps.

4.2 Phased Approach for App Development

If funded, the mobile app will be released in phases: the initial/first release and the multiple updates/phases of the app that will occur later. Since not all features from the list of stakeholder ideas can be added to the initial release, a filtering system was needed to see which features were more crucial to have in the app than others. The initial release will only include the primary features (the ones that are seen as non-negotiables for the app's success), while the not-included features will be released later with subsequent updates.

4.3 Filtering Criteria

After the initial stakeholder meeting, the ideas generated were presented to the same groups of stakeholders in a follow-up meeting. Based on the discussion of prevalent ideas as well as any new ideas for features, a cloud-based spreadsheet for ranking/filtering purposes was created. All ideas were put into separate rows under the associated ConOps section, and the names of the stakeholders were put in columns. The stakeholders were then asked to rank every item on a 1 to 5 scale based on how well they liked the feature and when the feature or concept should be implemented into the app. The scale went as follows:

1. Don’t like it, filter it out.
2. Not sure it fits.
3. Okay with it (whenever you want to put it in)
4. Like it, want it (Phase II)
5. Love it, have to have it (Phase I)

The survey sheet that was shared with the stakeholders through the cloud-based spreadsheet is attached in “Appendix F: Mobile App Concept of Operations Ratings Survey Sheet.”

4.4 Ranking

The ranking system allowed the stakeholders to focus more on what they thought about the features and concepts while still providing the critical information on phasing. Once the data was collected, the averages of the individual stakeholder’s rankings were taken as they filled out the spreadsheet. Table 4.1 shows the scope section of the spreadsheet that was used by the stakeholders to rank the different features and concepts. This example shows the individual rankings with the average score on the right.

The average score was used to filter and phase the individual features and concepts. The scoring system for phasing and filtering is as follows:

- Score of 4.5 to 5 – Phase I primary features
- Score of 3.5 to 4.5 – Phase II secondary features
- Score 2.5 to 3.5 – Possible additional features, no phasing currently
- Score of 1.5 to 2.5 – To be reevaluated after Phase II
- Score of less than 1.5 – Abandoned, but documented for record

Table 4.1 Example Ranking Spreadsheet for the Scope Section of ConOps

Scope	TAC Members								Average Score
	Glenn Blackwelder	Mark Taylor	Michael Blanchette	Travis Evans	Trevor Egan	Christopher Siavrakas	Ivana Vladisavljevic	Angelo Papastamos	
Make signal crossings more accessible and useable for pedestrians needing ADA assistance	5	5	5	5	5	5	5	5	5.0
Define what data is essential vs. optional for login	5	5	5	5	5	3	4	4	4.5
No additional equipment at the signals	5	5	5	3	2	3	3	2	3.5
Applied systemwide	5	5	5	5	5	5	5	5	5.0
Target fiber-connected signals (95% of Utah signals)	5	5	5	5	5	5	5	5	5.0
Aimed at helping those with disabilities (but can design it for others too)	5	5	5	5	5	5	5	5	5.0
Accommodate cyclists if possible	3	3	3	4	4	5	4	3	3.6

As expected, many of the features were unanimously given the rank of 5. Table 4.2 shows a sample of features with averages of 5. The table shows some of the critical goals and features that will make the application useful to both UDOT and users.

Table 4.2 Critical Goals and Features of the App

Concept	Section	Average Score
Make signal crossings more accessible and useable for pedestrians needing ADA assistance	Scope	5.0
Applied systemwide	Scope	5.0
Target fiber-connected signals (95% of Utah signals)	Scope	5.0
Aimed at helping those with disabilities (but can design it for others too)	Scope	5.0
High degree of accuracy in giving time to the direction the user is trying to cross	Operational Needs – System Function	5.0
User able to request more crossing time, to request green/walk extension, and/or have the system adapt to the user's walking speed and request the correct amount of time	Operational Needs – System Function	5.0
Central system (Maxview/Kinetics/Q-Free)	System Overview	5.0

Compatible with Android and iPhone	System Overview	5.0

4.5 Phasing and Filtering

The results of the ranking system are designed to decide what features in the app are critical to helping the target audience. It also tells us which concepts should be in the initial launch and which ones should be added in later phases. The inclusion of diverse perspectives and input of the stakeholders should help create a well-rounded app that will be created to help and be mindful of the community on multiple levels. The results of the Phasing and Filtering Stage of the ConOps is presented in **Error! Reference source not found.** through Table 4.10. The features are grouped by phase or category. It should be noted that no features scored low enough to be placed in an abandonment category. In the tables below, asterisks (*) note features that were moved to Phase I by default regardless of ranking results; these features are required for the app to function properly and within the goals of the system.

Table 4.3 Phasing Results: Scope

Scope	
Phase I	Make signal crossings more accessible and useable for pedestrians needing ADA assistance
	Define what data is essential vs. optional for login
	Applied systemwide
	No additional equipment at the signals*
	Target fiber-connected signals (95% of Utah signals)
	Aimed at helping those with disabilities (but can design it for others too)
Phase II	Accommodate cyclists if possible
Possible Features	N/A
To Be Reevaluated	N/A

Table 4.4 Phasing Results: User-Oriented Operations

User-Oriented Operations	
Phase I	Vibration and/or audio interactions to help the hearing/visually impaired
	Simple and large buttons
Phase II	Navigation feature / route options
	Phone accessibility modes able to interface with the app
	Ability to work as/with a navigation app
	Remove the requirement of pushing the ped button at a signal
Possible Features	Flashlight automatically turned on during dark hours while crossing
	Customizable mode profile for each person
	Customizable interface level (simple/complex)
	Workarounds for those who struggle to use apps/technology
To Be Reevaluated	Provide a special device for people without smartphones

Table 4.5 Phasing Results: Operational Needs – System Function

Operational Needs – System Function	
Phase I	User able to request more crossing time, to request green/walk extension, and/or have the system adapt to the user's walking speed and request the correct amount of time
	High degree of accuracy in giving time to the direction the user is trying to cross
	Accurate GPS data
	Ensure/confirm people are requesting time for the direction they desire to cross
	Real-time countdown until ped crossing in the app*
Phase II	Integrated with connected vehicle interfaces to alert drivers of crossing peds/bikes in their paths
	Distinguishing between bikers and peds
	Tracking capability
Possible Features	Ability to work on other smart devices besides phones (e.g., watches)
	Provide info on how far away the next ped crossing is
	Offline version of app available
To Be Reevaluated	N/A

Table 4.6 Phasing Results: Operational Needs – Organization Needs

Operational Needs – Organization Needs	
Phase I	Give an audible/vibration warning shortly before the phase starts to allow the user to prepare to cross*
	Capability to limit use of the app to intended modes only
	Capability to bar misuse of the app
Phase II	Identify signals with a large number of users that request more time
	Inform users of the amount of real time until their ped phase is coming
Possible Features	Rank possible routes according to usability/comfort based on origin-destination data
	Communicate with UDOT Click 'n Fix through the app to request signal fixes
	Estimate pedestrian delay
	Inform users which ped phase is up next
To Be Reevaluated	N/A

Table 4.7 Phasing Results: Operational Needs – Data

Operational Needs – Data	
Phase I	Collect ped/bike volume*
Phase II	N/A
Possible Features	Collect user feedback on intersection/crossing experience
	Collect user walking speed
	Collect user feedback on near misses
	Develop pedestrian Arrival-on-Green (AoG) metric
To Be Reevaluated	N/A

Table 4.8 Phasing Results: System Overview

System Overview	
Phase I	Compatible with Android and iPhone
	GPS and accuracy information
	Map interface*
	Central system (Maxview/Kinetics)
	Focus groups/testers
	Backup connections/servers*
Phase II	Database with sufficient storage
	Fiber-connected signals
	One-step/two-step sign in
Possible Features	Bluetooth
To Be Reevaluated	N/A

Table 4.9 Phasing Results: Operational & Support Environments

Operational & Support Environments	
Phase I	Messaging: Pedestrian info -J2735, SAE message*
	JSON protocol*
	NTCIP protocol*
Phase II	Doesn't overload a user's cell phone data
	GPS accuracy
Possible Features	Identify latency due to connection issue or network coverage (4G/5G)
	Data-free version/setting
	Collection of feedback and/or rating of the app
	Auto-start feature when walking outdoors is detected
To Be Reevaluated	N/A

Table 4.10 Phasing Results: Operational Scenarios

Operational Scenarios	
Phase I	Inform signal if pedestrian has not cleared the intersection when red begins and/or alter user when the conflicting movement gets a green light
	Ability to request more crossing time (either user- or system- requested) *
	Live countdown with delay estimates*
Phase II	Integrated with connected vehicle interfaces to alert drivers of crossing peds/bikes
	Backup connections/servers
	Driver mode that alerts them of pedestrians that may cross their path
Possible Features	Keeping the app passive / avoiding need of constant hands-on
To Be Reevaluated	N/A

4.6 Summary

The data collected from different stakeholder meetings were summarized using the methods in this chapter and then prioritized based on the preferences of the participants. This prioritized list was later used for detailed ConOps development and laying out the phased development options of the cell phone app.

5.0 RESULTS: THE CONCEPT OF OPERATIONS

5.1 Overview

This chapter presents the Concept of Operations document, minus the scope and reference documents since those have been discussed in previous chapters of this report.

5.2 User-Oriented Operational Description

This section provides an overview of the system and describes the strategies and constraints related to the system. Also, discussed are each of the user groups involved with the system, including the role of each group and how the user groups interact with the system.

5.2.1 Overview of the System

The system revolves around four key connections: 1) between pedestrians and the app, 2) between the app and the signal operations, 3) between UDOT managers/staff and the feedback received from the app and signals, and 4) between focus groups and decision-makers. The system employs new signal controller technology to make interaction between the app and the signal controller possible, and to pave the way for an overall successful endeavor.

Based on responses from stakeholder engagement, the user-oriented features are categorized into three groups: Phase I, Phase II, and later evaluation. Phase I includes features that are critical to helping the target audience and will be included in the initial launch. Phase II features and those for later evaluation are features that may be added after the initial launch to enhance user experience, and UDOT support. Consideration of diverse perspectives and input from the stakeholders will help create a well-rounded app that will be mindful of the community on multiple levels.

5.2.1.1 Phase I

The most important issues raised by stakeholders were those that ensure proper accessibility for the target populations. The following high-priority functions will be included in the first phase of the app:

1. The app interface will be **simple with large buttons**. This will ensure all user levels can easily use the app.
2. An embedded map will ensure the **requests are for the correct intersection and direction** and will aid with wayfinding.
3. The app will be equipped with **haptic/vibration and/or audio features** of interactions to assist the hearing or visually impaired. This will help users be prepared to cross and will specifically help visually impaired users know when the desired phase is starting/ending without relying completely on contextual cues.
4. The app will have an initial option of selecting **"regular" or "long crossing"** mode. This will inform the app to request the correct amount of crossing time from the signal. This particular feature will help a wide range of disabilities, who need additional crossing time, to request it.

5.2.1.2 Phase II

1. The app will benefit from **navigation features**. This could take one of two forms; either building navigation and route options into the app or providing the ability to integrate with a preexisting map application (e.g., Google Maps, Apple Maps, etc.). The first form, i.e., providing routing assistance within the app, would reduce the number of apps users may need to use for a single trip. It could also provide greater accuracy by guiding the user along a specific route leading the app to already know which direction a user plans to cross at a given intersection. The second form, i.e., ability to integrate with preexisting navigation applications, will enable the users to remain in that same navigation app if they had it active, without having to switch to a separate app to request ped times.

2. The app will have **different accessibility modes** interfaced with the app. This will provide visually / hearing impaired users a way to intuitively interact with the app or users with reduced manual dexterity to not be hindered in the use of buttons.
3. If the app is being used, it will **remove the requirement of pushing the ped button in the current system** altogether. However, the user will need to visually confirm the signal location and crossing direction through the app. There may be potential problems with removing this requirement based on app capabilities, which will need to be addressed. However, this should not detract from the benefits of users not needing to locate and press a push-button, particularly for visually impaired pedestrians who can have a hard time finding the button, and physically impaired pedestrians who may struggle with accessing the button.
4. The app will have a time-out feature that will **automatically close the app after a certain time duration** to better manage the battery, limit cell phone data, and to limit the call or request time.

5.2.1.3 Later Evaluation

Following are some of the user-oriented operations features that will be included as supplementary features for users. Currently, they are not assigned a specific phase.

1. **Automatic lighting of the smartphone flashlight** while a user is crossing at night or during dark hours.
2. **Customizable interface** going beyond simple accessibility, with users being able to choose either a **simple or a complex interface** based on preferences.
3. **Customizable mode profile** where users can tell the app and the system things about themselves (such as a bicyclist, scooter rider, or a pedestrian who needs extra time).
4. **Special devices** provided to those in the target audience who do not own a smartphone or who struggle with apps/technology.

5.2.2 User Groups

Stakeholder groups that were involved and those that will be involved in various stages of the project represent different user groups. These groups range from pedestrians to management-level engineers as shown in Figure 5.1. The subsections below describe these users, their involvement levels, and how they interact with other user groups.

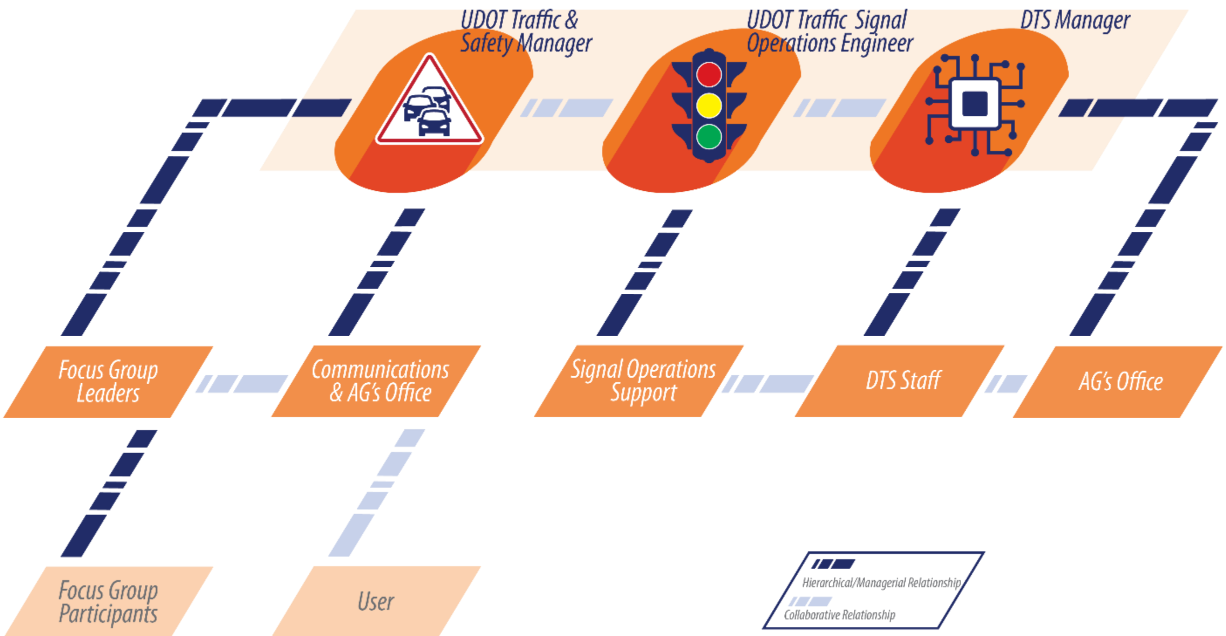

Figure 5.1 Organization of User Groups

5.2.2.1 Application Operators (Users)

Users of the application will initially fall under two groups of vulnerable users: pedestrians beginning in Phase I and cyclists beginning in Phase II. Although additional user types can be added and defined in later phases, these two will always make up the primary target user groups for the initial phases of app development.

Pedestrians

Pedestrians are the intended end-users of the app. When walking in an area with one or more signalized intersections, pedestrians can use the app to request a pedestrian phase at the signal for the direction they desire to cross. The app will provide feedback to the user with confirmation of the received request as well as an estimated wait time until the phase requested will be activated. The pedestrian user group is designed to be fully inclusive to all pedestrian types, including those with disabilities who require additional accommodations at signalized intersections (e.g., needing more time to cross).

Cyclists

If the app is rolled out to include features for bicycle riders, cyclists would perform similar roles as pedestrians, modified for their unique situations.

5.2.2.2 UDOT Traffic Signal Operations Engineer

The Traffic Signal Operations Engineer manages the overall implementation of and improvements to the app. This person will coordinate periodically with the DTS Manager, Traffic and Safety Manager, and focus group leaders to discuss any issues with or needed development of the app. This person will also work directly with Signal Operations Support to resolve any concerns with the central signal system. They are responsible for guiding the system implementation throughout the various steps and phases of application development. The focus will be on system interfaces and signal functionality.

5.2.2.3 Signal Operations Support

This person or team from UDOT Signal Operations is involved with upkeeping the central signal system. They meet with the UDOT Traffic Signal Operations Engineer to discuss any needed improvements in signal operations related to the app. They also work with the DTS Staff to resolve reported issues with the app. They will also support the Traffic Signal Operations Engineer in testing, verification, and validation that the signal operations systems are functioning as designed during the development steps.

5.2.2.4 DTS Manager

The DTS Manager will collaborate with the UDOT Traffic Signal Operations Engineer on desired improvements to the app. This person works with the DTS staff and developers to implement app improvements. The DTS Manager will also manage all contracting with outside developers and hiring for internal DTS staff as needed to meet the needs of application support throughout the lifecycle of the app. They are responsible for managing data standards as they pertain to storage, access, and availability.

5.2.2.5 DTS Staff

This person or team from DTS will develop the app, maintain it, and continue to develop the app as new features or phases are rolled out, as directed. The team can consist of internal and external developers. They are connected to the UDOT Traffic Signal Operations Engineer through the DTS Manager. They report to the DTS Manager with goals and tasks during development coming from the Traffic Operations team. They work with Signal Operations Support to resolve reported issues with the app.

5.2.2.6 Traffic and Safety Manager

This representative from the UDOT Traffic and Safety Division monitors the safety-related aspects of the app. They monitor the safety-related feedback received from the app's users. This manager meets with the UDOT Traffic Signal Operations Engineer to discuss any impact (positive or negative) the app is having on pedestrian safety as well as any improvements needed. They will guide app development features as they pertain to vulnerable and disabled user groups and coordinate with Focus Group leaders on features and needs.

5.2.2.7 Focus Group Leaders

Focus groups are especially critical during the development and early implementation phases of the app. The leader of each focus group will be a UDOT employee who will bring feedback and proposed app modifications to the UDOT team. They also will lead and monitor specific focus group testing and discussion. For this, UDOT may decide to team up with organizations such as Utah Developmental Disabilities Council (UDDC), but the procedures and schedules will be regulated by UDOT Traffic and Safety.

5.2.2.8 Focus Group Participants

Participants of the focus groups will help identify potential features of the app that will best assist pedestrians who are visually impaired or who have a mobility-related handicap. The participants will discuss and propose modifications to the app when they meet with their focus group leader. Focus groups can also be utilized as part of the app testing and validation.

5.2.2.9 Public Relations

This person or team from UDOT Marketing or Public Involvement will help advertise and direct the rollout of the app to the target population and anyone else interested in using it. They will be working together with the focus group leader to prepare surveys, and advertise for the meetings. They may also be involved in communicating to users how best to operate and make the most of the app's features.

5.2.2.10 Attorney General's Office

The Attorney General's (AG) office will supervise any legal issues related to the app and ensure the app is conforming to all data privacy standards and that it meets requirements for the Americans with Disabilities Act (ADA) with support from UDOT Traffic and Safety.

5.3 Operational Needs

This section provides a justification for the development of an app. The section also highlights the needs of the system operators that the app fulfills. These needs are categorized based on when they will be included in the app. As described previously, the three groups include: Phase I, Phase II, and later evaluation.

5.3.1 Justification for Development of an App

With the help of a mobile app, UDOT desires to improve the accessibility and availability of signalized intersections for pedestrians, especially those who are visually or physically impaired. Such improvements are traditionally made with additional hardware, but this approach can be costly, time-consuming, and limited in functionality and scalability, since additional equipment needs to be installed at each intersection. A system centered on a mobile app can provide desired pedestrian enhancements without requiring the installation of new hardware in the existing signals. Additionally, a mobile app will allow for advanced communication between the signal and the user, particularly the ability for the system to send a request to the signal controller to dynamically lengthen the pedestrian crossing phase for users who require additional time to cross. Advanced communication may also include informing pedestrians of the time to begin crossing and the time remaining to complete crossing. As a by-product, the system may also enable UDOT to collect quantitative and qualitative data that can help further pedestrian and signal improvements.

5.3.2 Description of Features

This subsection details specific goals that UDOT and partner agencies are trying to achieve through the app. Each of the following statements describes an operational need that *system operators* have. These needs will be satisfied by compliance with one or more system requirements. The features proposed in these meetings were subsequently rated according to preference by the various stakeholders involved in the discussions. The result of these ratings was a list of priority items to be deployed in the first phase of the app, a list of desired features to be incorporated in the second phase of the app, and a list of additional items either not assigned a phase or in need of further validation.

5.3.2.1 Phase I Features

1. The app will allow the user to **request more crossing time** through the extension of pedestrian walk time and/or have the system adapt to the user's walking speed and request the correct amount of time.
2. The app will be able to **send visual, haptic (vibration), and audio alerts to the user** shortly before the pedestrian crossing phase begins to allow the user to prepare to cross. Currently, an audio alert to cross is given through hardware set up at the signal. The app can provide similar and additional feedback to pedestrians without needing any additional hardware.
3. The app will **ensure/confirm** people are requesting time for the direction they desire to cross.
4. The app will have **a high degree of accuracy** in giving the required amount of time to the direction the user is trying to cross.
5. The app will provide **a real-time countdown** of the number of seconds that the pedestrian walk time is available.
6. The app will provide a **map feature** for users to view their location relative to the surrounding signals. With the map, the app will be able to show ped crossing locations. For

this to function, the app will need to have sufficient **GPS accuracy to identify** which signal they are using.

7. The app will have features in place that block users from requesting pedestrian phases if they are not near a signalized intersection and/or if they are using a motorized mode of transportation to **bar misuse of the app**.
8. The app will provide a countdown that will automatically close the app after a certain time duration. Default will be 1-hour, but the user can select in 30-minute intervals up to 3-hours of app usage time before it is closed.
9. The app will provide user feedback on **communication and server issues**.
10. The app may **collect data** to help UDOT continue to improve the pedestrian experience. Data to be collected includes the number of pedestrians requesting additional crossing time at each signal, and pedestrian and bike volume estimates. The data collected may include personally identifiable data, *i.e.*, username, email address, cell phone number, etc. As such, all data collection methods will follow UDOT data privacy standards with oversight from DTS and the Utah AG's office.

5.3.2.2 Phase II Features

1. The app will provide users with **the amount of time** until the phase they requested will begin. This can help users prepare to cross at the appropriate time and help them to arrive at the intersection at the right time.
2. The app will be able to **distinguish between users who are traveling as pedestrians and cyclists** in order to request the correct amount of crossing time.
3. The app will have some form of **tracking ability** so that it can inform the signal if the pedestrian has not cleared the intersection when the red begins and/or alert the user when the conflicting movement begins its green phase. Additionally, it will help in providing more crossing time to pedestrians who may need it.
4. The app will be able to provide data to UDOT to **identify signals where large numbers of users request and/or need additional time to cross**. This will help signal engineers make necessary changes to the crossing time at the intersections.

5. The app will be **integrated with connected vehicle interfaces** to alert drivers of crossing pedestrians or bicyclists in their paths.
6. The app will provide for users of **non-pedestrian modes**. A biking mode (to call bike phases) and a driving mode (to warn of pedestrians crossing ahead) will also be released. The app will be able to identify and distinguish between users who are traveling as pedestrians, bicyclists, and motorized passengers based on their travel speeds.

5.3.2.3 Later Evaluation

The features listed in this section are possible enhancements to the app and include supplementary features for intended users. Currently, they are not assigned a specific phase.

1. Given a desired destination, the app will be able to **rank possible routes according to comfort/usability** with the help of a route-selection tool and a database of available crossings.
2. The app will provide UDOT with feedback that can help the agency to improve the user experience. The app could **request user feedback** on crossing locations, pedestrian facilities, and the app's ease of use. In addition, the app could be **linked to UDOT Click 'n Fix** which could allow users to report issues with signals or roadway conditions.
3. The app will **collect user feedback on near misses** while crossing to help improve safety for non-motorized users at an intersection.
4. The app will **display the real-time distance** (and estimated walking time) to the next pedestrian crossing. This could help reduce the number of people crossing in the middle of the roadway corridor or block.
5. The app will inform a waiting pedestrian **which pedestrian phase is coming up next**.
6. The app will be **compatible with smart devices** other than cellphones (*i.e.,* smartwatches).
7. The app will collect user speeds to enable requesting **customized crossing times**.
8. The app will be able to **estimate pedestrian delays at signals** based on the time duration between pedestrian phase requests and the beginning of requested phases.

9. The app will also have an **offline version** to be used when mobile data is not available.
10. For users crossing at multiple pedestrian crossings along a corridor, the app will be able to track each arrival and later be able to develop a metric to be used as part of the automated measure system specifically **for pedestrians**.

5.4 System Overview

The core function of the systemwide pedestrian mobile application is the interactive messaging between users and the central signal system. This section describes the internal and external system components required to obtain this connectivity. Figure 5.2 provides an overview of the proposed system, including the user, the application, the central system, and the individual signal.

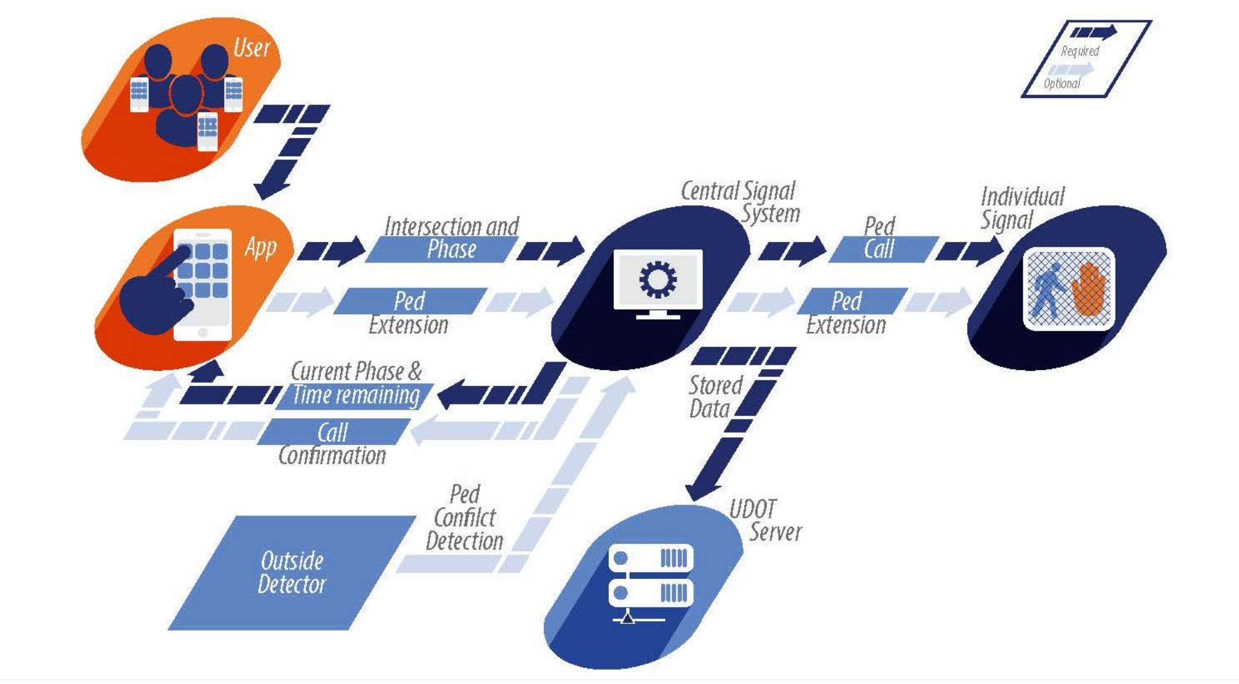

Figure 5.2 System Overview Diagram for an App Integrated with the Central Traffic System (High-Level)

The following steps detail the flow of information and tasks as system workflow. Some tasks and information may not be developed until later phases but are shown here for clarity.

The interactive messaging starts with the need for a road user to cross a road. The high-level overview of the process that follows a request for a pedestrian phase involves the following steps:

1. The user requests a pedestrian phase for a specific direction while in close proximity to a signalized intersection.
2. The app receives the request and does initial processing of the request to make it easily readable by the signal system. The request can be in the form of call placement on the specific intersection and phase number.
3. The app sends the request to the signal system.
4. The signal system receives the request and places a call on the specified phase and signal.
5. The signal system sends back a message to the app when the call is placed.
6. The app informs the user that the call has been placed and provides the number of seconds in which the requested pedestrian phase will begin.
7. At the time the requested pedestrian phase begins, the app triggers a vibration on the device and/or sends an audible message alerting the user of the active pedestrian phase.
8. When the phase begins, the user starts crossing.
9. Meanwhile, the app tracks the user until they exit a predetermined boundary around the intersection (e.g., 40 feet).
10. Near the end of the allocated pedestrian crossing time, the app places an extension request on the phase if the user has not yet finished crossing (based on the GPS location of the mobile device used by the user). If this is the case, the request is sent to the signal system, which receives the request and places an extension on the phase or on the all-red clearance time for the signal.
11. Once the user is outside the intersection boundary, the app stops tracking the user.
12. The entire act of requesting call, requesting extension, direction, and signal location is saved in the UDOT server and assigned an anonymous PIN which does not include the user’s personal information.

The system diagram can be segmented into 3 key components as shown in Figure 5.3:

1. App architecture, which captures the interactions between the app, the user, and the signal system.
2. Central signal system, which includes the interactions between the signal system and individual signal(s).
3. Server communication, which includes the interactions between the signal system and the UDOT server.

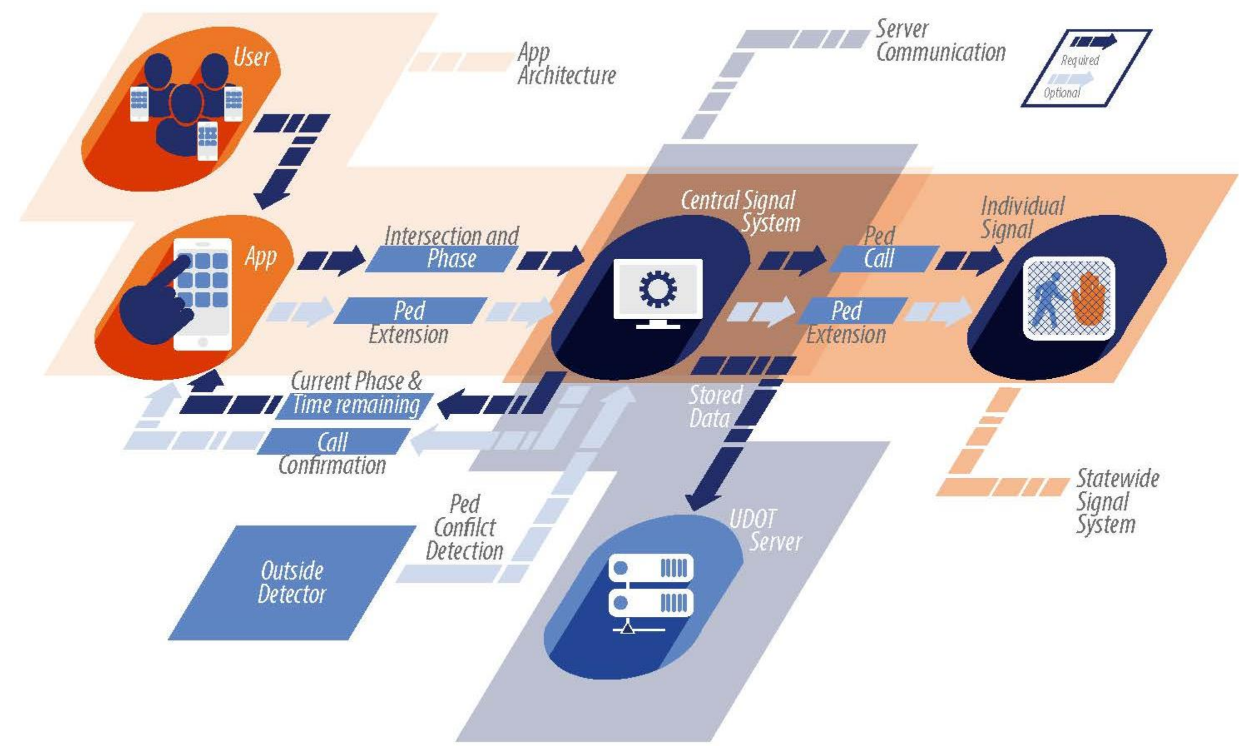

Figure 5.3 Key Components of System Overview

<u>5.4.1 App Architecture:</u>

A functional flowchart of the interactions between the app and the user is illustrated in Figure 5.4. The smartphone app will continuously monitor the location of the phone after initialization to determine initial location and direction of travel. When a user is within a certain range of an intersection, they will select their desired crossing direction and submit a request for the pedestrian phase. The app will ask the user to confirm the desired crossing direction and will send the request to the signal system once the confirmation is received. Signal timing information will thereafter be provided to the user in the form of an audible and/or visible message accompanied by cellphone haptic/vibration feedback.

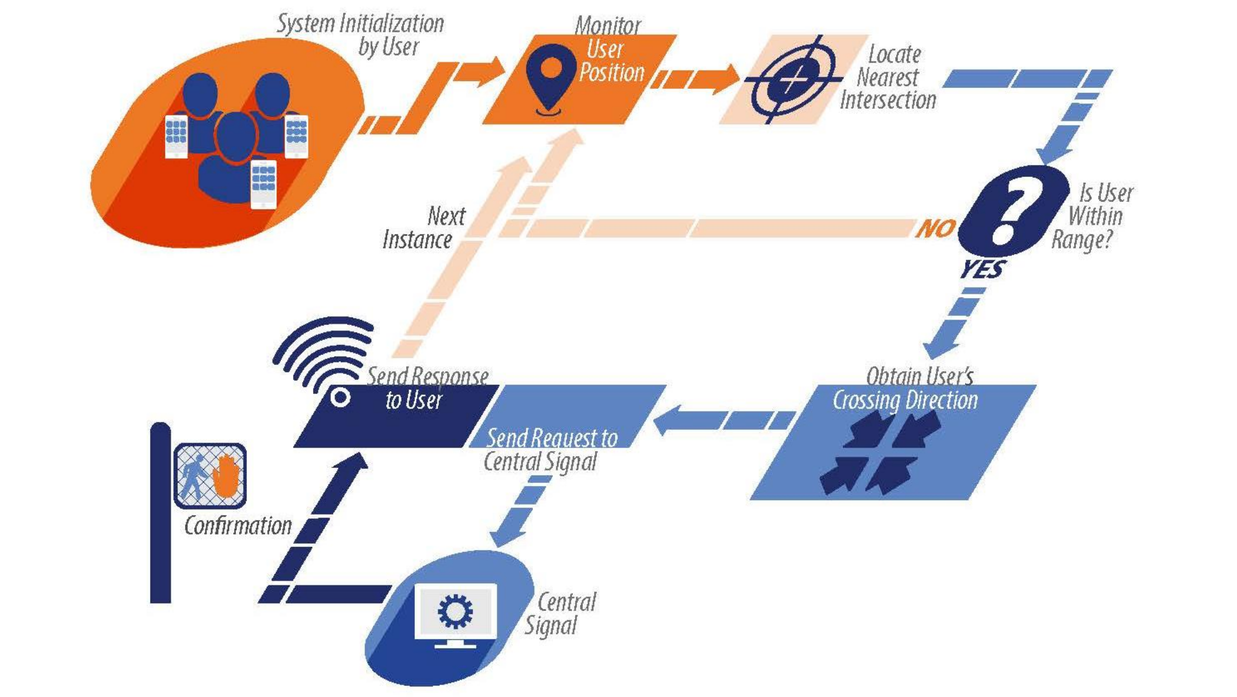

Figure 5.4 High-Level System Architecture of the Mobile Application

5.4.2 Central Signal System:

The central signal system will be responsible for receiving pedestrian phase requests and placing calls at each specific signal. Third-party software developed by Intelight is currently used to centrally manage Utah's signal system. After obtaining user confirmation about the crossing direction, the app will send the pedestrian phase request to the central system. The central system will then process the request for the specific signal and send back confirmation of the call placement to the app. The interaction between the central system and the individual signal will be based on the protocol used by the central system software. It should be noted that the current Intelight central software (Maxview) is unable to support the app, but it is being upgraded to a system that can support it (Kinetics) sometime in 2022.

5.4.3 Server Communication:

Figure 5.5 shows the server communication and data storage method of the app. The server communication will start when a user downloads and installs the app on their cellphone. After the user installs the application, some personal identification information (i.e., name, phone number, email) will be saved in the app's internal database. The other components of the server will not be activated until the user initiates a request through the app. After the initiation of a request on the app, only the request-specific information (i.e., signal ID, direction to cross, etc.) will be conveyed to the central signal system. The anonymized request-associated signal event data will then be logged to the UDOT ATSPM (Automated Traffic Signal Performance Measures) server through a signal controller. Other data is logged to an intermediate data storage location where the data will be stored for one day. After that, all protected information will be removed before the final dataset is saved to the UDOT server. From the server, this filtered and semi-protected data will be available to UDOT partner agencies, the app developers, and DTS.

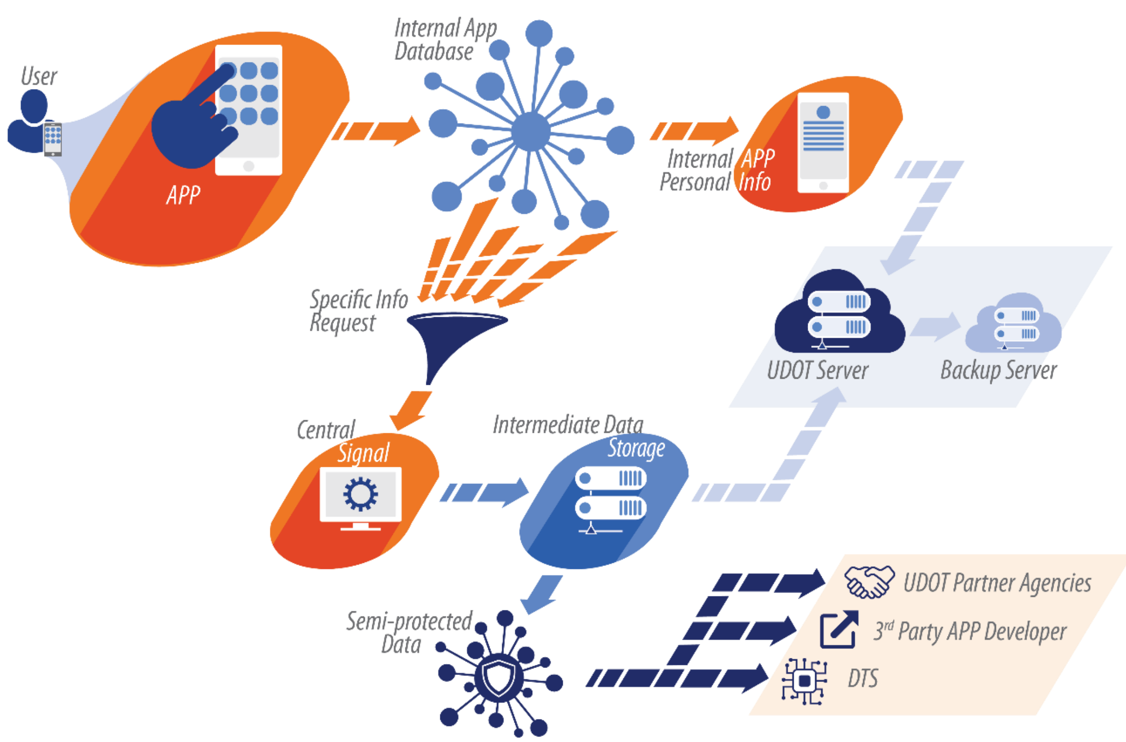

Figure 5.5 Internal and External Server Communication for the Mobile Application

The system has several other key items to consider that go beyond what is presented in the overview shown in the figures above. Data privacy and tracking are primary concerns, as personally identifiable data is much more controlled than other data, though there is more flexibility for data collected for safety operations.

Further app development should also involve focus groups or testing groups. Additionally, it would be desirable for the system to account for future integration with connected vehicle interfaces, connection with devices other than smartphones (such as watches, tablets, etc.), and integration with known map interfaces (such as Bing Maps).

5.4.4 System Layers / Organizational Interfaces

Figure 5.6 shows the different key components of the app and the roles of each.

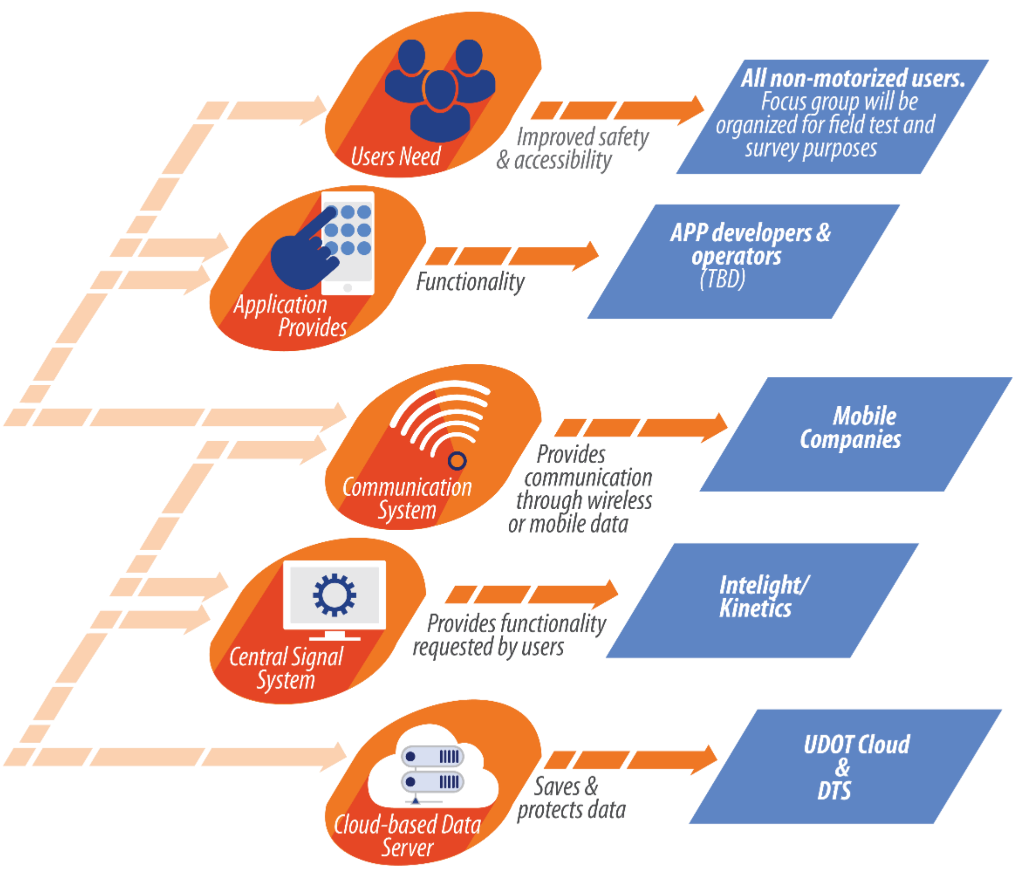

Figure 5.6 Organizational Interfaces

5.5 Operational and Support Environments

This section describes the environments in which the system operates. The needs for facilities, equipment, hardware, software, and personnel are listed. Additionally, the legal constraints, operational procedures, and necessary support are given, along with a description of the phasing with which the system will be implemented. Note that not all support items are needed for Phase I development, but they are included for clarity.

5.5.1 Facilities

The facilities needed to allow the system to run smoothly include:

- The UDOT Traffic Operations Center (TOC) which houses the central signal system
- Cloud storage for the app operating system, required data, statistics, performance measures, and feedback collection
- Backup Server that activates when the main server is down

5.5.2 Equipment (Phase I)

The necessary equipment for the system to operate includes:

- Traffic signal controller to communicate to the central signal system (some intersection controllers are connected to the central system via other methods, such as modems and wireless)
- Pedestrian crossing and phasing
- Cellular communication / cell phone or device data service to establish connection between the app and the central signal system. The communication needs to have sufficiently low latency to carry the information in a timely manner

5.5.3 Hardware

The necessary hardware for the system to operate includes:

- Smartphones (Android or iPhone) or smart device (tablet, watch)

- GPS sensors installed in smartphones
- Any hard drives and cloud storage required for data storage

5.5.4 Software

The necessary software for the system to function includes the following protocols and features:

- JavaScript Object Notation (JSON) for data exchange between the app and the server
- NTCIP (National Transportation Communications for Intelligent Transportation Systems) Protocol that sets communication and vocabulary standards for transportation-related technology, so no matter the manufacturer, the technology can communicate with one another (Perry, 2017)
- SAE J2735 standard message set to utilize Dedicated Short-Range Communications for Wireless Access in Vehicular Environments (DSRC/WAVE, referenced simply as "DSRC") communications systems (SAE, 2020) or C-V2X equivalent (not yet available).
- Ability to report an error with the app or send a fail report
- Signal operations software capable of sustaining the functions of the system is also required. The current software used by UDOT is Maxview by Intelight which is unable to perform all of the necessary operations. However, Intelight has plans to release Kinetics software, which is capable, and UDOT will be switching to this new software sometime in 2022.

5.5.5 Personnel

Supporting staff needed to keep the system working to its full potential include the following. The roles of these individuals or teams are discussed in detail in 5.2.2.

- Signal operations engineer and signal operations support
- TOC maintenance personnel
- DTS manager

- Utah Attorney General’s (AG) office
- App developer team for routine update and maintenance of the app
- Marketing/public outreach staff to oversee rollout of the app and any user feedback
- Team responsible for performance measures review such as downtime, user complaints, penetration rate, etc.
- Team (DTS staff and app developer personnel) to identify latency due to connection issues or network coverage

5.5.6 Legal Support

The system must also work within given legal constraints to protect the privacy of end users of the app and ensure the app is following all safety protocols. UDOT will work together with the Utah AG’s office to ensure the app is operating within the following legal constraints.

- UDOT’s strategy for removing Personally Identifiable Information (PII) from cellphone Bluetooth data
- HIPAA requirements for the protection of Personally Identifiable Information (PII)
- ADA requirements for the safe crossing of streets for handicapped persons

5.5.7 Operational Procedures

For phase I or the initial release, the app will require manual input and confirmation from the end user. For later phases, the app may have the option to automatically function where it auto-starts when a user is walking outdoors. The base scenarios for different phases along with some “non-ideal” scenarios are discussed in detail in Section 5.6.

5.5.8 Support Necessary

As an additional support, before rollout of the app, a focus group will be used to test the app and its usefulness for the target audience and any other desired user groups. A help resource will be needed for the times the app is down. Updates to the app will need to be made to integrate more of the stakeholders’ desired features and to eliminate any bugs that arise.

Additionally, the latency between the app and the system (and vice versa) will need to be identified so that appropriate loading notifications can be provided.

5.5.9 Phasing

The environments of the system discussed above will be available in different phases of the app rollout. The assignment of an environment to a phase was based on stakeholder feedback.

Phase I environments include:

- JSON Protocol
- NTCIP Protocol
- J2735 SAE messaging

Phase II environments include:

- Reducing the amount of cellular data required by app functions
- GPS accuracy to allow app to track position of pedestrians inside the crosswalk

Additional desired environments currently unassigned a phase include:

- Identification of latency due to connection issues or network coverage
- A data-free/offline version of the app
- Ability to detect when a user is walking outdoors and automatically start up the app
- App rating and feedback collection abilities

5.6 Operational Scenarios

This section describes different potential scenarios that demonstrate the application of the system relative to core users and the stakeholders that will allow the system to work properly. Along with different phases of the app release, the conditions described in this section are also categorized as “primary scenario”, “failure scenarios” and “misuse scenarios”.

5.6.1 Phase I Scenarios

Scenarios in this section describe the app and its uses based on features available in Phase I (the initial release).

5.6.1.1 Standard Scenario

This scenario describes a typical/normal use of the system. Assuming all technology related to the system (e.g., Kinetics system, GPS location and geofences, app, etc.) are prepared and working properly, this scenario needs only to involve pedestrian users. Note the order of interaction between the pedestrian, the system, and the signal controller.

Upon arriving at a signalized intersection, a pedestrian (the user) opens the app on their mobile phone (Android or iPhone device with data connection). The app automatically recognizes that their GPS location is near the signal, and it displays the possible directions a user could cross on top of a map. If neighboring signals are spaced closely to the signal, the user may need to visually confirm the location of the intersection at which they desire to cross. The user selects their desired direction, and the app asks for confirmation of the crossing direction before sending a request to the system. If the user has preset their app settings to indicate that they typically need additional crossing time, the pedestrian phase request will also include with it the instructions to lengthen the pedestrian walk and/or flash “don’t walk” phase. The central signal system receives the request, processes it, puts a ped call in the specific signal controller accordingly, and sends an in-app notification to the user that the request has been processed. The app displays in real-time how many seconds are remaining until the requested phase will begin. Shortly before the crossing time begins, the app reminds the pedestrian to prepare to cross with an appropriate audio and/or haptic/vibration and/or visual alert. When it is time to cross, the app notifies the user through a different audio and/or haptic/vibration and/or visual notification that they may begin crossing. While crossing, the user does not need to interact with the app and can give their full attention to crossing the street safely before conflicting traffic gets a green light. If the user were to check their phone while crossing, the app will display a real-time countdown of the time remaining to finish crossing.

5.6.1.2 Fail Scenarios

This section describes scenarios during which something non-ideal occurs. Each scenario will be presented with a statement describing the situation, a few bullet points offering potential causes of the situation, and a few bullet points presenting possible reactions to the situation that the app will provide. More than one bullet point on the list can be true for a given scenario.

The mobile device used by the pedestrian cannot locate the pedestrian or shows an incorrect location.

Possible causes:

- The location feature in the phone is not turned on
- The GPS feature of the phone is not working correctly

Possible reactions:

- The app notifies the user that the location feature must be turned on for the app to function
- The app notifies the user that the app cannot locate the user and requests that the user manually zoom in on the provided map to select their location
- The app notifies the user that the app cannot locate the user and tells the user to press the push-button to request crossing time.
- A message pops up in the app asking the user to report this issue to the app maintenance team

The mobile device used by the pedestrian fails to send communication to the system.

Possible causes:

- The device is not connected to cellular or Wi-Fi, and use of cellular data is disabled

Possible reactions:

- The app notifies the user that there is no connection and that they should press the push-button to request crossing time
- The app notifies the user that cellular data must be turned on for the app to function

The system fails to send a request confirmation.

Possible causes:

- Connection with the UDOT server is down
- The signal controller is undergoing maintenance
- The central signal system is undergoing an update or maintenance
- The signal is in flash mode (flashing red lights)

Possible reactions:

- The app shows an “error message” to the user
- The app requests that the user employ the pedestrian push-button instead to request a phase

5.6.1.3 Misuse Scenarios

This section will describe possible ways a user may attempt to misuse the app as well as present possible methods to block such attempts. These scenarios will be presented with a statement describing the misuse situation, a few bullet points describing methods with which such misuse attempts could be blocked, and a few bullet points offering reactions to the situation that the system could give.

User attempts to request a pedestrian phase but is not near the signal

Possible methods for blocking this misuse:

- The app disables the ability to request a phase if the location of the user is not within a specified distance from the signal connected to the system
- The app rejects any requests sent to signals located more than a specified distance from the user
- In the case that the app cannot confirm a user is near a signal due to GPS issues, the associated fail scenario will be activated

Possible reactions:

- The app greys out (disables) any in-app buttons used to send requests
- The app sends a notification to the user that their request was not accepted because they are not near a signal

User attempts to request a pedestrian phase but is on a motorized transportation mode

Possible methods for blocking this misuse:

- The app disables the ability to request a phase if the location of the user is in the middle of a street
- The app disables the ability to request a phase if the average speed of the user is over a defined pedestrian speed

Possible reactions:

- The app greys out (disables) any in-app buttons used to send requests
- The app sends a notification to the user that their request was not accepted because they are using motorized transportation

5.6.2 Phase II Scenarios

Scenarios in this section describe the app and its uses based on features available in Phase II.

5.6.2.1 Enhancements to Standard Scenario

Phase II of the app is intended to provide additional enhancements not described in the standard scenario of Phase I. These enhancements include:

- The app has the ability to work as/with a navigation app
- The app interfaces with a map that assists users in selecting a route and displays planned crossing locations
- The accessibility modes turned on for the user's phone will also work in the app
- The user will not need to press the pedestrian push-button if requesting a phase with the app
- The app provides the ability to open a user account on the app that will save the user's preferences for interface settings
- The app will be enhanced to use a minimum amount of the user's cellular data
- A bicycle mode that allows bicyclists to request a pedestrian phase (see the Bicycle Mode scenario)
- Driving mode that alerts drivers of crossing pedestrians (see the Driver Mode scenario)

5.6.2.2 Bicycle Mode Scenario

For a user with a bicycle, before beginning the ride, the user opens the app on their mobile phone (Android or iPhone device). While riding, the app registers that the speeds match that of a bicyclist and not a pedestrian, and the app switches to a bicycle mode. Upon arriving at a signalized intersection, the app automatically recognizes that the GPS location of the user is near the signal, and it selects the movement/direction for the request based on the user's location in the roadway similar to vehicle detection (left-turn movement if the user is in the left-turn lanes, through movement if the user is in a through lane). The Kinetics system receives the request sent automatically by the app, processes it, prepares the signal controller accordingly, and sends an in-app notification to the user that the request has been processed. The user puts away their phone and prepares for the light to turn green. When the green indication is given on the signal head, the user proceeds to safely cross the intersection.

5.6.2.3 Driving Mode Scenario

Before starting to drive, a driver with the app installed on their cell phone can open the app and select the driving mode. As the driver makes their way to their destination, the app will send audio notifications through the vehicle's Bluetooth if a pedestrian using the app is crossing their route and is within a certain distance from the car.

5.6.2.4 Fail Scenarios

This section gives the same fail scenarios as found in the section for Phase I but presents additional possible reactions that could be implemented in Phase II. For conciseness, the possible causes of each situation will not be repeated as they are described in the previous section.

Pedestrian has not finished crossing at the end of the allotted crossing time.

Possible causes:

- The pedestrian began crossing late
- The walking speed of the pedestrian was slower than the crossing time accounted for

Possible reactions:

- The app detects through its geolocation feature that the pedestrian is yet to clear the intersection and sends the information to the central signal system that extra green time for the concurrent vehicle phase or additional red clearance time is needed. The system then extends the concurrent vehicle phase or the red clearance time for that phase until the pedestrian has completed the crossing movement
- The app alerts the user that the conflicting movement has begun its green phase
- The app allows the pedestrian to submit a request for additional crossing time beforehand (this request would need to be submitted before the original allotted crossing time is over)

The system fails to send a request confirmation.

Possible reactions:

- The system switches to a backup server (in case the UDOT server is down) and requests that the user reenter their request
- The system sends error detail reports to UDOT and/or DTS staff periodically so personnel can review and fix errors

The app is unable to detect the location of the user.

Possible causes:

- The mobile device of the user has not allowed location services for the app

Possible reactions:

- The app requests that the user turns on location services
- The app requests that the user employs the pedestrian push-button instead to request a phase

5.6.2.5 Misuse Scenarios

This section will describe possible ways a user may attempt to misuse the app as well as present possible methods to block such attempts. These scenarios will be presented with a statement describing the misuse situation, a few bullet points describing methods with which such misuse attempts could be blocked, and a few bullet points offering reactions to the situation that the system could give. Scenarios, methods for blocking, and reactions available in Phase II are listed below. For conciseness, the possible methods of blocking of each situation will not be repeated as they are described in Phase I.

User attempts to request a pedestrian phase but is using motorized transportation

Possible reactions:

- The app greys out (disables) any in-app buttons used to send requests
- The app sends a notification to the user that their request was not accepted because they are using motorized transportation

User attempts to request a pedestrian phase but is on a bicycle

Possible methods for blocking this misuse:

- The app disables the ability to request a phase if the average speed of the user matches that of an average bicyclist.

Possible reactions:

- The app greys out (disables) any in-app buttons used to send requests
- The app asks the user if they would like to switch to Bicycle Mode

5.6.3 Scenarios with Possible Additional Features

Other enhancements to the app that are desired but not planned include the following scenarios:

- **Passive Mode Scenario:** The app will not need to be constantly hands-on and will go to "passive mode" when a user starts crossing. When the user is inside an intersection, the app will not interact with the user to avoid possible distraction.
- **Offline Mode Scenario**: This scenario is in addition to the other responses to the fail scenario of "the mobile device used by the pedestrian fails to send communication to the system". The app could ask the user if they would like to switch to an offline mode.
- **UDOT Click 'n Fix Feedback Scenario**: This scenario becomes possible when the app is linked to UDOT Click 'n Fix app. After the use of the crossing function using the app, it will request user feedback on crossing locations, pedestrian facilities, and the app's ease of use. Any feedback related to intersection improvement will direct users to UDOT Click 'n Fix which would allow users to report issues with signals or roadway conditions.
- **Connected/Autonomous Vehicle Conflict Avoidance**: This scenario becomes possible when the app can be linked directly to connected vehicles. If the connected/autonomous vehicle (CAV) and pedestrian are both connected to the app and there is a situation where a pedestrian is crossing the path of the vehicle, the CAV is alerted of the situation and

avoids the conflict. This scenario requires that specific conflict avoidance strategies be coded in the system of the CAV.

6.0 RISKS FOR APPLICATION DEVELOPMENT

6.1 Overview

A qualitative risk analysis was performed to obtain a deeper understanding on which project tasks, outputs, or events would influence the success of the mobile app. This includes identification of project risks and the ways the project team can address those risks. Risk assessment is the identification and discussion of influences on the overall success of the project. The purpose of performing a risk assessment is to preemptively identify challenges to reaching success and opportunities to accelerate success before the challenge has fully arrived or the opportunity is missed. Identifying these challenges and opportunities beforehand allows time for important preparation.

Some critical questions to consider when performing a risk assessment are:

- What are the priorities of the project?
- How is success defined?
- What are the key milestones on the path to success?
- What are the real threats/risks to the progress of the project?
- What are these risks founded on?
- What is the significance of each risk/challenge?
- What opportunities exist (or may exist) that could be used to springboard this project?

Answers to these questions can be organized according to topic (e.g., funding, market penetration, or equipment); doing so allows related challenges and opportunities to be analyzed side by side.

While the identification of the risks has some inherent value, much of the worth of performing a risk assessment stems from the discussion of the identified risks. The discussion includes the likelihood of the risks and the preparations and actions that can be taken to minimize the risks and maximize the chances for the success of the project. Strategies can be formed, and collaboration between teams can result in new approaches to the challenges that may be faced.

6.2 Mobile App Risk Assessment

The risk assessment for the pedestrian mobile app project is organized into topics pertaining to the project. In particular, the risks listed are related to the two critical pieces of the project: the business case and the operational development. **Error! Reference source not found.** shows the personnel with responsibilities over these pieces and lists the goals of each. These goals are described in further detail below.

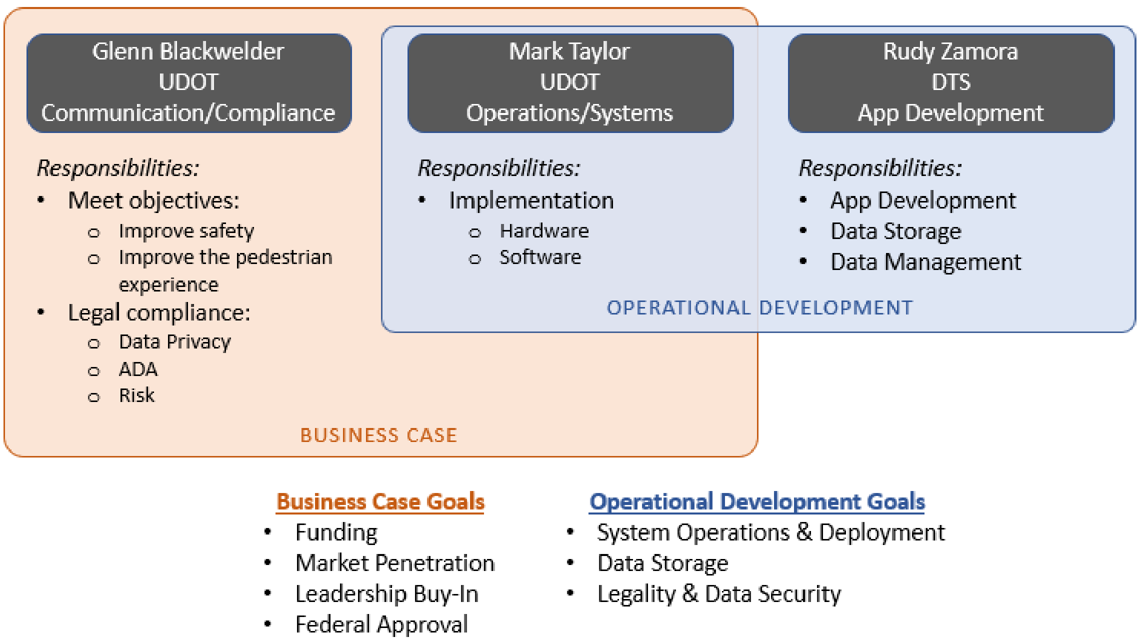

Figure 6.1 Project Organization

Business Case Goals:

- *Funding* – The app will be fully funded
- *Market Penetration* – The app will have a determined number of users as compared to the total estimated market for the app
- *Leadership Buy-In* – Local and UDOT leadership will buy into the idea of the app and remain committed
- *Federal Approval* – FHWA will view the app as an effective tool for assisting pedestrians with disabilities

Operational Development Goals:

- *System Operations & Deployment* – The app will function in conjunction with an operational central system and will not require additional hardware.
- *Data Storage* – The app will have the ability to store necessary data
- *Legality & Data Security* – The app will store data in an adequately secure manner

The identified risks, challenges, opportunities, and strategies for each of the goals are listed in the following sections.

6.2.1 Business Case

6.2.1.1 Funding

- *Challenge* No funding sources have yet been identified
- *Challenge* A large amount of the budget must be found from outside UDOT Traffic and Safety
- *Risk* Not enough funding may be identified
- *Risk* Federal funding agencies may question the large project budget
- *Risk* UDOT funds spent on this project may be wasted if another entity develops a similar app first
- *Opportunity* A new infrastructure bill grant program may be passed soon. If it passes, it would be a good source of funding
- *Strategy* Be prepared with a ballpark budget
- *Strategy* Seek some funding through UDOT
- *Strategy* Seek funding through grant programs
- *Strategy* Use the DTS software prioritization process
- *Strategy* Involve DTS in the budget-making process

6.2.1.2 Market Penetration

- *Challenge* Users will expect a full rollout to all signals they interact with. If the app only works for a handful of signals they use (e.g., it works for the UDOT signals but not for the city-owned signals), then it likely won't gain as much use or popularity

- *Risk* If a portion of the funding must be used to continue installing pedestrian buttons (see the Federal Approval subsection), then there might not be enough budget left to develop the app in a way that provides all the necessary features for the target audience
- *Risk* The app might not be popular within the target audience
- *Risk* The app might not be widely adopted
- *Risk* The app could require too much cellular data to run and thus cost too much for users
- *Risk* A private entity may develop a similar app before UDOT. The success of a UDOT-developed app depends on its being the only one of its kind for pedestrians in Utah

6.2.1.3 Leadership Buy-In

- *Challenge* There are 54 local jurisdictions involved in the Utah signal network. Getting them on board with UDOT about using the app will require a lot of coordination
- *Risk* The legislature or UDOT leadership might say no to the app because they do not want to deal with privacy issues
- *Risk* Local agencies may resist adoption for a variety of reasons—i.e., 1) they might not want their signal timing plans to be altered, 2) they might have privacy concerns and/or restrictions, 3) they just might not like the idea of the app
- *Risk* UDOT leadership and/or FHWA might not think the app will be effective at improving the crossing experience for pedestrians with disabilities
- *Strategy* Lobby UDOT leadership and local agencies to show the benefits of the app and increase their interest in supporting it
- *Strategy* Define what success looks like, what the performance criteria are, and what is the desired benefit of the app

- *Strategy* Focus on how the app has the potential to improve the pedestrian level of service and safety by leveraging technology in innovative ways

6.2.1.4 Federal Approval

- *Challenge* The FHWA ADA compliance committee might still require the installation of Accessible Pedestrian Signals at traffic signals in Utah
- *Risk* The compliance standards might be too rigid to accept the app as a solution
- *Strategy* Collaborate with the Utah Developmental Disabilities Council to gain support for the app as an acceptable strategy to making signal crossings accessible
- *Strategy* Lobby FHWA to show how the app concept satisfies (and goes above and beyond) the purpose of the ADA signal crossing standards

6.2.2 Operational Development

6.2.2.1 System Operations & Deployment

- *Challenge* Software is expensive
- *Challenge* A few city signals lack the proper hardware
- *Challenge* Technology is continuously improving and may be difficult to keep up with
- *Challenge* The app will need to be maintained, even when new features aren't being developed
- *Challenge* The system will likely have a small amount of time when it is interrupted due to app maintenance, signal controller maintenance, central signal system maintenance or updates, and lost connections with the server
- *Challenge* Pedestrian phases will be unavailable if the signal is in flash
- *Challenge* MOT or similar circumstances can affect the expected pedestrian crossing operations (e.g., location, maneuver, timing) at an intersection
- *Challenge* Additional crossing time given to pedestrians can result in the interruption of coordinated traffic flow

- *Risk* Kinetics may not be fully rolled out in time
- *Risk* Kinetics may not be able to perform all the requested features
- *Risk* The app might be misused
- *Risk* Available technology may not be reliable or accurate enough to accomplish desired operations scenarios (e.g., phone GPS accuracy, Bluetooth)
- *Risk* Some locations may not have the necessary infrastructure to allow proper app functionality (e.g., missing cellular data coverage)
- *Strategy* Plan for app failure scenarios and prepare responses in advance
- *Strategy* Warn users in advance of scheduled maintenance to the app, signal controller, and/or central signal system

6.2.2.2 Data Storage

- *Risk* Data storage and management might be difficult
- *Risk* Data storage may be insufficient
- *Risk* Back-up data storage may not be set up in time
- *Risk* Pedestrian data collected and stored may be in a form that can't be effectively used, filtered, or accessed

- *Strategy* Use cloud-based storage

6.2.2.3 Legality & Data Security

- *Challenge* There are restrictions on data privacy and location tracking
- *Challenge* Liability must be assigned in case a pedestrian using the app is involved in a crash
- *Risk* Unclear or incorrect information obtained from the app may result in risky or unsafe pedestrian behavior
- *Strategy* Coordinate with the AG's office to ensure the app functions within legal constraints

6.3 Summary

The qualitative risk assessment performed in this project has been successful in identifying key risks, challenges, and opportunities at the initial stage of the project. In the later stages of the app development, the issues identified will need to be addressed and a comprehensive risk assessment may be necessary.

7.0 CONCLUSION

7.1 Summary

People with disabilities generally have difficulty crossing intersections. The current Accessible Pedestrian Signal (APS) system requires pedestrians to search for a push-button if one even exists. It often requires the pedestrian to move away from their path of travel, which often is hard for people with wheelchairs or visual disabilities. Due to the high cost of APS installation, most agencies do not deploy them at all signalized intersections. UDOT is intending to develop an app which will be able to communicate with the central signal system. This application, when developed, will help place pedestrian calls on signals through a user's smartphone. This report summarizes tasks performed toward the development of the ConOps for the app.

A ConOps serves as a foundation for the systems engineering process. For this project, the document was prepared for all the stakeholders based on their input in various stakeholder meetings. Major goals of a ConOps are met through reviewing the FHWA document number FHWA-HOP-07-001. This document was followed to ensure the ConOps answers all the key questions as well as that it follows the necessary framework. Through the development of the ConOps it was confirmed that there are no known fatal roadblocks along the development path. However, proper funding will need to be identified for development of the app. Some initial risks and challenges were discussed which, if addressed in a timely manner, will be helpful in securing the required funding.

Future work will focus on the next step in system engineering, "Vee" (mentioned in Chapter 2), which is the development of system requirements. The goal would be to follow the steps mentioned in the diagram and work through all the way to the final step: validation of the developed, deployed, or refined system.

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APPENDIX A: KICKOFF MEETING SUMMARY

This appendix contains meeting summary from the Kickoff meeting that was arranged between the project team and TAC members on 12/02/2020.

1. Introduction by Mark Taylor: Utah has an impressive connective system for signals. 99% of UDOT and 95% of partner agencies' signals are connected to the central network. We want to use this system to make the crossings at the signals more accessible and useable for people needing ADA assistance, pedestrians, and bicyclists. The goal is to develop a concept for an app that interfaces with the Maxview signal (central system) and alerts people of how much time they have left to finish crossing. There are 2 systems that he mentioned that serve a similar purpose - "The KITS Central System" (developed by Kimley-Horn), Census Network app. The end goal of this project is a Concept of Operations and to apply for FHWA funding to roll out an app. Rudy Zamora added to that, as this is a research project, there will be some limitations on usage of the product. Even though we come up with an app, it is not going to be immediately available for the public.

2. All the TAC members introduce themselves.

3. David Bassett gives a presentation on Concept of Operations (ConOps) and the need for it in the funding request to FHWA. The presentation involves a definition of ConOps, the "V" diagram, and a summary of a literature review conducted on other similar cell phone apps. Bob Chamberlin requests to add in "KITS" and "Census Network" to the literature review.

4. David Bassett and Glenn Blackwelder clarify the difference between the final ConOps document and the research report. The final ConOps is a very technical document on the app which will have the features of the app, the step-by-step process of the app, etc. The research report, on the other hand, will contain sections such as Literature Review, Methodology, and many others, according to the UDOT research report template.

5. Concept Development: Mark Taylor asks to incorporate "marketing" within the concept if possible.

6. Concept Development Plan (stakeholders): Bob Chamberlin presents the question of whether or not we have enough representation in the TAC team. Everyone agrees that we have a diverse team and some more names are offered that might be helpful going forward:

a. Mark Taylor: ADA specialists in Orem

b. Stephany Tomlin: Angelo Papastamos, who works with central Planning and is over the TravelWise program

c. Glenn Blackwelder: Someone/group to think about the privacy issues. Because this app will have some tracking features to it

7. Travis Evans: "We would like the option to track at least to some levels. Not the personal information and such but the movement of people which can later be used to create a database of volumes. Because getting NMV and car volumes becomes problematic in some projects." Mark Taylor mentions if we are dealing with data and privacy, we must keep in mind the abusers. What happens if someone abuses the system from the app?

8. Christopher Siavrakas adds in - to somehow incorporate connected vehicles to the scope. Is it possible to connect the ped app to the infrastructure so it alerts drivers if there is a slow crossing ped or ADA at the crossing? Travis Evans mentions Tesla showcased during UDOT conference has some similar features. Something to think about.

9. Meeting reaches almost its end. Bob Chamberlin clarifies the schedule is 12 months to finish the project. David Bassett shows the schedule flowchart divided into 4 quarters. Some of the tasks overlap. For now, the goal is to finish the Lit Review within January. There will be 3 deliverables (number still needs to be confirmed between Glenn Blackwelder, Bob Chamberlin and David Bassett). Bob Chamberlin asks for a 2-week turnaround for comments on the deliverables

10. Mark Taylor asks why we are somehow eliminating bicyclists from the scope. David Bassett clarifies we want to address all the NMV. The hierarchy is ADA, Pedestrians and then Bicyclists. Glenn Blackwelder says we will want to go in this order and address bicyclists if time and budget allow.

APPENDIX B: INITIAL STAKEHOLDER MEETING SUMMARY: CUSTOMER STAKEHOLDERS

A summary of the meeting of the customer stakeholder group (held on February 24, 2021 From 4:00 PM – 5:00 PM). This meeting was in the form of a brainstorming session which followed a brief project introduction and presentation of goals. All the ideas for the app from the brainstorming session are listed in separate sections of the initial ConOps (from Point 2 onwards) and the stakeholders' names were also documented for followup.

Attendees: Bob Chamberlin, Glenn Blackwelder, Mark Taylor, Ivana Vladisavljevic, Travis Evans, Trevor Egan, Derek Lowe, Michael Blanchette, Stephanie Tomlin, Thomas McMurtry, Ivan Hooper, Emilie Jordao, Blake Unguren, Shawn Larson, Rob Eldredge, Blair Tomten

1. Brief Project Intro
    a. Glenn: Accommodating pedestrians with extra needs (ADA) has been a subject of concern in UDOT. With the current configuration, people push buttons at a pedestrian crossing, but the crossing time is fixed. The scope of this app can be twofold: Firstly, identify users who might need additional time and getting feedback from the app to tell them they are getting the needed extra time. Why not provide a better experience with an app without changing any physical equipment at the signals?
    b. Mark: Overnight we can equip every intersection in Utah with the technology/app as soon as it becomes available. The sky's the limit here - the app can give audible messages, better understand users, tie into future technology such as connected vehicles, etc.
    c. David Bassett: To summarize the scope, how can we help non-motorized road users with the existing signal and intersection configuration? Who else can we include? How can we expand it into other active transportation users?
2. Brainstorming Discussion
    a. Scope
        - Bob: Is the focus on pedestrians with disabilities? All pedestrians? Cyclists?

- ◊ David: Answer to Bob's question- the scope of the project has grown from helping ADA to a mobile app that ties with the central signal system (basically used by all non-motorized road users).

- Travis: Can the app be linked to a connected vehicle interface so they know a ped/bike can be crossing their path?

b. Reference Documents

- David: Discusses individual member involvement as stakeholders in the project. As the stakeholders also work with different agencies, they will be able to convey or connect their feedback to the project.
- David: Codes, Methods, ADA requirements etc. – any document that can be helpful in this concept of operation, stakeholders are requested to forward to the TAC.
- Thomas: Crosswalk Assistance (an app), shows a "Stop" sign. Not just for signalized crossing. It can be used for stop intersection.

c. User-Oriented Operational Description

- Mark: School of the blind in Southern Utah (probably Hurricane or St. George) reached out; they are very willing to provide input and feedback. After we have put together a draft, they will be happy to take a look.
- Ivana: If I specify my destination like a navigation app and specify my mode, can the app be equipped to check all the nearby intersections in the route/direction and give an estimate when I will reach an intersection and also if that ped signal will be green for me?
  - ◊ Stephanie: Like "green wave" (Amsterdam) can it tell me whether or not I will make the light (primarily for cyclists)?
  - ◊ Glenn: Knowing the difference between bike and ped can give the appropriate amount of time to cross on a side street and provide the correct minimum (and potentially know when it is safe to cut the minimum). AASHTO bike minimum time is different than ped crossing minimum time. So, this can be helpful for intersections that have separate bike crossing signals.

- Mark: Provide in the map the “real time” to cross instead of the fake “countdown” time
- Glenn: Can it tell peds which ped phase is coming up next so they don’t push both ped buttons. Also, a message such as “Your phase will start in XX seconds.”
- Trevor: It would be helpful if it provides information about how far the next ped crossing is in the direction of travel so people do not cross at the middle of the road. Glenn mentioned this matter was also brought up in one of the field reviews.
- Trevor: Alternative ways to interface using different accessibility modes? For example, for the hearing impaired, the phone vibrates
- Thomas: If I am 30 feet from signal, the app vibrates and asks do you want to cross and in which direction do you want to cross. People will select which direction.
- Thomas: The app has a feature of being lit or turns the flash in the mobile on, so drivers are aware someone is crossing.
- Thomas: Notification in the app, as you approach the intersection (like a vibration or something) then the user requests ped crossing time when he is 25 seconds away from the intersection.
- Blake: Show actual countdown on the app for both sides, so the user can decide which direction to cross.
- Thomas: Tough to develop an app that satisfies everyone. Some people will like a lot of options, some people will probably like just 2 buttons.
- Thomas: Having 3 options, easy, medium, complex -- interface based on user.
- Bassett: For hearing impaired, the app says “turn from this to this.”
- Thomas: For vision impaired, the app has to convey the information verbally. Bing, you have to put a request in.
- Thomas: Whatever the interface, I want to get the feedback that the request was received by the app or something like that.
- Thomas: What if the app blocks other apps from being used in the crosswalk?

- Emilie: Just a pop-up notification that, if you are in a crosswalk, says, "You are in a crosswalk, pay attention."
- Thomas: Mode choice in the app--what type of user you are.
- Emilie: No ads in the app.
- Blair: Bind person – they don't know where the buttons / cars are. LPI is bad for them because they want to hear the cars going before they start crossing. Can the app tell them, cars in N-S are going? Chirps and stuff are not very helpful for them. They are rather distracting.

d. Operational Needs

- Stephanie: Any opportunity to capture active transportation count data/information can fill a data need.
- David: Can we tell the signal when the ped has not cleared the intersection dynamically as a fail-safe?
  - ◊ Mark: Can be done by extending all-red. Can be used to give time to peds who are still at the middle of the intersection.
- Mark: Needs to be able to track and control if someone is misusing or abusing the app to the detriment of the network → very important.
- Ivan: What is the penetration rate? How many people are using it vs. how many people are pushing buttons? And who is doing both?
- Thomas: Data collection-→ ask people if they need more time at the end of countdown. Also, ask how many people are crossing with you. If 6 people are crossing together, increase the time. Probably people with kids are crossing.
- Emilie: O-D data will be helpful, also speed information.
- Blake: Can we collect the speed information so the app knows how fast a person can cross the crosswalk so the app can guess the estimated time.
- Blair: Offline service? Download offline map and then even if you are disconnected it serves you.
- Blair: Route / destination input?

- Blair: Lag of yellow to red is very dangerous for bicycles. Can we extend if someone is trying to cross at yellow?
- Blair: Great if the signals were set up to detect you far from the signal.
- Blair: If there is a way to extend green time for someone who presses the actuation at the end of the ped phase.
- Blair: Think about pedestrians when there is no car around, also the cars when there are no people around and they are waiting for a green.
- Blair: Looks like you are leaving the signal, do you want to cancel the call? So that people do not become desensitized because there are no people around but there's a call.
- Blair: Love the countdown timer. It's in Asia and Europe.
- Shawn: Also need to think about peak hour. People are willing to wait more during that period.

e. System Overview

- Mark: The app needs to be systemwide.
- Trevor: Can we expand it from phones to smart watches (other smart devices not just cellphones)?
- Emilie: Should have a feature to select when the app will be able to track your movement.
- Thomas: Integrate it with an existing UDOT app.
- Rob: Make sure it's not a stand-alone app so it can be integrated with 3rd party apps like Garmin / Strava, etc. Because if it's a stand-alone app, some people will never use it.
- Blair: In Wisconsin, there's loop detector for bicycles, so people coming up to the intersection don't have to stop. Can we do something like this in Utah?
- Bassett: Can do with GPS and geofencing.

- Bassett: If the app detects you at the edge of the crosswalk, you are already crossing, so cancel ped request.

f. Operational and Support Environments

- Mark: What kind of accuracy and latency can we expect with the technology and equipment we have? What will be the feasible area of influence around an intersection? (Depends on GPS tolerance)
- Mark: Is this going to overload the user's mobile data? Storage issue of the cellphone is something to think about.
- Ivana: Can we collect near-miss data with the app? This can be very helpful in the safety analysis. Probably a button in the app saying, "near-miss."
  - ◊ Trevor: Feedback "how was your crossing" rating?
  - (a) Glenn: User comfort feedback can also help us inform why some ped crossings are underused.
  - (b) Mark: Feedback can also be associated with work orders if something needs to be fixed (link to Click 'N Fix app).
- GPS (or maybe accelerometer) data can help us know if user has not cleared the intersection by the end of the phase.
- Travis: Identify signals with a large number of users that request more time. Should we hardcode the extra time into such intersections? Other volume data?
- Shawn: User comfortability / crossing experience feedback after crossing.

g. Operational Scenario

- David: Discusses what different groups' contribution can be. For example, ideas on what the system should do.
- Mark: The app will be tied to GPS but to make sure it is also tied to ped button. As when someone arrives at intersection, GPS will not be able to tell if user wants to cross E-W or N-S. This is also important from a safety perspective. To make sure users are not solely dependent on the app.
- Thomas: Use the app as detection (like the ped button), also as a flasher (like the flag).

- David Bassett: ATSPM measure -AOG for peds. Greenwave?
- Thomas: Different ATSPM measures of pedestrians based on the app.
- Shawn: TSP but for peds. Arrow?

h. Other

- Stephanie: Is there an opportunity to incorporate active transportation counts in the app?
- Travis: Opportunity to collect counts from the intersection whenever possible. Currently Strava used to collect data but it is not as widely used.
- Bob: Question - "Can green time/walk time for ped crossing be extended?"
    - ◊ Mark's answer: Yes, by a push button hold, if the feature is available. There are 2 locations on Redwood Rd where this feature is available, and it is always abused. If it can also be connected to the app, this would require a firmware change in the central system.
- Bob: Is there a way to know if someone has not crossed yet and is still at the intersection?
    - ◊ Mark's answer: Not yet with the current technology
- Michael: Expressed concerns about relying solely on GPS data if any signal timing is being adjusted. Michael has prior experience in using GPS data in downtown Atlanta and it was spotty, at best. With the density of the area, the taller buildings, and tighter signal spacing, the information was not reliable. Moving forward with the app, we should be careful in promising any potential safety enhancements or pedestrian extensions based on GPS data to communicate with the signals. Probably this will not be as much of a concern in less dense areas but could foresee this being an issue in areas like downtown Salt Lake City, where the granularity of the GPS data may not be enough to tell which pedestrian crossing a person is actually using at a particular signal.

APPENDIX C: INITIAL STAKEHOLDER MEETING SUMMARY: OPERATORS STAKEHOLDERS

This appendix contains a summary of the meeting of the operators' stakeholder group (held on March 4, 2021 from 3:00 PM – 4:30 PM). This meeting was in the form of a brainstorming session which followed a brief project introduction and presentation of goals. Meeting involved gathering ideas from UDOT operators to get the user's point of view. All the ideas for the app from the brainstorming session are listed in separate sections of the initial ConOps (from Point 4 onwards) and the stakeholders' names are also documented for followup.

Attendees: Bob Chamberlin, Angelo Papastamos, Heidi Goedhart, Trevor Egan (ADA), Mark Taylor, Glenn Blackwelder

1. Brief Project Intro (Mark/Glenn/David)
    a. Glenn: Accommodating pedestrians with extra needs (ADA) has been a subject of concern in UDOT. With the current configuration, people push buttons at a pedestrian crossing, but the crossing time is fixed. The scope of this app can be twofold - Firstly, identify users who might need additional time, and getting feedback from the app that they are getting the needed extra time. Why not provide a better experience with an app without changing any physical equipment at the signals?
    b. Mark: Overnight we can equip every intersection in Utah with the technology/app as soon as it becomes available. The sky's the limit here. The app can give audible messages, better understand users, tie into future technology such as connected vehicles, etc. Eventually it's not just Utahns that will benefit from this app, it will be all the people going through these 30,000 intersections every day.
    c. David Bassett: To summarize the scope, how can we help non-motorized road users with the existing signal and intersection configuration. Who else can we include? How can we expand it into other active transportation users? Initially this project started out to help the visually impaired. Now it has branched out to possibly all disabilities, bikes and pedestrians--like Mark said, "the sky is the limit here"
2. Brainstorming Discussion

a. Scope

- Mark: At initial stages of the app, helping everyone might not be feasible because of infrastructure and financial constraints.
- Mark: It's important to define our user base. The group that desperately needs it to get around are our target population. We will try to incorporate more features to address other user groups as we go.

b. Reference Documents

c. User-Oriented Operational Description

- Heidi: Customizable for each person (mode profile).
- Heidi: Is there a possibility of providing a special device instead that would fill the needs that people without smartphone/data plans would be able to utilize?
- Angelo: Simple and large buttons.
- Heidi: Not necessary to be constantly hands on; taking away attention from surroundings. The more passive, the better.
- Heidi: Can it be as easy as RFID/ski passes? To make it automated and easy?
    - ◊ Glenn: While this is a very good idea, RFID/toll collector/ski passes require hardware installation and regular maintenance. Which eventually becomes expensive.
- Focus groups to better assess the types of people that would be using the app?
    - ◊ Angelo: We can get focus groups started on this easily.
- Autostart the app, or at least autostart from another app?

d. Operational Needs

- Heidi: How do we specify what mode users are using, and lock people out who are outside of the potential users, i.e., people using transit/in cars?
    - ◊ Could potentially tie it to push-button press, but be mindful that some of the target groups may not be able to physically push the button.
    - ◊ Another idea would be a lock-out method based on speed of the mode (example-Pokemon Go).

- Angelo: Seniors struggle using apps; buttons can also be hard for seniors to get to.
  - ◊ Glenn: Getting this out there sooner rather than later could help the next senior generation get accustomed to help app penetration. For now, there can be a balance between both--the app should be easy to maneuver for all focus groups.
  - ◊ Heidi: Agreed. Technology adoption in certain populations is a barrier we need to consider or accommodate a work-around.
  - ◊ David: A solution might be to categorize user.
    - (i) Heidi: Yes. Probably a customized interface based on user.
- Angelo: Take the wins where you can get them. Even if we have to make incremental changes in phases that is still improvement.
- Glenn: At night, can we use info from the phone to get feedback on lighting?

e. System Overview

- Mark: Concerned about accuracy of GPS and also prefers push-button activation to determine direction and monitor/cut off abusers
  - ◊ Angelo: From experience of walking with navigation apps, the GPS has been accurate enough. But agrees that direction can be an issue.
  - ◊ Heidi: GPS on phones is between 2'-5' average, which is a fair distance at ped-ramps/intersection corners.
- Trevor: Can we tie into a UI that people may already be familiar with such as Google or Apple?

f. Operational and Support Environments

- Glenn: To make it easier to use, can we have a map interface? Start and end destination feature?
  - ◊ Heidi: Usually people take same routes every day (home to work/school and vice-versa). So, an option for pre-set routes can be helpful.
- Trevor: Encourages incorporating O-D information, routes, bike trails to the interface. And provide rating of different routes based on usability or comfort.

- Bob: Will be helpful if the app has predictive element to find the app. When someone starts walking, it pops up and asks, “Do you want to turn this on?”

g. Operational Scenario

- Heidi: The app should be able to adjust itself based on user data (ai). The walk speed varies between users. The app should be able to make a note of that to give correct estimated arrival times.
- Mark: The app can alert drivers of jaywalkers that might be crossing their paths.
- Mark: It would be cool if the app shows estimated delay for peds.

h. Other

- Data needs
  - ◊ Heidi and Angelo: If we can get pedestrian volume / volume of users with special needs, it will be helpful to concentrate on specific regions to evaluate infrastructure needs.
  - ◊ Glenn: Would be interested in knowing how the data collected from the app is being used.

APPENDIX D: INITIAL STAKEHOLDER MEETING SUMMARY: MANAGERS

This appendix contains summaries of the meeting of the manager stakeholder group. Unlike the previous 2 stakeholder meetings, this meeting was spread out through different days due to schedule conflicts and diversity of topics covered.

Meeting 1:

Attendees: Glenn Blackwelder, Mark Taylor, Derek Lowe (DTS), Avenue Consultants
March 9, 2021, 3:00 PM – 4:00 PM
UDOT Google Meet

Reference Documents:

1. DTS list of data restrictions - data that cannot be collected through the app.
2. ADA & security testing document → ADA compliance (website https://dts.utah.gov/security/compliance)
3. Software will have to go through "DTS Contract".
4. Policy of Software Lifecycle
5. Follow-Up Item 1: Security document to fill out by software developers, and anyone who will have access to user data - network diagraming and data diagramming.
6. Follow-Up Item 2: UDOT Maintenance App (This app can give us the accuracy info, document info, what is allowed or not).

Connection Type: This needs to be included in the ConOps

Mark: "It is estimated that 95% of signals are connected to the network by fiber. The rest of the network is connected through a combination of radio and fiber, and cellphone. For this reason, the app will initially focus on fiber connected."

There is no exact number because it changes every month. Mark Taylor knows this from Lynne Yocom (UDOT Fiber Optics Manager).

Questions that need further clarification:

1. Glenn: Is there a restriction on collecting Bluetooth data? (Derek: There is a DTS list of data that cannot be collected through the app).
2. Glenn/Derek/D. Bassett: Latency of the request due to network (4G or 5G)/device/location. With the devices we will be using, what is the maximum latency? Is it acceptable?

Meeting 2:

Attendees: Shane Johnson and Tom Stiles (Intelight), Mark Taylor, Derek Lowe, Avenue Consultants

Date & Time: Monday, April 5, 2021, 11am – 12pm Mountain Time - Denver

Overview: Meeting was conducted to discuss how a mobile app could potentially connect to Intelight's Central System, in particular how this could be used to facilitate pedestrian crossing at traffic signals. Intelight runs approximately 30,000 signals in North America. If the app is developed with an innovative vendor like Intelight or KITS, future work becomes more organized. Before the meeting, a list of questions was sent out which were discussed during the meeting-

Q1: How can the central system place a pedestrian phase call when asked by an outside source?

A1: Intelight is releasing a new Kinetic Signals program. Kinetic signals will allow for connecting to outside source, API has already been tested.

Q2: What sort of delay would be expected when logging the pedestrian phase call from an outside source?

A2: There was a rough app that Intelight built to test the latency issue which showed 500 milliseconds of latency. CV app (Georgia).

Q3: What sort of delay would be expected when sending the pedestrian phase to the signal controller from the central system?

A3: Latency with MaxTime controllers between app and Controller going through Central System is 0.5 seconds. Latency with other controllers between app and Controller going through Central System is no more than 2 seconds (1 to 1.5 for NTCIP)

Q4: What information would be needed to identify which pedestrian phase should be called?

A4: Intersection and phase.

Q5: How can a pedestrian phase be lengthened by the central system over the existing walk time in the controller?

A5: Shane: If you think of pedestrian phase as TSP (transit signal priority), it is possible. Mark mentions there can be 3 ways to handle ped extensions - 1) walk 2 in the controller, 2) ped clearance 2 which might run into a countdown issue and therefore not a good option, 3) keep walk and countdown the same, but extend All Red time between phases. It is better for the system if this extension request/time comes through central system.

Q6: How can we hold a pedestrian phase green from an outside source such as if an app through GPS determined the pedestrian was still in the crosswalk?

A6: It can be something similar to DERQ (http://en.derq.com/) used in Midwest and United Arab Emirates can detect conflicts with pedestrians, vehicles, or other vulnerable road users, to avoid collisions.

Q7: What would be needed to return a call-placed confirmation to an outside source?

A7: Central System will be able to return confirmation that call has been placed. J2735 messages (SAE message) are adding ped warning message for the cars. They can be researched for further use.

Q8: Is it possible to detect which ped phase is next?

A8: Through NTCIP this will be very easy.

Q9: What information could be provided to the outside source in regard to which pedestrian phase will be called next?

Q10: What information could be provided to the outside source in regard to how long until the pedestrian phase is going to be served?

A10: Wait time until pedestrian phase is more complex and may need to be estimated.

Q11: Is it possible to provide accurate countdown?

A11: Yes, it is possible.

Q12: How about an interface between app API and Kinetic system?

A12: There has to be a central system that does that logic. Intelight will be able to build that service.

Standard / Reference Documents:

Protocol: JSON, NTCIP,

Messaging: Pedestrian information - J2735, SAE message (it has a map)

Shane and Tom think this app has a good possibility of going into production. Current version of Intelight Maxview will not be able to perform any of the above-mentioned activity. However, Intelight is upgrading to Kinetic Signals really soon and Kinetic is capable of performing all of these with ease. Avenue will reach out to Himanshu Wad from Intelight for further investigation of the technical aspects of Kinetic.

Meeting 3:

Attendees: DTS (Rudy Zamora, Derek Lowe), Glenn Blackwelder, Mark Taylor, Avenue Consultants

Date & Time: Monday, April 12, 2021, 8am – 9am Mountain Time - Denver

Discussion: Meeting was in the form of a Q/A session where Rudy Zamora answered questions regarding DTS's rules and restrictions.

Q1: The initial concept is that the app will require the user to log in and it will collect some sort of data from them. Are there any DTS restrictions for this? Is there any specification for "dedicated server" or "cloud-based server"?

A1: This will largely depend on the scope of work--what data is essential vs. which is optional. This will help identify which data will be restrictive or not, and it will go from there. So, it's very important to develop a good scope of work. As for the server, the data can be saved in the UDOT server and any 3rd party who may have access to the data will have to follow UDOT's rule. And the login should go through a separate discussion later down the road, i.e., if it needs to be a single sign-on.

Q2: Clarification on single sign-on for external vs. internal UDOT apps?

A2: It can be external or internal but single sign-on might not be applicable for this app. As with the "Click 'N Fix" app, it needs the user to update their password every 90 days. But the ped app will be different--more robust, more flexible.

Q3: Are there any DTS preferences for the app development, i.e., language, method, does it have to be web-based or can be an app?

A3: DTS uses VisualStudio.net, GCP (Google Cloud Platform). There are DTS/UDOT apps already being developed and used. So, there should be no restriction there.

Q4: How can we keep the cloud/server from failing? Or is there a backup plan?

A4: Currently TOC uses “Barracuda Appliance”. Also, if the app is cloud based, the data/app will be natively available when server fails.

Q5: Any rules on managing personal data?

A5: Yes, there will be. First, will need to identify data needed.

Q6: Everything done on UDOT (apps, services) requires 2-step verification. Will the app be different?

A6: Single sign-on and 2-step verification are two different concepts. This app can function without single-step sign-on and still be a 1-step verification.

Q7: Will there be a password change requirement?

A7: If the app uses single sign-on, it will need a password change every 90 days.

Q8: Will the Department be in favor of an app that might require seasonal maintenance?

A8: The app will need to factor in annual maintenance, should be included in the 5-year contract of the app.

To summarize, Rudy Zamora thinks this a pretty straight-forward app when it comes to DTS rules and regulations. He proposed an idea that if the app goes into development phase and there is field testing or a research need, Department vehicles can be included in the contract for possible use. Also, when it is time to provide a cost estimate for the funding request, Rudy can help provide a rough ballpark.

Meeting 4:

Attendees: Attorney General’s Office--James Palmer, Glenn Blackwelder, Mark Taylor, Avenue Consultants

Date & Time: Friday, April 16, 2021 1:30pm – 2:30pm Mountain Time – Denver

Q1: Restriction on data collection?

A1: Email address can be used as personally identifiable number (PIN) and after that, if they are converted into numbers and collected health, address, phone number information, and cannot be traced back to one person then that data collection is OK.

Q2: What about collecting real-time GPS data? This will be necessary for the app to function.

A2: If location data is collected it will be data collection for safety purposes and probably can be argued in court if it gets to that. Furthermore, there has to be strict agreement/contract that whatever data we collect cannot be given out under any circumstances (GRAMA request). Controlled data → we can collect it for the app to function. But we cannot give it away.

Q3: Since a person wouldn't know his/her walking speed, we want the app to monitor the speed to request sufficient ped time from the signal. Also, speed monitoring will help to shut people down who might be trying to abuse the system. Will that be an issue?

A3: This is data collection for safety and to stop misuse of the app, so shouldn't be an issue. But Jim isn't 100% sure, needs research on his part.

Q4: This app will necessarily collect O-D data and can be tracked back to a person. This can be an issue when there is a GRAMA request, and we will have to give that data out.

A4: This needs further brainstorming. There can be a way where no data is stored that ties to the PIN or user login. They are converted to mere numbers (user 1, user 2…).

Q5: What are the implications of collecting ped volume data through the app? This is different from tube counts or any other vehicle counts collected through detections.

A5: If this can be tracked back to the individual, then this might be problematic. But if the data is converted to look like the intersection car counts, where it will show no user info, then it should be good.

Q6: What needs to be done to make it ADA compatible?

A6: Needs to run through lawyers specialized in ADA to evaluate whether it is properly accessible by persons with disabilities and if it is efficient. If the project mentions ADA somewhere, it should be ensured this can jump through that hoop. Otherwise, there have been instances of projects getting shut down if they failed to meet the criteria.

Q7: Can cell phone numbers be collected?

A7: Yes. But we cannot give out that information to anyone else even under GRAMA request.

Reference Documents (Followup Required)

1. Statutes related to data collection for safety purposes, volume data collection (Jim Palmer)
2. HIPAA, federal laws to account for - a documentation (Jim Palmer)
3. Whitepaper on Bluetooth data (Glenn Blackwelder)

Overall, Jim Palmer thinks this is a really good idea for an app and the population that is going to benefit from this is higher than we are anticipating. So, however many challenges we face, there should be a way to figure it out. Something to be kept in mind is that as we progress, lots of legal variables will be popping up such as HIPAA, relevant federal laws, etc. Also, after the app is launched if the data is stored somewhere, UDOT is going to get GRAMA requests. A team of attorneys will be needed to sort this through, and it is important to include in the contract that “we will not share users’ data.” Of course, not storing the data will save this headache altogether.

Meeting 5:

Attendees: Mark Taylor, Himanshu Wad (Intelight), Avenue Consultants

Date & Time: Monday, April 26, 2021 2pm – 3pm Mountain Time – Denver

Topic: Continuing discussion about the potential for creating a mobile app which will connect to Intelight's central system and facilitate pedestrian crossing at traffic signals.

Discussion: Meeting was in the form of a Q/A session with Himanshu where he answered questions regarding Intelight's capabilities and restrictions when it comes to developing the mobile app in question.

Q1: How can the central system place a ped call when asked by an outside source?

A1: Through Kinetic Signals' graph QL API it will be possible to pass information in/out of the signal. So, requesting time from the central system is possible with today's settings. Sending feedback from the central system to the app will require some work on Intelight's side.

Q2: What sort of latency issues might occur?

A2: Refer to Shane's answer from meeting 2.

Q3: Is it possible to tie direction to the central system? Let's say a pedestrian wants to cross the street in NB direction using east leg, does Kinetic identify approaches in such a way that it would be possible to join by direction/approach?

A3: Easy way is to request time for a phase not a direction. There is setting available in the "configuration" of Maxview which will require some work if app goes into production phase and this is the direction that is chosen. Himanshu will get back to Avenue with a .csv file exported from "configuration".

Q4: After ped has placed a call, is there a way to send feedback to the app?

A4: Phase and call status is readily available in Maxview once a call is placed and can be sent out. Getting the time estimate will require CV license. Himanshu will check to see if the time estimate is for “veh phase” or “ped phase” and get back. If it is “veh phase” then the estimate will require some adjustment (Leading Pedestrian Interface, LPI)

Q5: Depending on different ped speeds, is there a way to manipulate ped times? As in walk 3, walk 4,…

A5: This involved back and forth discussion between Mark and Himanshu. Kinetic has an option of walk extension (with a maximum value of walk max) with which if pedestrians are detected within the crosswalk can extend walk time before the flash “don’t walk” (FDW) starts. This was the result of requests from GDOT and ODOT, especially useful for event management. But this will not be very helpful for this particular scenario as we want the extension of the ped clearance not the walk time. Another option might be putting the cross traffic into hold and add vehicle extension later to the same phase. However, this might cause constant changes to signal timing and hence not be an option → Further brainstorming and solution development needed for this.

Q6: What happens when Kinetics is going through a software update? Will the app lose connection?

A6: Maxview requires an update annually when it shuts down for maximum 6 minutes in the middle of the night. There has to be a failsafe message embedded into the app that if it cannot connect it shows a message “app not available”. Kinetic (Graph QL) will not need to be updated.

Q7: What happens if Kinetic loses COM?

A7: Maybe it will return NULL values. Himanshu will confirm and get back.

Q8: What other known issues might interfere with the app?

A8: Intersection in flash, if the user is commanding a phase hold the cross direction will not get a ped phase, preemption and sometimes TSP (if omitting peds)

Meeting closes with some action items for Himanshu Wad. He will confirm and compile the answers and get back to Avenue by the end of the week.

APPENDIX E: FOLLOW UP STAKEHOLDER MEETING SUMMARY

This appendix summarizes the efforts from the follow-up meeting with stakeholder groups. It involved people from the initial stakeholder meetings. In these meetings, the ideas generated in the initial stakeholder meetings were presented and the stakeholders were given the opportunity to add or modify any of the topics mentioned in the documents developed so far. Additional ideas are listed below.

- Angelo P: It will be important to research the needs of senior and elderly people because of the difference in the community when it comes to technology and mobility.

- Q: How would we prevent abuse from motorists? GPS-based system or show the whole network. (Michael B)

    - A: Speed based issue, going so fast will turn off the app. Proximity based, must be in proximity of the crossing (David B.)

- Glenn B: There should be a way to share summary stats. Distribution of the data, rather than individual data.

- Angelo P: Things to keep in mind - "No decisions about us without us" for making decisions for the disabled community and blind community, for example. The focus groups will help with this. They should be as diverse as possible.

- Shawn L: Consider how many users will be using the bus.

- Q: Do we know if it is possible to push the button from the app and go to the button to our signal? (Trevor E.)

    - David B: It would bypass the button and show up as a ped request.

- Glenn B: A thought on the GPS data, we can make a list of which signals have better tracking ability and which ones have weak signals. Through cell phone signal information, we should be able to do that.

- Glenn B: There can be an option for offline version of the app, connect the app to the connected vehicle structures, we already have the infrastructure to tie those into.
  - David B: Ultimately it would not be adding equipment to the app, but as the connected vehicle technology gets added, it can help with letting drivers know when someone is crossing nearby.
- Glenn B: Having it connected to the Connected Automated Vehicle structures, get a warning on your phone if a vehicle is approaching, reminder to pay attention to when ped phase is ready.
- Trevor E: Talking about our transition plan, request accessibility or improvements.
- Ivana V: User settings, would it be possible to have more customizable settings?
  - David B: We have not fully defined the user settings; we will need to have some sort of time aspect included.
- Glenn B: Did we confirm what kind of restrictions are with additional walk time?
  - Mark T: a) We cannot change the counted down timer, so we could extend all red time if there is a ped there or extend the adjacent green. b) Program a second walk-up for those in a group who need more walk time.
- Glenn B: A combination of multiple methods may be needed to help with those who need more walk time.
- Ivana V: Documenting near-misses through the app
- David B: More on the connected vehicle or manual input. Without connected vehicles, the ped will have to say if a car almost hit them. User feedback or a part of the connected vehicle phase.
- Mark T: We have to start thinking about the internal cost and resource cost, any way to put an estimated cost on the resources. One stakeholder feels the app does not include

everyone, so they do not support it. But they are wanting audible push buttons. Even if something like this works, the feds will try and get us to put noisy push buttons everywhere.

- Travis E: We will probably have to do both. Making the app itself ADA accessible. Incorporate colorblindness. There are different levels of ADA accessibility for media and a resource to go to reference.

- Glenn B: UDOT Communications may work with this and be a resource. UDOT HR could also help.

APPENDIX F: MOBILE APP CONCEPT OF OPERATIONS RATINGS SURVEY SHEET

This appendix shows the survey spreadsheet shared with the stakeholders.

	Glenn Blackwelder	Mark Taylor	Michael Blanchette	Stephanie Tomlin	Travis Evans	Trevor Egan	Christopher Siavrakas	Derek Lowe	Ivana Vladisavljevic	Angelo Papastamos	Heidi Goedhart	Rudy Zamora	Jim Palmer	Shane Johnson	Tom Stiles	Himanshu Wad
SCOPE																
Make signal crossings more accessible and useable for pedestrians needing ADA assistance																
Define what data is essential vs. optional for login																
No additional equipment at the signals																
Applied systemwide																
Target fiber-connected signals (95% of Utah signals)																
Aimed at helping those with disabilities (but can design it for others too)																
Accommodate cyclists if possible																
USER ORIENTED OPERATIONS																
Navigation feature / route options																
Ability to work as/with a navigation app																
Provide a special device for people without smartphones																
Flashlight automatically turned on during dark hours while crossing																
Vibration and/or audio interactions to help the hearing/visually impaired																
Simple and large buttons																
Customizable mode profile for each person																
Customizable interface level (simple/complex)																

Phone accessibility modes able to interface with the app																
Work-arounds for those who struggle to use apps/technology																
Remove the requirement of pushing the ped button at a signal																
OPERATIONAL NEEDS SYSTEM FUNCTION																
Ensure/confirm people are requesting time for the direction they desire to cross																
High degree of accuracy in giving time to the direction the user is trying to cross																
Accurate GPS data																
Tracking capability																
Distinguishing between bikers and peds																
Real-time countdown until ped crossing in the app																
User able to request more crossing time, to request green/walk extension, and/or have the system adapt to the user’s walking speed and request the correct amount of time																
Offline version of app available																
Provide info on how far away the next ped crossing is																
Integrated with connected vehicle interfaces to alert drivers of crossing peds/bikes in their paths																
Ability to work on other smart devices besides phones (e.g., watches)																
OPERATIONAL NEEDS ORGANIZATION NEEDS																
Capability to bar misuse of the app																
Capability to limit use of the app to intended modes only																
Identify signals with a large number of users that request more time																
Communicate with UDOT Click 'N Fix through the app to request signal fixes																
Rank possible routes according to usability/comfort based on origin-destination data																
Estimate pedestrian delay																
Inform users which ped phase is up next																

Inform users of the amount of real time until their ped phase is coming																
Give an audible/vibration warning shortly before the phase starts to allow the user to prepare to cross																
OPERATIONAL NEEDS DATA																
Collect user walking speed																
Collect ped/bike volume																
Collect user feedback on intersection/crossing experience																
Collect user feedback on near-misses																
Develop pedestrian Arrival on Green (AoG) metric																
SYSTEM OVERVIEW																
Database with sufficient storage																
Compatible with Android and iPhone																
GPS and accuracy information																
Bluetooth																
Fiber-connected signals																
Central system (Maxview/Kinetics)																
Map interface																
Focus groups/testers																
Backup connections/servers																
One-step/two-step sign in																
JSON protocol																
NTCIP protocol																
Messaging: Pedestrian info -J2735, SAE message																
OPERATIONAL & SUPPORT ENVIRONMENTS																
Doesn't overload a user's cell phone data																
GPS accuracy																
Identify latency due to connection issue or network coverage (4G/5G)																
Data-free version/setting																
Collection of feedback and/or rating of the app																
Auto-start feature when walking outdoors is detected																

OPERATIONAL SCENARIOS																
Keeping the app passive / avoiding need of constant hands-on																
Ability to request more crossing time (either user- or system- requested)																
Integrated with connected vehicle interfaces to alert drivers of crossing peds/bikes																
Inform signal if pedestrian has not cleared the intersection when red begins and/or alert user when the conflicting movement gets a green light																
Driver mode that alerts them of pedestrians that may cross their path																
Backup connections/servers																
Live countdown with delay estimates																