Development of AccessPath: A pedestrian wayfinding tool tailored towards wheelchair users and individuals with visual impairments

Final Report

Final Report: September 2, 2020

Publication Number: FHWA-JPO-21-846

U.S. Department of Transportation

Produced by ATTRI BAA – Development of AccessPath: A pedestrian wayfinding tool tailored towards wheelchair users and individuals with visual impairments

U.S. Department of Transportation FHWA Office of Operations

Notice

Quality Assurance Statement

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

Technical Report Documentation Page

1. Report No. FHWA-JPO-21-846	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Development of AccessPath: A pedestrian wayfinding tool tailored towards wheelchair users and individuals with visual impairments; Phase 1 Final Report		5. Report Date September 2, 2020 6. Performing Organization Code
7. Author(s) Eric Sinagra		8. Performing Organization Report No.
9. Performing Organization Name and Address Pathway Accessibility Solutions, Inc. 1401 Forbes Ave Suite 303 Pittsburgh, PA 15219		10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH6117C00005
12. Sponsoring Agency Name and Address U.S. Department of Transportation ITS Joint Program Office 1200 New Jersey Avenue, SE Washington, DC 20590		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

pathVu is developing AccessPath, a pedestrian wayfinding app tailored towards wheelchair users and people with visual impairments. Typical pedestrian wayfinding apps do not use the sidewalk network to provide navigation, nor do they know the quality of the routes that they direct their users. In addition, these apps are not user-friendly for people with disabilities. AccessPath considers the pathway network, quality of routes, and user settings when suggesting pedestrian routes to travel. AccessPath can be used for pre-trip planning or real-time navigation.

17. Keywords	18. Distribution Statement
Pedestrians with disabilities, smartphone app, navigation, wayfinding, accessibility, walkability	

19. Security Classify. (of this report)	20. Security Classify. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	75	

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

Acknowledgements

Pathway Accessibility Solutions, Inc. (pathVu) would to acknowledge and thank the many people who were involved in the success of this project, specifically the University of Pittsburgh, ACHIEVA, and the many individuals who participated in focus groups, testing, and surveys. We would like to especially thank the ATTRI team for your guidance and support throughout the project and for the opportunity to develop a well-needed tool for people with disabilities.

Table of Contents

List of Tables

List of Figures

Executive Summary

ATTRI Background

The United States Department of Transportation's (USDOT's) Accessible Transportation Technologies Research Initiative (ATTRI) is a joint USDOT initiative, co-led by the Federal Highway Administration (FHWA), Federal Transit Administration (FTA), and Intelligent Transportation Systems Joint Program Office (ITS JPO), with support from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR), and other federal partners. The ATTRI Program is leading efforts to develop and implement transformative applications to improve mobility options for all travelers, particularly those with disabilities. ATTRI research focuses on removing barriers to transportation for people with visual, hearing, cognitive, and mobility disabilities. Emerging technologies and creative service models funded by ATTRI offer all Americans enhanced travel choices and accessibility at levels once only imagined. The USDOT has awarded application development funding for Wayfinding and Navigation, Pre-trip Concierge & Virtualization, Safe Intersection Crossing with NIDILLR awarding a grant in the Robotics and Automation technology area. Working together, the four technology areas will provide the basis for an accessible transportation network that is far more economical, expansive, and welcoming than we have now, which is of increasing importance not only to travelers with disabilities, but to all travelers in the United States.

AccessPath

The overall goal of this project was to develop a mobile app that provides pedestrian navigation and directions to people with disabilities based on their abilities to navigate sidewalks and pedestrian pathways. Typical travel apps neither focus on pathway quality nor consider the user's comfort navigate those routes. To that end, AccessPath provides real-time step-by-step directions customized to a user's comfort settings. Each pedestrian has unique abilities and disabilities, and so their routes must be customized to their individualized needs. The app provides the ability to submit reports about hazards, construction, accessible entrances, and the level of accessibility indoors. This enables people with disabilities to contribute data to help others as well as understand important accessibility features about points of interest. The app provides other important features such as favorites, alerts, recent paths, What's Around Me, and VoiceOver/TalkBack compatibility.

Every feature that was integrated into AccessPath was a result of numerous discussions and involvement from people with disabilities. Four focus groups were conducted, one with each of the following disability groups: mobility/wheelchair user, blind/visually impaired, cognitive disability, and hearing impaired. Further, people with disabilities were included from the beginning of the project to identify key design components, such as button size, text size, and screen reader compatibility. In Phase 2, a survey was conducted with people with disabilities to understand which features should be prioritized in future development efforts. This list prioritizing feature development helped to identify the features to be included during Phase 2.

The data that was collected for this project was primarily done with pathVu's proprietary pathMet device, which identifies sidewalk conditions such as tripping hazards, roughness, running slope, cross slope, imagery, and geo-location. pathMet is further described below. pathMet data was collected in Pittsburgh, PA during Phase 1 to serve as a test dataset (60 miles). During Phase 2, pathMet was collected in Washington, DC (50 miles) in order to continue to scale and test in other cities. In order to test scalability in a remote city without pathMet data, sidewalk and curb ramp data was collected in Portland, OR (50 miles) using aerial imagery. This type of data provides only the shortest route compared to custom routes when using pathMet data. Following this project, pilot studies will be conducted in Portland and Washington, DC as a way to continually implement, develop, and test the app.

In order for others to be able to utilize the routing capabilities and algorithms developed as part of this project, an application programming interface (API) was developed. The API has three components: Routing, Locations, and Users. These APIs allow other developers to implement the major components of the AccessPath app, including navigation, reporting, and user comfort settings. This project not only provides a standalone app to be used, but provides future development capabilities that work towards the goal of a Complete Trip.

This project's focus was to provide routes that customized to each user's ability to navigate rather than the assumption that a sidewalk exists and that it is equally navigable for every user. The major accomplishments of this project include:

- Development of Android and iOS smartphone apps that provide accessible pedestrian directions. These apps allow users to identify the best routes for them to travel, submit reports about potential hazards and accessibility features, and receive alerts to hazards along the route, allowing them to be more independent.

- Development and documentation of APIs for use by developers to integrate into future development projects, such as a multi-modal transportation app. The APIs provide pedestrian routing, location and reporting, and user settings services. Pedestrian routes are based on algorithms that consider pathway quality and user settings.

- Data collection was conducted to test and scale the app performance areas. Data was collected in Pittsburgh, PA using pathMet (60 miles), Washington, DC using pathMet (50 miles), and Portland, OR using high definition aerial imagery (50 miles).

pathVu Background

pathVu is a startup (private C Corp) located in the City of Pittsburgh whose mission is to build a global database of sidewalk and pedestrian pathway data to improve the accessibility, mobility, and safety of all pedestrians – of any ability. pathVu utilizes proprietary technology to collect high-fidelity data about sidewalk conditions. pathVu works with cities and civil engineering to help collect accurate, high-quality sidewalk data and to prioritize improvements to the infrastructure. pathVu spun out of the University of Pittsburgh in 2014 where its co-founders researched the effects of sidewalk conditions on wheelchair user comfort, leading to the development of a ASTM International standard regarding the measurement of sidewalk roughness. Sidewalk roughness is used in this project as one of the comfort settings in the app, described in more detail below.

Chapter 1. Technology Background

Data Framework

A useful framework used to describe pathVu data is through our Sidewalk Data Solution Table (SDST) below (Table 1), which describes the type and quality of sidewalk data that our tools collect (Level 1-4), and how it can benefit both pedestrians and municipalities. The cells with dark borders indicate work that had been completed prior to this project, and the two cells with dashed borders indicate work that was completed by developing AccessPath. As will be described below, pathVu is able to collect Levels 1-4 type using existing data or tools developed. Level 1 & 2 data can be provided in useful ways to Municipalities, and Level 2 data for pedestrians. AccessPath allows pedestrians to benefit from Level 3 & 4 data by planning routes along the highest quality sidewalks, and providing them re-routing options when they are confronted with inaccessible pathways.

Table 1: Sidewalk Data Solution Table

Data Quality Level	Description	Use of Data for Municipalities	Use of Data for Pedestrians
Level 1	Sidewalk/Crosswalk Center Lines	Basic Analytics & Statistics	Accurate path visualization for self-navigation
Level 2	Discrete Attributes, e.g. trip hazards	Location and prioritization of sidewalk repairs	Identification of hazardous paths
Level 3	Connected Network of Paths	Not Applicable	Wayfinding/Navigation around problem areas
Level 4	Continuous Attributes, e.g. roughness	Not Applicable	Wayfinding/Navigation fully accessible routes

pathMet

pathVu has developed two data collection tools so that Levels 1-4 data can be collected. pathMet (Figure 1) is a multi-sensor rolling sidewalk profiling tool. pathMet includes a GPS, cameras, a laser profiler, a gyroscope, accelerometer, and encoders. The system generates high fidelity data, allowing it to simultaneously collect Levels 1, 2 and 4 data and Level 3 (connected sidewalk network) can be immediately generated from the data. pathMet identifies the following pathway conditions continuously as it is pushed along the surface: geographic information systems (GIS) location, WPRI (wheelchair pathway roughness index), running slope, cross slope, tripping hazards, length, and width, all while collecting images every ten feet.

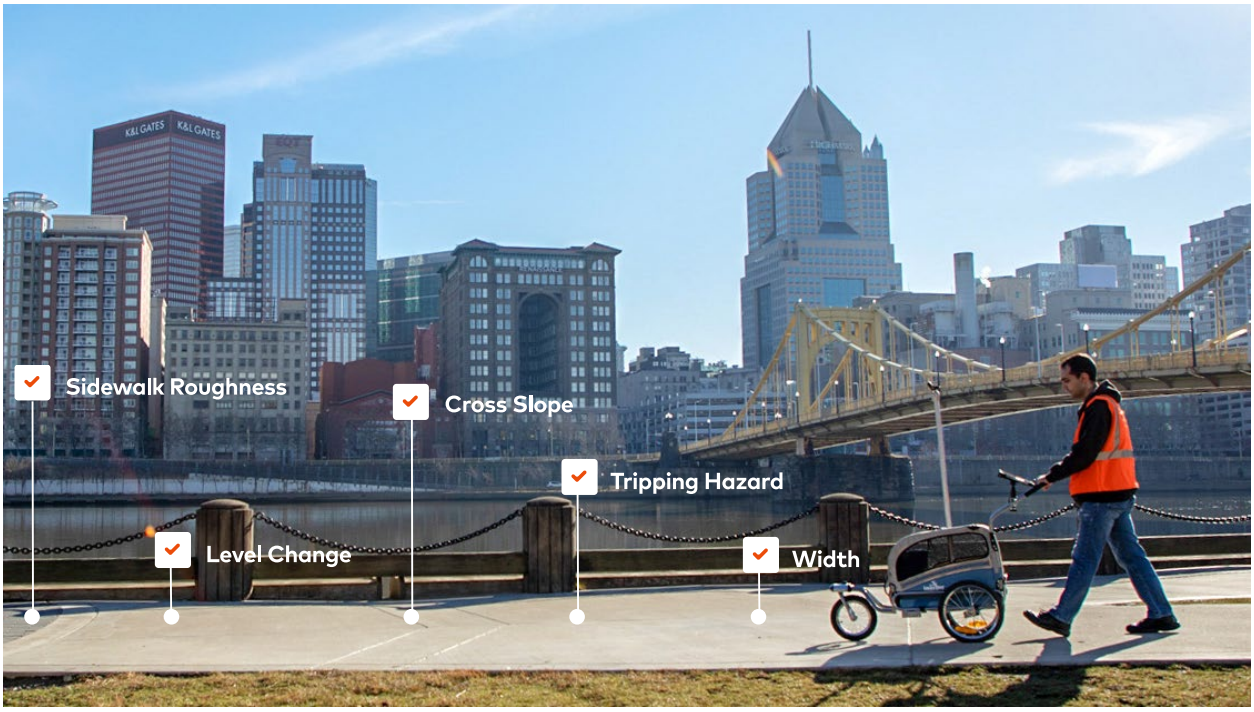

Figure 1: pathMet Image of Data Collection (Source: pathVu)

pathVu Crowdsourcing App

pathVu has developed a mobile application, the pathVu Crowdsourcing App (Figure 2) for both Android and iOS which can be used by pedestrians. The tool facilitates 'crowdsourcing' of sidewalk attributes and since its launch, pedestrians have collected thousands of sidewalk attributes in cities across the U.S. and in a select number of cities internationally. pathVu Crowdsourcing app features not only allow users to report the location of pathway attributes, but users can confirm the existence of previous reports and even suggest edits to existing reports. pathVu has integrated this crowdsourcing functionality into AccessPath. As a result, the old pathVu Crowdsourcing app is outdated and will be replaced by AccessPath.

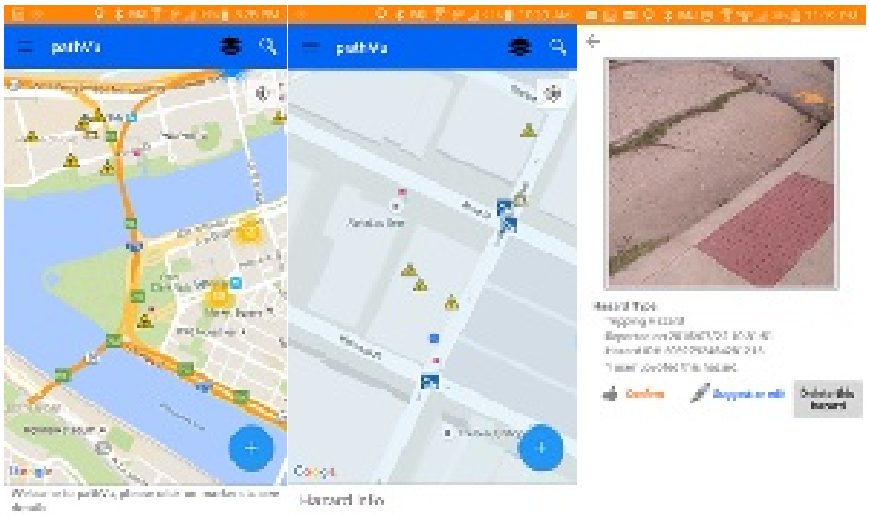

Figure 2: pathVu Crowdsourcing App Screenshots (Source: pathVu)

pathVu Data Visualization

pathVu's data visualization (Figure 3) for municipalities is tailored toward their needs, but most commonly a sidewalk quality report is generated, which includes a shapefile (typical for GIS data) that provides highly detailed information that can be visualized on popular software platforms such as ArcGIS and Google Earth. pathVu also provides a customized visualization platform through a website login for clients. The online map as well as the pathVu Crowdsourcing app are the visualization tools offered free of charge to pedestrians. Thus, the pathVu Crowdsourcing app serves as both a data collection tool for pedestrians as well as a visualization tool. A pedestrian can open the app to collect and review sidewalk attributes that are nearby to their location using a satellite or more basic base-map to help with visualization.

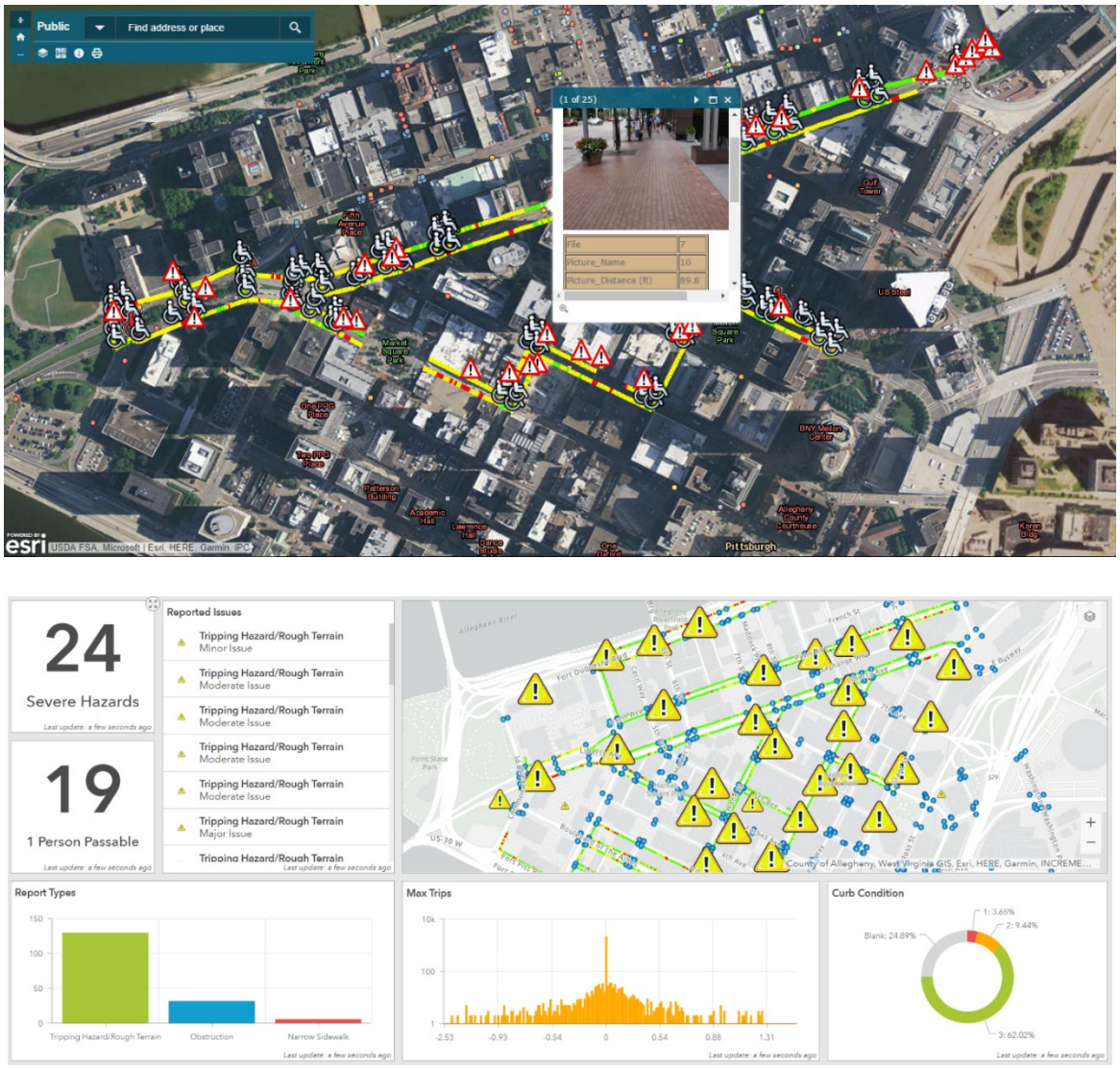

Figure 3: pathVu Data Visualization (Source: pathVu)

Personalized Navigation System (PNS)

Dr. Hassan Karimi, our colleague and collaborator on this project, has prototyped a personalized navigation system (PNS) that operates on the University of Pittsburgh campus. Dr. Karimi's team have manually collected Level 1, 2 and 4 data, and generated a connected sidewalk and crosswalk network of the University of Pittsburgh (Level 4) (Figure 4). The PNS allows pedestrians to plan routes around campus, and the routes can be tailored to their preference related to sidewalk slope, cross-slope and whether there are stairs along the route. PNS is currently a web-based system which can be accessed either through a traditional web browser or on a mobile device, through the mobile web browser. Example of two route options are shown in Figure 5.

Figure 4: University of Pittsburgh map of connected sidewalks and crosswalks
(Source: University of Pittsburgh)

AccessPath combines Dr. Karimi's PNS and the pathVu Crowdsourcing App, and result in real-time navigation functionality and crowdsourced data. Data used in AccessPath can be collected with pathMet, AccessPath, manually, or aggregated from open-sourced data.

Figure 5: PNS interface (shortest path in blue, personalized path in red)
(Source: University of Pittsburgh)

Clearly existing approaches and techniques have been focused only on pre-trip planning solutions which, while needed, are not complete as they do not have the navigation component. This project is focused on both wayfinding (pre-trip planning) and navigation (step-by- step real-time guidance through localization) solutions. Therefore, the advantages of AccessPath compared to other related projects are that: (a) AccessPath provides a complete mobility assistance solution to pedestrians, i.e., both wayfinding and navigation; (b) The AccessPath approach utilizes pedestrian pathways (sidewalks), which currently are not widely digitally available; and (c) AccessPath takes into account the ADA standards in building the sidewalk database for wayfinding and navigation.

Chapter 2. Phase 1 Development

Overview

The primary objective of Phase 1 was to develop a mobile app that provides people with disabilities with accessible pedestrian navigation. As a way to understand the needs of people with disabilities, a focus group was conducted with people with mobility and visual disabilities. Since the initial target audience of this project was people with mobility and vision disabilities, Focus Group 1 included five wheelchair users, five people with a vision impairment, one wheelchair user with a vision impairment, and one caregiver without a disability. Focus groups with people with cognitive and hearing disabilities are described later.

This focus group established “must-have” features and recommended design considerations for the mobile app. These must-have features are summarized below. Focus Group 1 was conducted prior to any app development, which provided important design feedback. Lastly, this focus group identified the type of data needed to be collected in order to meet their requirements.

User Needs Identification: Focus Group 1

This section describes the objectives, protocol, and results of the Focus Group 1. The testing was conducted on August 8, 2017 and August 9, 2017 as two sessions. The focus group was led by Eric Sinagra, pathVu CEO and project manager. Five participants participated in session 1: three wheelchair users, one visually impaired, and one wheelchair user with a visual impairment. Five participants participated in session 2: two wheelchair users, two visually impaired, and one without a disability but a visually impaired caregiver.

The primary objective of the focus group was to hear from people with wheelchair users and people with visual impairments to understand how AccessPath should be designed and which features to include. By listening to the needs of users, we could more accurately design the app around what the user wanted rather than based on our pre-conceived assumptions. The feedback allowed us to understand how to incorporate accessibility-friendly functionality, which features were most important, and how the app should look and feel from a visual and non-visual perspective. These objectives were met by identifying the answers to the five primary questions shown below.

1. How do uses move around the community? What troubles do they have?
2. What apps do they use on a daily basis?
3. What features do they like to see in apps? What features do they dislike?
4. What are the “Must Have” and “Like-To-Have” features in a pedestrian navigation app?
5. What design features are most important?

Wheelchair User Must-Have Features

Wheelchair users identified this list of features as those that must be included in the app. The bullet under each item describes how this feature was implemented into the app.

- ***Sidewalk location*:** The ability to see the location of sidewalks and other pathways on a map shown in the app. Further, using the sidewalk location to provide navigation options.
    - This feature is implemented in the Set A New Path and Preview Destination features described above. Users receive directions from their origin to their destination along the sidewalk/crosswalk network. Further, the map screens identify the sidewalk location and condition based on a green-yellow-red color coding, where green is good, yellow is moderate, and red is a bad sidewalk.
- ***Crosswalk location***: The ability to see the location of crosswalks and other pathways on a map shown in the app. The quality of the crosswalk nor the details (crossing signal attributes, type of crosswalk, etc.) need to be included as a must-have feature. Further, the crosswalks should be used to provide navigation options.
    - This feature is implemented in the Set A New Path and Preview Destination features described above. Users receive directions from their origin to their destination along the sidewalk/crosswalk network. Further, the map screens identify the sidewalk location and condition based on a green-yellow-red color coding, where green is good, yellow is moderate, and red is a bad sidewalk.
- ***Curb ramp***: The ability to see the location of curb ramps and missing curb ramps on a map shown in the app. Further, the general condition and whether the curb ramp is passable or not should be identified. The location of curb ramps (or those that are missing) should be considered in navigation so that the route avoids missing curb ramp locations.
    - All maps in the app include curb ramp locations and visualize them on the map via a blue icon. Users have the ability to turn this layer visualization on/off. If the data has been collected about the curb ramp, the overall quality of the curb ramp can be viewed by selecting the curb ramp icon on the map. A pop-up menu appears with the image, slope rating, lippage rating, and overall rating. Missing curb ramps act as barriers that re-route a user along a different path.
- ***Impassable segments***: The ability to understand which pathway segments are unpassable. This should be built into a step-by-step navigation feature. Participants identified possible segments that should be considered impassable:
    - Construction
        - The Set A New Path and Preview Destination features will route users around segment identified as Construction.
    - Tripping hazard greater than certain height (3 inches)
        - Set A New Path and Preview Destination consider the location and severity of tripping hazards and will re-route a user based on the pathway condition and the users specified comfort settings.

    - Running slope of certain degree (10 degrees)
        - Set A New Path and Preview Destination pathway running slope and will re-route a user based on the pathway condition and the users specified comfort settings.
    - Cross slope of certain degree (4 degrees)
        - Set A New Path and Preview Destination consider pathway cross slope and will re-route a user based on the pathway condition and the users specified comfort settings.
    - Width less than certain amount (20 inches)
        - Set A New Path and Preview Destination consider pathway width and will re-route a user based on the pathway condition and the users specified comfort settings.
    - Broken segment/Rough that is too severe
        - Set A New Path and Preview Destination consider pathway roughness and will re-route a user based on the pathway condition and the users specified comfort settings.
- ***Audible/Vibrate alerts as you approach a hazard***: Participants would like to be alerted to hazards as they approach an object, similar to an app they are familiar with called Waze. Participants want the app to provide audible cues (and haptic if possible) as they approach potential hazards.

    - The Comfort and Alert Settings menu allows users to turn on/off the alert feature which audibly and visually alerts users as they approach a reported tripping hazard.

- ***Reads step-by-step directions***: Participants want the real-time, step-by-step directions for the suggested route read to them aloud. Like typical apps, the directions should update as they progress along the route.

    - The Set A New Path feature provides users with audible and visual step-by-step directions as users travel along their specified route.

- ***Profile options***: Participants want to have the ability to choose from preset settings and user types tailored to their user preferences.

    - Users can choose from preset profile options or customize their settings in the Comfort and Alert Settings menu.

Wheelchair User Design Recommendations

Wheelchair users identified this list of design features that they would like to see implemented in the design to make the experience more accessible and user-friendly. Throughout the design process, our team attempted to implement these design requirements to help make the app accessible. Much progress has been made to implement each of these features, however we believe continued testing and feedback is needed to perfect accessibility, especially regarding one's ability to use the app completely without use of one's hands.

- ***Large button sizes***: Wheelchair users would like to have large button sizes implemented in the design of AccessPath. Many wheelchair users have dexterity challenges, and large button sizes provide them with a better ability to press the intended button. Further, this provides better visualization for those with low vision.

- ***Ability to be used without use of hands***: Wheelchair users would like the ability to use AccessPath without the use of their hands. This means that the user wants the navigation to be hands-free as they are travelling around and after the destination has been sent. Although it would be nice to be able to set the destination verbally, this was not a requirement.

- ***Simple***: Wheelchair users expressed the desire for the interface to be clean and simple. They would like the screens designed without clutter. A simply designed interface makes the app easy to understand and easy to select the desired app features. Just like the large button sizes, this makes the app easy to operate.

Blind/Visually Impaired Must-Have Features

People with visual impairments identified this list of features as those that must be included in the app. The bullet under each item describes how this feature was implemented into the app.

- ***Screen Reader***: Participants would like the ability to use the phones screen reader (VoiceOver or TalkBack) with all applicable attributes of the app.

    - The appropriate text descriptions and tags have been applied to buttons so that VoiceOver and TalkBack can be used throughout the app. It has been tested with all parts of the app. The only component of the app that is not functional with the screen readers is the map itself, which is a heavily visual-based feature.

- ***Audible/Vibration alerts***: Participants would like to be alerted to potential hazards in their path as they approach those conditions. They would like to be re-routed around locations that are inaccessible, such as where there is construction. They would like these alerts to be both audible and haptic (if possible).

    - As identified above, these features are implemented through the Set A New Path, Preview Destination, and Alerts features of the app. The app audibly alerts users as they approach reported hazards and provides audible step-by-step navigation directions.

- ***Reads step-by-step directions***: Participants want the real-time, step-by-step directions for the suggested route read to them aloud. Like typical apps, the directions should update as they progress along the route.

- ***Repeat directions button***: Participants would like the ability to request that the app speak the current directions again. For people with visual impairments, this is valuable to constantly be reminded of the current step along the route.

    - The Set A New Path feature provides users with audible and visual step-by-step directions as users travel along their specified route.

- ***Pre-trip planning***: Participants would like to be able to virtually walk through the steps of their trip prior to experiencing it in the real world. This will allow them to familiarize themselves with the route ahead of time.

    - The Preview Destination feature provides the ability to virtually walk through the directions from an origin to destination. Users can see the route on the map or follow the list of directions. The list of directions has the ability to repeat the directions, advance to the next step, or view the previous step allowing people with visual impairments to make a mental map of the route.

- ***Orientation***: Participants would like a feature that announces their current orientation and location in case they "get turned around" and lose their bearing.

    - This feature is implemented as part of the initial direction read to the user in the Set A New Path feature. There are challenges in accurately implementing this feature, especially because it is often required that the user starts moving prior to receiving their orientation.

- ***Sidewalk location*****:** The ability to see the location of sidewalks and other pathways on a map shown in the app. Further, using the sidewalk location to provide navigation options. However, some users did say that they sometimes still walk along routes that do not have a sidewalk.

    - The maps shown in the app always show the sidewalk and crosswalk locations that have been collected and included in the database. These paths can serve for purely visualization purposes or be included in the suggested routes via their condition data.

- ***Crosswalk location***: The ability to see the location of crosswalks and other pathways on a map shown in the app. The quality of the crosswalk nor the details (crossing signal attributes, type of crosswalk, etc.) need to be included at this time. Further, the crosswalks should be used to provide navigation options.

    - The maps shown in the app always show the sidewalk and crosswalk locations that have been collected and included in the database. These paths can serve for purely visualization purposes or be included in the suggested routes via their condition data.

- ***Curb ramp location***: The ability to understand the location of curb ramps and missing curb ramps. Further, the general condition and whether the curb ramp is passable or not should be identified. This is helpful when navigating intersections.

    - All maps in the app include curb ramp locations and visualize them on the map via a blue icon. Users have the ability to turn this layer visualization on/off. If the data has been collected about the curb ramp, the overall quality of the curb ramp can be viewed by selecting the curb ramp icon on the map. A pop-up menu appears with the image, slope rating, lippage rating, and overall rating. Missing curb ramps act as barriers that re-route a user along a different path.

- ***Impassable locations***: Understanding the location of impassable pathway segments is very important for people with visual impairments. This is especially important to understand ahead of time. Participants would like the app to route them around impassable areas, such as when there is construction. Further, they would like the ability to adjust their settings based on their level of comfort. For example, some people are comfortable navigating mild construction while others may not feel comfortable.

    - The Set A New Path and Preview Destination features consider construction and the user's ability to navigate certain pathway features when suggesting routes. The routes do not consider the level of construction being conducted (mild vs impassable) but will do so in future versions of the routing algorithms.
- ***Profile options (default and presets)***: Participants want to have the ability to choose from preset settings and user types tailored to their user preferences.
    - Users can choose from preset profile options or customize their settings in the Comfort and Alert Settings menu.

Blind/Visually Impaired Design Recommendations

People with visual impairments identified this list of design features that they would like to see implemented in the design to make the experience more accessible and user-friendly. Throughout the design process, our team attempted to implement these design requirements to help make the app accessible. Much progress has been made to implement each of these features, however we believe continued testing and feedback is needed to perfect accessibility. Of the design requirements identified below, the one with the most room for improvement is the app contrast, especially within the map itself.

- ***Compatible with VoiceOver and TalkBack***: One of the most important design features for people with disabilities is for the app to be compatible with VoiceOver and TalkBack. Many people with visual impairments use this feature as a regular means of using a smartphone, and this is an important feature to be included.

- ***Conversational language***: People with visual impairments would like the text language in the app to be conversational so that they understand what will happen when a button is pressed. When an app is not conversational, the text is often short and unclear. This can make it difficult to understand what will happen next in the app, especially after selecting a button. By making the app conversational, it should avoid confusing language and make it more user-friendly.

- ***High contrast***: People with low vision would like the app design colors to have high contrast. The high contrast will make the text and content easier to read and see. They would also like the ability for the app to be compatible with in-phone accessibility contrast features.

- ***Simple***: People with visual impairments would like the design to be simple, structured, and straight forward. A simple design will make it easy for them to follow and limit confusion that can be caused by a cluttered screen. The app should have good flow that makes sense. Simplicity is very important for accessibility for people with visual impairments.

- ***Do not use dropdown menus***: People with visual impairments prefer menus that are not dropdown menus. Radial button menus and similar types of menus are preferred because it is easier to navigate when using VoiceOver.

Focus Group 1 Discussion

Focus Group 1 was conducted in order to understand which design and app features wheelchair users and people with visual impairments would like included in AccessPath. This feedback was the cornerstone on which our app requirements were based for Phase 1. By taking a user-centered design approach, we listened to what the end user wanted, and designed based on what they wanted rather than based on our assumptions of their needs. The focus group was conducted with 10 participants: five wheelchair users, three with visual impairments, one wheelchair user with a visual impairment, and one without a disability. The focus group was conducted by having an open discussion with participants and asking questions regarding the types of issues they have navigating sidewalks, the app features they liked, the app features they disliked, and other similar questions.

The results of the focus group were divided into must-have, like-to-have, and top design features, organized by wheelchair users and people with visual impairments. The must-have features were the ones with the highest level of priority, while the like-to-have features would be considered for future development. The design features were primarily features that should be considered to improve accessibility.

For wheelchair users, the must-have features were focused on the question, “Can I get there?” Wheelchair users’ primary focus was making sure that there was a path, curb ramps, and no major obstructions. On the other hand, the like-to-have features focused on improved route customization and additional pathway details, such as curb ramp quality, transit stop accessibility, and point of interest accessibility.

People with visual impairments’ must-have features included a route quality features as well as in-app accessibility components. Similar to wheelchair users, people with visual impairments wanted to make sure that there is a route available to get to their destination without major barriers. They also wanted to make sure that the app itself is accessible. Accessibility features that were identified as especially important are screen reader (VoiceOver and TalkBack), contrast, and audible cues.

Focus Group 1 provided a solid foundation for the features that should be included into AccessPath. Many of these features were incorporated into the app during Phase 1, while others will need implemented during future development efforts. The goal of AccessPath was to incorporate as many of these features that was reasonable. One of the challenges of this project was to build an app that is clean and simple, but meets the needs of users of all abilities.

Algorithm Development

The purpose of this section is to demonstrate the steps required to implement the routing algorithm used in AccessPath. Users set their comfortability settings within the app, which are then passed to the routing algorithms to determine the optimal route based on those custom user settings. Focus Group 1 identified the important pathway attributes to be considered by the algorithm when determining the route. Each person who uses AccessPath has different abilities and disabilities. The routing algorithms allow the user to dictate the types of routes he/she prefers to travel. A paper published by Kasemsuppakorn and Karimi [1]was used as the primary source to develop the AccessPath algorithms.

Methodology

As of the date of this report, the following parameters (previously referred to as attributes in other reports) are used in the routing algorithms: tripping hazards, running slope, cross slope, and roughness. Length is always used regardless of the other parameters included. Figure 6 shows screenshots of AccessPath and the list of possible comfortability settings. The image on the right shows a screenshot of the type of question asked for each parameter.

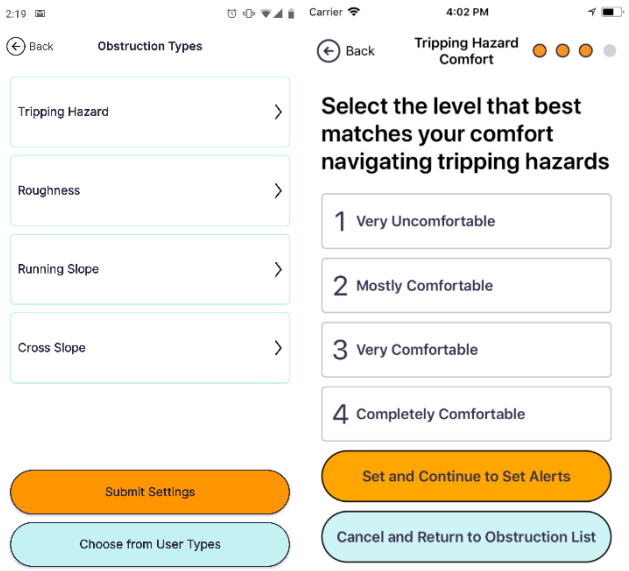

Figure 6: AccessPath Comfort Settings (Source: pathVu)

[1] Kasemsuppakorn, P. and Karimi, H. A. Personalized Routing for Wheelchair Navigation. Journal of Location Based Services, Vol. 3, No. 1, pp. 24-54 (2009).

Algorithm Protocol

The following are the steps required to take the parameters, send them to the algorithm, and output the optimal route.

1) Prioritizing parameters using Analytic Hierarchy Process (AHP) method

Step 1 involves gathering the user profile, settings, and preferences information. This information is gathered in the settings menu shown in Figure 7. Further, the user type information is gathered during the onboarding process and saved in the settings menu.

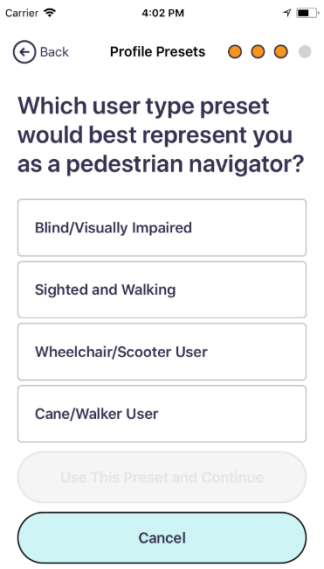

Figure 7: Screenshot of AccessPath User Type Screen (Source: pathVu)

After the user information is gathered through the app interface, a weight is assigned to each parameter. The level of importance for each sidewalk parameter must be calculated based on the user's preferences. The user preference information goes through a process where each parameter from the app is compared to the other parameters. The result is a weight for each parameter which identifies the level of impact in the algorithm and resulting route.

Quantifying Impedance Level

Next, an impedance score for each sidewalk segment must be calculated based on the user's preferences. Here, a membership function is defined for input variables (weight factors from step 1 and sidewalk parameters) and output variable (impedance level score). Then, a fuzzy inference system was designed. The fuzzy inference system consists of rules that indicate the degree of impedance for each sidewalk segment given the combination of sidewalk parameters and its weight factor.

2) Cost calculation

After establishing the weights, attribute values, and impedance level in the previous step, this information is used to calculate a cost value for each segment. The cost is used to understand how much "interference" there is for the user based on those custom settings and weights. Higher cost values will typically be avoided in an attempt to find the route with the lowest cost.

3) Computing Optimal Route: Using Customized Dijkstra's Algorithm

The last step in the algorithm process is to use Dijkstra's algorithm to calculate the optimal route using the cost values calculated in the previous step. Dijkstra's algorithm is a method of calculating the lowest cost route between points. This is often used to calculate the shortest path. In this case, Dijkstra's algorithm is used with the calculated cost values of each segment to find the path with the smallest cost. This resulting path is the suggested route displayed to the user in the app. Dijkstra's algorithm is a common method used in many navigation and routing problems. In this app, Dijkstra's algorithm is used indirectly through the API routing service used in the app. Figure 8 below shows an overview of the process that was followed above, including a breakdown of the four difference steps.

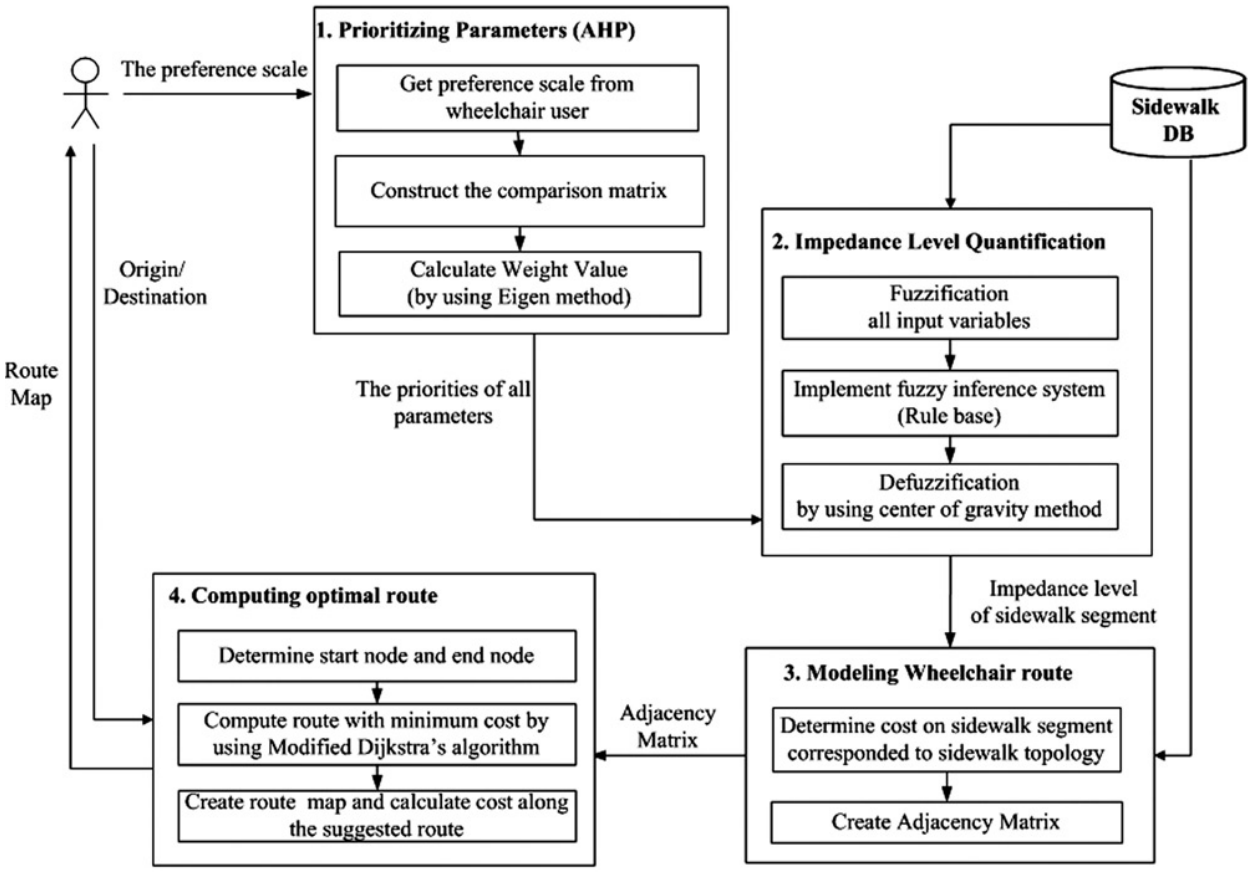

Figure 8: Algorithm Workflow Diagram (Source: University of Pittsburgh)

AccessPath Algorithm Summary

The resulting algorithms described above show the process of taking the user's comfortability settings and turning them into quantifiable values that determine the optimal pedestrian route. This workflow is specifically used to be able to accommodate the varying abilities of each user. Each user of AccessPath has different abilities, and so the suggested routes should reflect the uniqueness of each person.

During the evolution of this app, these algorithms, attribute values, and parameter ranges have adjusted in an attempt to continually improve the performance of the app. As AccessPath is continually tested, more data should be gathered regarding how people use the app and the adjustments that are needed to enhance performance. These algorithms outline the process that should be followed, but not necessarily the final values used in the calculations.

Phase 1 Features

After conducting a focus group with wheelchair users and people with visual impairments and developing the AccessPath algorithms, we began designing and building the AccessPath app. The following features were those that were developed during Phase 1.

1) ***Set A New Path***: *Set A New Path* (Figure **9**) provides real-time step-by-step directions from the user's current location to a destination. Like similar navigation apps, users can enter their destination by entering an address or searching for a point of interest. Users can use VoiceOver or TalkBack for entering their destination. Unlike typical navigation apps that use the road network to provide directions, AccessPath directions based on the pedestrian network of sidewalks and crosswalks, and considers the user's custom Comfort Settings described below.

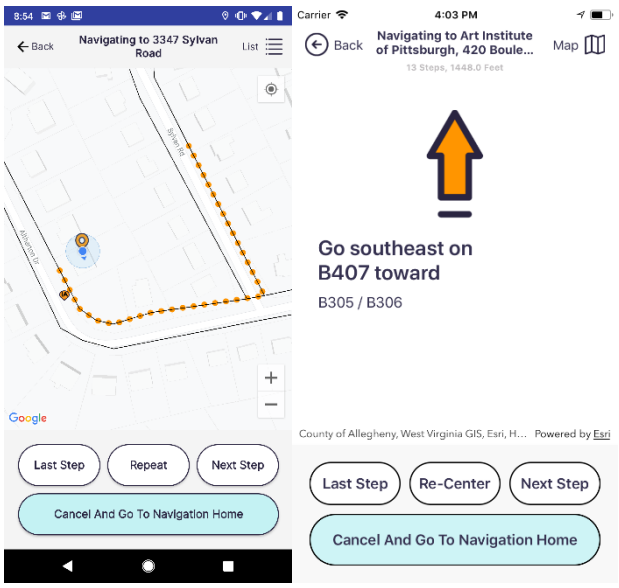

Figure 9: Screenshots of Set A New Path Feature (Source: pathVu)

2) ***Preview Destination***: *Preview Destination* (Figure 10) provides pre-trip planning directions based on a user's Comfort Settings. Like similar navigation apps, users can enter their starting/ending locations. They can do this by entering an address or searching for a point of interest. By default, the user's current location is set as the starting point. Users have the ability to walk through the set of directions to understand the details of the suggested route prior to taking the trip. VoiceOver and TalkBack can be used to set the starting and ending locations as well as virtually walk through the directions.

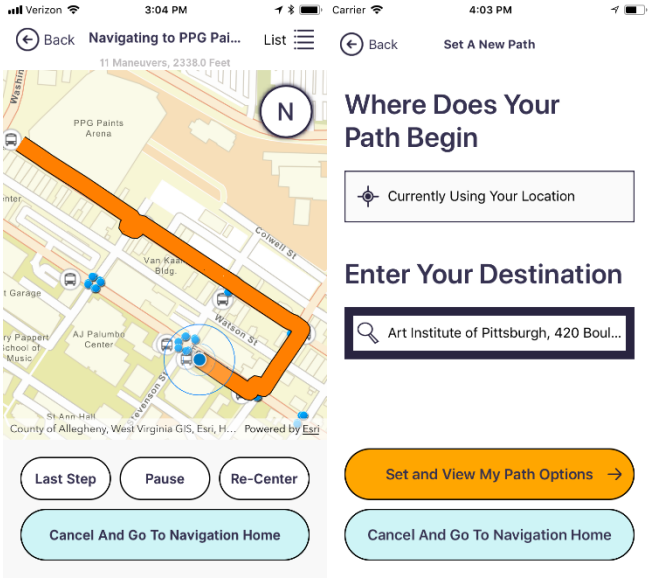

Figure 10: Screenshots of Preview Destination Feature (Source: pathVu)

3) ***Comfort and Alert Settings***: *Comfort and Alert Settings* (Figure 11) is a settings menu that allows users to specify which sidewalk attributes they prefer to travel or avoid and their level of comfort doing so. Users can set their comfort settings for the following pathway attributes: tripping hazards, roughness, running slope, cross slope, and width. Users select their level of comfort navigating each attribute, with 1 representing very uncomfortable and 4 representing completely comfortable. This information goes into the routing algorithms and determines the suggested path to travel. In addition to having custom settings, users can select from wheelchair/scooter user, blind/visually impaired, sighted and walking, or cane/walker user profiles. This is for users who prefer not to set custom settings. VoiceOver and TalkBack can be used to set one's Comfort Settings.

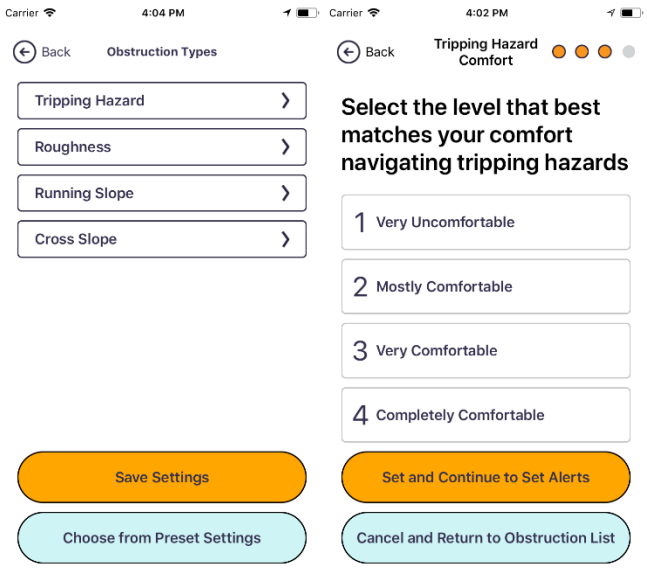

Figure 11: Screenshot of Comfort Settings Screens (Source: pathVu)

4) ***Screen Reader***: A Screen Reader, such as VoiceOver or TalkBack (Figure 12), can be used in the app so that users, especially those with visual impairments, can interact easily with the various app features. The Screen Reader is functional with all components of the app including:
    a. Set A New Path
    b. Preview Destination
    c. Comfort Settings
    d. Entering in start/end address
    e. Address/point of interest search
    f. Selecting user profiles
    g. Alerts
    h. Recents

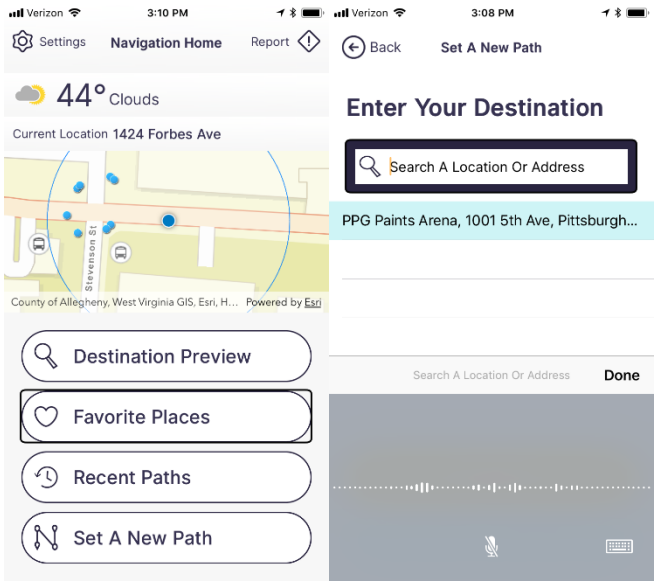

Figure 12: Screenshot Showing Screen Reader Capability (Source: pathVu)

5) ***Favorite Places:*** The *Favorite Places* (Figure 13) feature allows users to save their favorite locations for quick access or to be alerted as they approach each favorite place. Users can save their Favorite Places with custom names. When selecting a Favorite Place, the Set A New Path feature opens with directions to that Favorite Place from the user's current location.

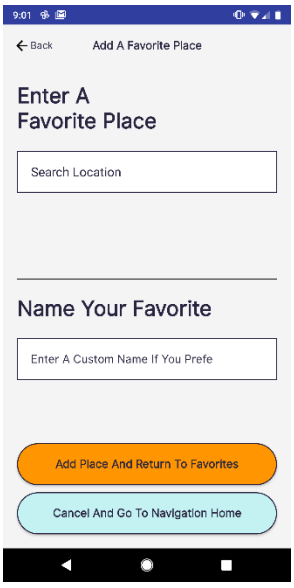

Figure 13: Screenshot of Favorites Screen (Source: pathVu)

6) ***Recent Paths:*** Similar to the Favorite Places feature, *Recent Paths* (Figure 14) is used for quick access to a user's recent destinations. This feature stores up to five recent destinations. When selecting a Recent Path, the Set A New Path feature opens with directions to that destination from the user's current location.

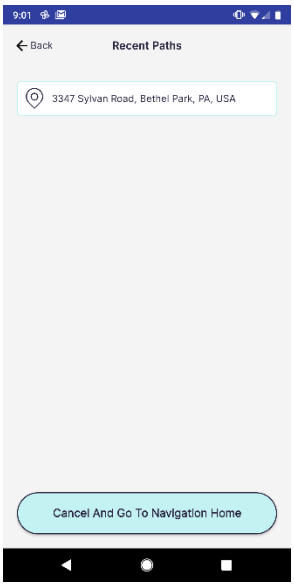

Figure 14: Screenshot of Recent Paths Screen (Source: pathVu)

7) ***Alerts***: *Alerts* (Figure 15) notify users of either their favorite locations or reported hazards along the route. Users can customize their Alerts preferences in the Settings menu. For the current version of the app, the Alerts feature is only able to be used if users are using the Set A New Path feature. This feature utilizes audible, visual, and vibrational cues to alert users.

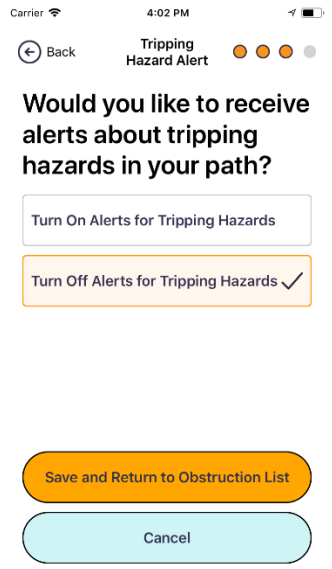

Figure 15: Screenshot of Alerts Settings (Source: pathVu)

8) ***Reports:*** Users can submit *Reports* (Figure 16) regarding potential hazards along pathways. These reports can be used to alert users of potential hazards visually, audibly, and haptically. When submitting reports, users submit an image, location, and type of report. Hazard types include tripping hazards, construction, curb ramps, and other. Users can choose to be alerted to hazard reports that are submitted. When approaching a hazard that has previously been reported, users can up-vote or down-vote whether the report still exists.

Figure 16: Screenshot of User Reports on the Map Screen (Source: pathVu)

Chapter 3. Data Collection and Implementation

Pathway Attributes

During Phase 1, we identified key pathway attributes to include in our app and API based on the Focus Group 1 results. The attributes included in this project were identified as key attributes in identifying an accessible route. These attributes are the first step in future development efforts and do not encompass all potential pathway attributes. Table 2, Table 3, and Table 4 below show the pathway (sidewalk and crosswalk), curb ramp, and transit stop attributes and their units used in the database and routing algorithms for this project. It is not a requirement that all attributes are collected for every city nor for the app to function. The main requirement for navigability is that there is a connected network of sidewalks and crosswalks.

These attributes comprise only the current attributes and do not encompass all possible attributes to be collected. Some attributes may not be used in this project but are listed below for future data collection.

Table 2: List of Pathway Attributes in the Navigation Database

Field	Description	Units
FID	Unique ID for pathway	None
Picture_Di	Image distance from the beginning of the run	Feet
Max_Roughn	Maximum roughness for that segment	mm/m
Max_Runnin	Maximum running slope for that segment	Degrees
Max_Cross_	Maximum cross slope for that segment	Degrees
Max_Trips_	Maximum tripping hazard over 0.25 inches for that segment	Inches
Num_Trips	Number of tripping hazards greater than or equal to 0.25 inches	None
Max_Dep_in	Maximum depression over 0.25 inches for that segment	inches
Num_Dep	Number of depressions over 0.25 inches for that segment	None
Overall_Le	Total length of a particular run (same file name)	Feet
Segment_RA	Route Accessibility Index (RAI) of that segment	None
Run_RAI	Average RAI of all the segments of a particular run	None
Width	Width of particular segment	Inches
Image_URL	URL for image	None
File Name	File name of a particular run	None
Picture Name	Unique ID for image	None
Flags	Subjective hazards flagged during data collection	None
PictureFile	HTML to make image appear in popup window	None
Type	Segment type (sidewalk, crosswalk, construction, etc.)	None
Street Name	Name of corresponding street parallel to segment	None
Length	Length of segment	Feet

Table 3: List of Curb Ramp Attributes in the Navigation Database

Field	Description*	Data Range
FID	Unique ID for each curb ramp	N/A
Latitude	Latitude of curb ramp point	Decimal degrees
Longitude	Longitude of curb ramp point	Decimal degrees
Detectable Warning	Does it have detectable warning	Yes/No
Lippage (1-Poor, 3-Good)	Quality of transition from street to curb ramp or curb ramp to sidewalk	1-3
Width (1-Poor,3-Good)	Quality of width of curb ramp	1-3
Slope (1-Poor,3-Good)	Quality of running or cross slope of curb ramp	1-3
Obstructions	Are there obstructions on or near the curb ramp	Yes/No
Overall Condition (1-Poor,3-Good)	Overall quality of curb ramp	1-3
CreationDate	Creation date of this curb ramp	Date
Creator	Creator of this curb ramp on map	N/A
EditDate	Date data was last edited	Date
Editor	User who last edited data	N/A
ImageURL	URL to access image	N/A
Passability	Is the curb ramp passable or note	Passable/Not Passable

Table 4: List of Transit Attributes in the Navigation Database

Field	Description***
FID	Unique ID for each transit stop
Latitude	Latitude of transit stop
Longitude	Longitude of transit stop
StopID	Unique ID given by port authority for each transit stop
Stop_Name	Name/Location of stop
CleverID	Unsure (taken from port authority)
Direction	Direction into or out of downtown
Route_coun	Unsure (taken from port authority)
Timepoint	Unsure (taken from port authority)
Routes	Transit routes that stop at this location
PatternSeq	Unsure (taken from port authority)
Mode	Mode of transportation this stop supports
Shelter	Type of shelter
Stop_type	Type of transit stop
On_avwk_CY	Unknown (taken from port authority)
Off_avwk_C	Unknown (taken from port authority)

***Note: This data was aggregated from Port Authority of Allegheny County and so the meaning of some data may not be understood. Fields may be modified to accommodate other transit agencies. For this project, only latitude and longitude were used.

Data Collection

During Phase 1, the attributes identified in Table 2 were collected using pathMet, pathVu's proprietary pathway measurement tool. Data collection occurred along approximately 60 miles in the Downtown and Oakland neighborhoods in Pittsburgh, PA. This data was implemented into the AccessPath app and served to test the routing algorithm developed during Phase 1. Figure 17 shows a screenshot of the pathways collected in Pittsburgh. Users can navigate along these routes. Since pathMet was used to collect condition ratings along these pathways, the resulting route from AccessPath is based on the pathway quality. Further, the user comfort settings (parameters) and pathMet data go into the routing algorithm developed during Phase 1 to output the custom route for each user based on their ability to navigate pathway conditions.

It should be noted that the routing algorithm can only be used where data has been collected and added to the database. In some instances, only pathway centerlines are collected. Centerlines refer to a collection of lines in GIS that represent the center of a feature, in this case a pathway, sidewalk, or crosswalk. The resulting routes for this type of data will show only the shortest path and will not consider pathway condition. On the other hand, areas that have pathMet data will consider the condition of the pathway along with the user's settings. Images that were collected have been de-identified to respect the privacy of pedestrians and to protect their identity (Figure 18).

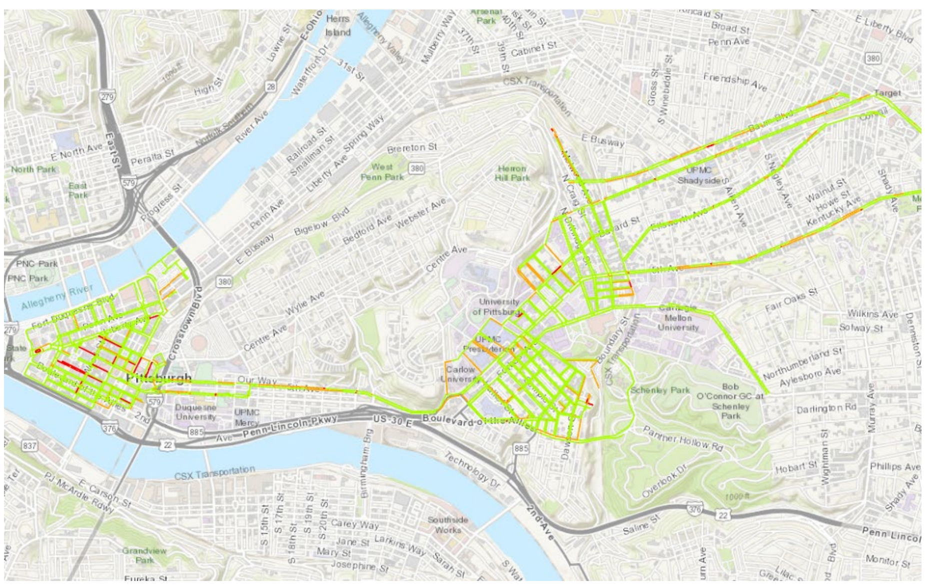

Figure 17: Map of Data Collection Areas in Pittsburgh, PA (Source: pathVu)

Figure 18: Sample pathMet Image with faces de-identified (Source: pathVu)

During Phase 2, the goal of data collection was to test scalability. This was done by collecting data along 50 linear miles in two additional cities: Portland, OR and Washington, DC. The same pathMet data attributes that were collected in Phase 1 were also collected in Washington, DC. Figure 19 shows the five neighborhoods where data collection was divided: Georgetown, Chinatown, Waterfront, Navy Yard, and Congress Heights. The data collected in Washington, DC allows app users to receive custom routes based on their settings and pathway condition. A pilot project will be conducted with the D.C. Department of Transportation (DDOT) for continued testing of the app and feedback from end users. This pilot is beyond the scope of this project and will be conducted after project conclusion.

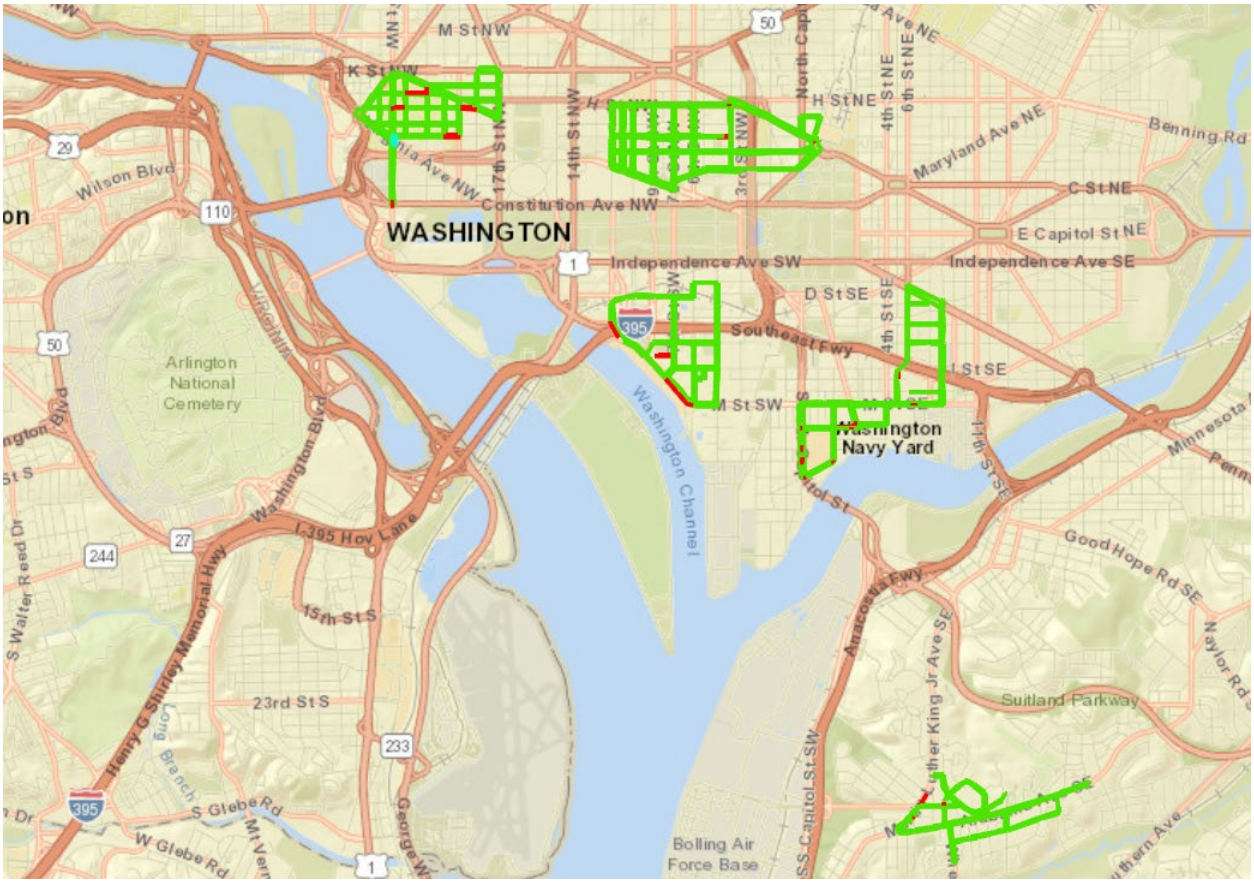

Figure 19: Map of Data Collection Areas in Washington, DC (Source: pathVu)

Lastly, data collection occurred in Portland, OR by mapping the pathway centerlines and curb ramp locations only along 50 linear miles. Figure 20 shows where data was collected in Portland, primarily around Downtown and Portland State University. Data collection was conducted by using high definition aerial imagery to identify the pathway and curb ramp locations. Consequently, the routes that are shown to the user in Portland are based on the shortest path only and do not consider pathway condition nor user settings. This data collection was conducted in order to test scalability in a city where pathMet data was not collected. Users are still able to know where the pathways are located but do not know which are most accessible. Further, this provides an opportunity to test how the reporting function can be valuable for data collection. A pilot project will be conducted in Portland to continually test the app and its scalability without pathMet data. This pilot is beyond the scope of this project and will be conducted after project conclusion.

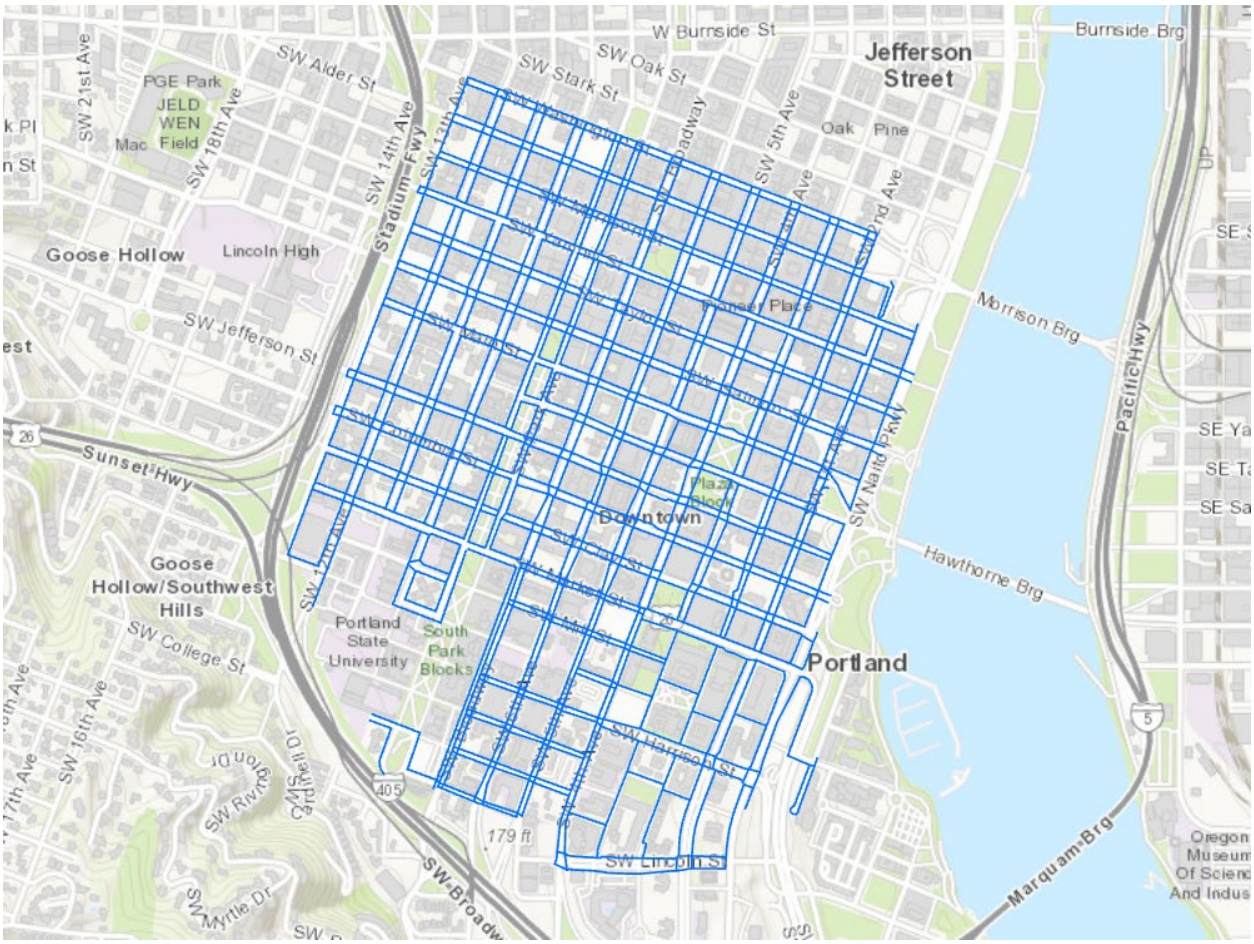

Figure 20: Map of Data Collection Areas in Portland, OR (Source: pathVu)

Chapter 4. User Needs Identification (continued)

Overview

In order to receive continued feedback from people with disabilities throughout the development of the app, we conducted two additional focus groups during Phase 1. Focus Group 2 included a discussion with four people with cognitive disabilities and three caregivers without a disability. Focus Group 2 served as a discovery discussion to understand the needs and challenges of people with cognitive disabilities. Although the feedback from this discussion may not have been directly or immediately implemented into the app during this project, the results serve as guidance on how to proceed with future development efforts.

Similarly, Focus Group 3 served as a Phase 1 app review as well as a ranking of future app features to be included. Four wheelchair users, one person with a visual impairment, and one caregiver without a disability participated in Focus Group 3. It was organized as an open discussion allowing users to review the app, ask clarifying questions, and suggest potential improvements. This method allowed our team to observer how users initially interact with the app and identify improvements based on those observations and user questions. The focus group concluded by participants identifying nine top features they would like to be considered for future versions and ranking their level of importance.

Lastly, the purpose of Focus Group 4 was to listen to the needs of people with hearing disabilities to understand their navigation challenges and to identify which features should be considered in future app development phases. It was important to conduct Focus Group 4 so that people from each of the four primary disability classifications were heard: mobility (Focus Group 1), visual (Focus Group 1), cognitive (Focus Group 2), and hearing (Focus Group 4). Although the original focus of the app was on navigation for wheelchair users and people with visual impairments only, the results of Focus Group 4 allows us to plan for future feature improvements that will benefit people with hearing disabilities as well. These results have provided a foundation for the types of features and design criteria that are important to consider so that the app is accessible for people with hearing disabilities.

By listening to the needs of users, we were able to more accurately design the app around what the user wants rather than based on our pre-conceived assumptions. This approach was used in each focus group. Since development is a dynamic process, this additional feedback and suggested improvements from all focus groups should be considered when prioritizing next steps. This chapter does not encompass all of the feedback from each focus group, but summarizes the major results.

Focus Group 2 (People with Cognitive Disabilities)

This section presents an overview of Focus Group 2. A detailed list of questions and responses are found in Appendix A: Focus Group 2. Focus Group 2 was conducted in order to understand which design and

app features people with cognitive disabilities and their caregivers would like included in AccessPath. By taking a user-centered design approach, we listened to what the end user wants, and designed based on what they want rather than based on our assumptions of their needs. The focus group was conducted with 7 participants: four people with cognitive disabilities and three caregivers without a disability. The focus group was conducted by having an open discussion with participants and asking questions regarding the types of issues they have navigating sidewalks, the app features they like, the app features they dislike, and other similar questions. The results of the focus group were divided by the major questions that were asked during the focus group. The participant responses were recorded under the preceding question that was asked.

The results from this focus group identify important features that should be considered for integration to assist those with cognitive disabilities. The major features that were identified are: 1) Accuracy 2) Simplicity 3) Repetition 4) Pre-trip planning 5) Avoid Change. The app and its data must be accurate, otherwise the user will not be able to trust it and will not use it. The design and functionality needs to be simple and flow smoothly. Simplicity limits the cognitive load and makes it more user-friendly. Users want confirmation that what they are doing is correct. This can be done by repeating directions, alerts, or in any way affirm what the user should be doing. Repetition helps the user think linearly and structured. Pre-trip planning is very important to allow the user to identify obstructions along the route prior to experiencing those conditions in the real world. All of these components should be implemented in a way to avoid sudden change for the user. Sudden changes in plans or design will cause the user to grow anxious. All of these features should focus on ways to reduce user anxiety if something unexpected occurs.

At the end of the focus group, participants were asked if there were any additional comments or takeaways. Participants reiterated some major points.

- Keep it simple. Simplicity and structure help to avoid confusion and frustration.
- Change from the norm is a negative. Implement features that will avoid sudden changes in routing and design.
- Add the ability to share routes with friends. This helps others know that the user is safe.
- Reiterate that what the user is doing is correct. Repetition is helpful.
- Inaccuracies can be harmful. It is important to always have accurate data.
- Crowdsourcing allows the user to be involved and contribute in order to help others.
- Participants would check it daily if it alerted them when new obstructions appear.

Focus Group 2 provided a solid foundation for the features that should be included into AccessPath to help people with cognitive disabilities navigate safely and independently. Because this project is focused on wheelchair users and people with visual impairments, many of these features were not be incorporated into the app. However, this feedback should be considered for future development efforts. The goal of AccessPath was to incorporate as many of these features as reasonable. One of the challenges was building an app that is clean and simple, but meets the needs of users of all abilities.

Focus Group 3

Focus Group 3 was conducted on November 19, 2018 and was organized as an open discussion moderated by pathVu and included a survey at the end. The discussion included three sections: 1) Review of the app, 2) Open discussion, and 3) Feature-ranking survey. After reviewing the app and having any questions answered, participants identified areas for improvement. Participants were asked which features were missing from the current version of the app (at the time of the focus group). Although their comments regarding the version were recorded, they were asked to focus on the missing functionality instead of refinements to existing features. Participants commented on the features that they would like to see in the future, while the other participants added to and supported the need those features. Participants collectively established the list of top features. Descriptions of these top features and the responses by participants can be found in Appendix B.

Focus Group 3 was conducted in order to understand which design and app features people disabilities and their caregivers would like included in the next phase of AccessPath. This focus group continued building on the user-centered design approach. The focus group was conducted with six participants: four wheelchair users, one person with a visual impairment, and one caregiver without a disability. The focus group was conducted by reviewing the current version of the app with participants, having an open discussion to establish top feature preferences, and asking users to complete a survey ranking those features.

The results from Focus Group 3 show the prioritized rankings of nine app features by the six participants. Participants identified these three features as top priorities: 1) Accessible entrances 2) What is around me 3) Points of interest indoor accessibility, which were later implemented into the app as part of Phase 2. These features were well aligned with what was expected. Users discussed that the top priority is knowing the location of the accessible entrance in respect to which side of the building. Further, it was just as important to know whether the building/point of interest is accessible.

However, it was slightly surprising that the “What is around me” feature was ranked so highly. Participants clarified that this feature was very important when getting oriented to their surroundings. It was also important to use for navigation purposes. People often use landmarks as reference points for wayfinding. This can be especially valuable for people with visual impairments as they find their way to their destination.

Focus Group 4

Focus Group 4 included individual discussions with four people with a hearing disability: two deaf-blind, one deaf, and one hard-of-hearing individuals. The primary objectives of the focus group were: 1) To listen to people with hearing disabilities to understand the challenges they face when navigating the pedestrian environment, 2) Identify app features to be considered in future development efforts. The feedback allowed to understand how to incorporate accessibility-friendly functionality, which features are most important, and how the app should look and feel from a visual and non-visual perspective. These objectives were met by identifying the answers to the four primary questions shown below. Detailed questions and responses are found in Appendix C.

1. *What challenges do you have navigating pedestrian paths?*
2. *How do you currently navigate?*

3. *What apps do you like to use?*
4. *What accessibility features are most helpful?*
5. *If the app could do [blank], I would use it every day.*

Focus Group 4 was conducted in order to understand the challenges that people with hearing disabilities face as they travel the community as a pedestrian or by transit. The responses from users help to identify which design and app features people with hearing disabilities would like included in AccessPath. By taking a user-centered design approach, we listen to what the end user wants, and design based on what they want rather than based on our assumptions of their needs. The focus group was conducted with 4 participants: two people who are deaf-blind, one deaf, and one hard-of-hearing. The person who is hard-of-hearing participated through an individual interview, but their responses have been included here. The focus group was conducted by having an open discussion with participants and asking questions regarding the types of issues they have navigating sidewalks, the app features they like, the accessibility features that are most helpful, and other similar questions.

The results from this focus group identified important challenges that people with hearing disabilities face navigating pedestrian pathways. This section does not necessarily present the solutions to those challenges. More than one possible solution may be viable and reasonable. Future development efforts should consider the time, effort, cost, and user needs when deciding the best solution. The biggest challenges that focus group participants identified are: 1) Intersections 2) Emergency Vehicles 3) Restaurant ordering 4) Poorly lit routes. Each of these challenges are a result of the user's inability to hear their surroundings. Intersections can be dangerous because of cognitive overload as a user tries to stay aware of when it is appropriate to cross the street while being aware of oncoming cars and traffic. Similarly, emergency vehicles can be dangerous if a user does not see the lights since they cannot hear the sirens. Further, communication can be a challenge for people with hearing disabilities especially at restaurants and other points of interest. Lastly, poorly lit areas can cause a person with a hearing disability to feel anxious and unsafe since they can neither hear nor see potential dangers due to the poor lighting. These challenges can present potentially dangerous conditions for people with hearing disabilities and should be considered during design iterations to improve safety.

Focus Group 4 provided a solid foundation for the challenges that people with hearing disabilities face navigating pedestrian pathways. Although solutions to these problems were not necessarily incorporated into this version of the app, the purpose of this focus group was to identify those challenges so that solutions may be implemented in future development. It is important that anything that is done audibly in the app also be implemented visually, and even through haptics. People with hearing disabilities should continue to play an active role in future development, providing design and performance feedback through testing.

Chapter 5. Prioritized Feature List

Following Focus Group 4 with people with hearing impairments, we conducted a survey with people of varying abilities and disabilities to help rate which features were most important to them. The features included in the survey were based on the results from previous focus groups from Phases 1 and 2. The survey results helped to establish a prioritized list of features to be implemented into future versions of the app based on user preference, level of difficulty of implementation, cost, and scalability. During Phase 1, users suggested numerous features that they would like to added to the app, as well as improvements on past features. Without this prioritized list of improvements, it can be difficult to know which order to add the features. Further, the priority should be primarily based on the user's ratings, while also considering the cost, level of effort, and scalability factors. Some features may be very desirable, but in reality are difficult to implement or difficult to find solution. For this reason, the prioritized list is important. This survey included thirty-three people with the following disabilities: wheelchair (8), vision (4), cognitive (7), hearing (8), crutches (1), and caregivers with no disability (5). A full list of survey questions can be found in Appendix D: Feature Prioritization List along with feature definitions.

Methodology

Prioritization Factors

Prior to creating the prioritized list of features, it was determined by pathVu that the important factors for prioritization include: 1) User ratings, 2) Level of effort needed for implementation, 3) Scalability, and 4) ATTRI rating. Additionally, any additional costs necessary, such as those from third parties, were identified but not included in the calculation of the priority described below.

1) **User's Rating:** User ratings were gathered from thirty-three survey participants. People with and without disabilities were asked to rate the importance of thirty possible features to be included into the app. The thirty features were chosen based on previous focus groups in Phase 1 (people with mobility, visual, and cognitive disabilities) and Phase 2 (people with hearing disabilities). ***This chapter describes the process for gathering participant survey responses.***

2) **Level of Effort:** The level of effort was reported based on pathVu's estimates of the time and difficulty of implementing each feature by one junior level software developer.

3) **Scalability:** Scalability was reported based on pathVu's determination of how easily the feature can be scaled across the country, and eventually the world. Scalability considered both the ability to implement the feature in the app, as well as the ability to scale any necessary data collection across the country for that feature to be used.

4) **ATTRI:** This category shows the priority ratings determined by members of the United States Department of Transportation ATTRI team. ATTRI was provided with the ability to submit priority suggestions since they are closely involved in the development of these navigation and wayfinding technologies for people with disabilities.

5) **Additional Costs:** Additional costs include any costs outside of the time needed by the software developer. Typical added costs include those associated with the purchase of a third-party API (application programming interface).

Results

Feature Rankings

The list below shows the fourteen priority ranking groups and the features that have those rankings. A rank of 1 represents highest priority, where a rank of 14 represents lowest priority. Features having the same ranking means that they have the same level of priority. A full description of each feature can be seen in Appendix D.

Feature Rankings:

Rank 1: Legend
Rank 2: Redirecting and Rerouting
Rank 3: Haptic Alerts
Rank 4: Transit Accessibility, Emergency Button
Rank 5: Indoor Accessibility, Accessible Entrances, Share My Route, Changes to Route
Rank 6: Crossing Signals, Rate My Sidewalk
Rank 7: Bus Arrival
Rank 8: What is Around Me, Rideshare, Family Restrooms, Accessible Parking, My Direction
Rank 9: Multimodal, What Am I Passing, Sidewalk View
Rank 10: Yelp
Rank 11: Extended Crosswalk Time
Rank 12: App Contrast
Rank 13: Point System, Outdoor Seating
Rank 14: Pedestrian Traffic
Rank 15: Service Animal Restroom

Additional Comments

This Section shows the list of additional comments or feature suggestions made by participants. These comments are in response to Question 34: “Specify any features that we missed here (optional).” These comments are taken verbatim from the survey responses and may not be complete sentences or thoughts. The user type that made each comment is shown in parentheses following the comment. (WCU = wheelchair user, BVI = blind/visually impaired).

- New obstacles due to construction (WCU)
- A feature that would point out a desired route that has no accessibility (WCU)
- Degrees of slope or incline (WCU)
- Paving material such as bricks or stones (WCU)
- Bicycle lanes that could be used by wheelchair users (WCU)
- Alert people of barriers (open manhole covers, sidewalk scaffolding, light poles in your path, etc.) (None)
- Voice option male/female (WCU)
- Conditions of sidewalk – i.e. is it lifting (None)
- Help button for additional info (BVI)
- Alarm when bus is 1 minute away (BVI)
- Ability to shake phone to get information (BVI)
- Flag location of where you parked (BVI)

Prioritized Feature List Discussion

The prioritized list of features established in this report was conducted primarily to understand the order by which features should be implemented into the app based on user preference, level of difficulty of implementation, cost, and scalability. Although thirty possible features are presented as part of this report, it does not encompass all possible features to be included in the app. The thirty features were established based on responses from previous focus groups.

User surveys were conducted in order to establish user preference. The average of the survey results, combined with the estimated level of effort for implementation and the ability to scale, established a prioritization calculation between 1 (low priority) and 5 (high priority). One possible calculation is shown in this report. If desired, the prioritization calculation can be modified by creating different weighted than what was used in this report. This method presents one method of prioritization.

One alternative method for prioritizing feature implementation is by disability rather than using the average score. For example, one may choose to prioritize within each disability type and implement the top feature identified by each disability first. In this case, the top feature for wheelchair users is “Accessible Entrances.” It received an average rating of 5.0 by all wheelchair users. No other feature received a 5.0 rating. Similarly, users from other disability types may have a different top priority. Since each disability type has unique needs compared to the other disability types, this method allows each group to be heard and not averaged in with the other disability types. Although this averaging method was used in this report, it was used as an example and not the only possible prioritization method.

Chapter 6. API and Phase 2 Features

The primary development efforts of Phase 2 included the development of an application programming interface (API) and incorporating select features into the AccessPath app. First, the AccessPath API was developed to allow future developers to build on this project's success. Phase 1 focused on the development of a mobile application, but mobile apps do not allow others to utilize the implemented features. Consequently, we developed an API comprised of three sections that allows others to implement accessible routing features into their custom apps: Routing, Locations, and Users APIs. These APIs were implemented into the AccessPath app.

Second, the features selected to be included during Phase 2 were identified from previous focus groups and the prioritized feature list. During Phase 1 focus groups, three app features were identified as having high importance for people with disabilities: *What is Around Me*, *Accessible Entrances*, and *Indoor Accessibility*. After conducting the surveys to establish the prioritized feature list, these features were confirmed to be the next features that would be implemented into the app. Even though these features had not had the highest ratings in the feature list, they were consistently features that were asked for by users. *Accessible Entrances* and *Indoor Accessibility* were implemented into the app via the AccessPath API, while *What is Around Me* was implemented directly into the app without the API.

Each API below can be accessed online at https://github.com/pathVu/AccessPath/tree/master/API or by reaching out to the pathVu team at info@pathvu.com.

Phase 2 Features

The Phase 2 features that were implemented into the app are briefly described below.

1) ***What's Around Me***: *What's Around Me* is a button on the main map screen (Figure 21) that allows users to quickly identify the points of interest that are within a 1/8-mile radius. This feature allows users, especially those with visual impairments, to understand the places that are nearby. What's Around Me presents the points of interest as a list or map view. If the user selects a point of interest, Set A New Path opens with the route from the user's current location to the selected point of interest.

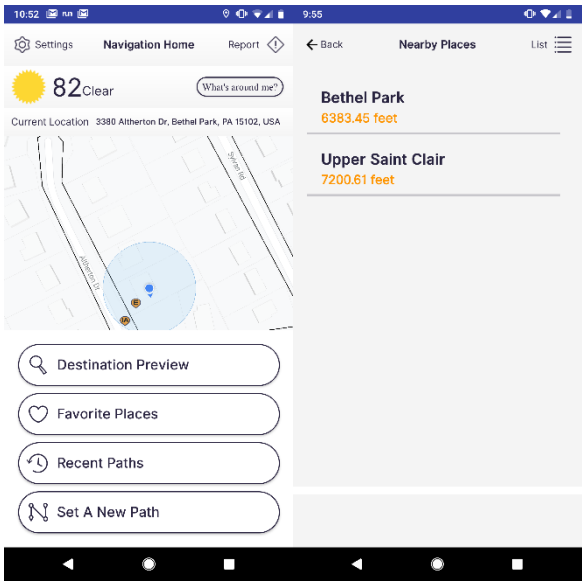

Figure 21: Screenshots of the What's Around Me Feature (Source: pathVu)

2) ***Accessible Entrances***: Users can use the Reporting feature (Figure 22) to submit reports about *Accessible Entrances.* The feature works similar to previous reporting capabilities but allows for additional details to be reported about the level of accessibility of building entrances. The user reports the image and location of the building entrance. Now, users can understand whether an accessible entrance is on the North or South side of the building, for example. Further, this feature allows users to report details about the number of steps present, whether there is a ramp, and if there is an automatic door. These feature is implemented via the Locations API described below.

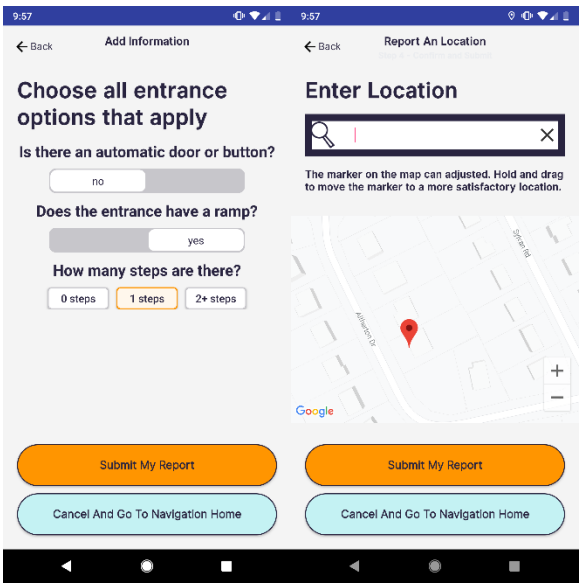

Figure 22: Screenshots of the Accessible Entrances Reporting Feature (Source: pathVu)

3) ***Indoor Accessibility***: The *Indoor Accessibility* feature (Figure 23) provides the ability to report the level of accessibility indoors within a particular point of interest (restaurant, store, building). Indoor Accessibility provides the ability to report data about point of interest's restroom type, restroom steps, spaciousness, and braille menu. This feature does not provide indoor directions but rather specific details about the level of accessibility inside the point of interest. The details about the restrooms are especially helpful to wheelchair users and people with a mobility disability to understand the number of steps leading to the restroom and whether the restroom has an accessible stall. The spaciousness detail also provides feedback as to whether a wheelchair user can easily maneuver around the establishment. Lastly, the braille menu feature helps people with visual impairments who read braille to understand whether there is a braille menu at the restaurant.

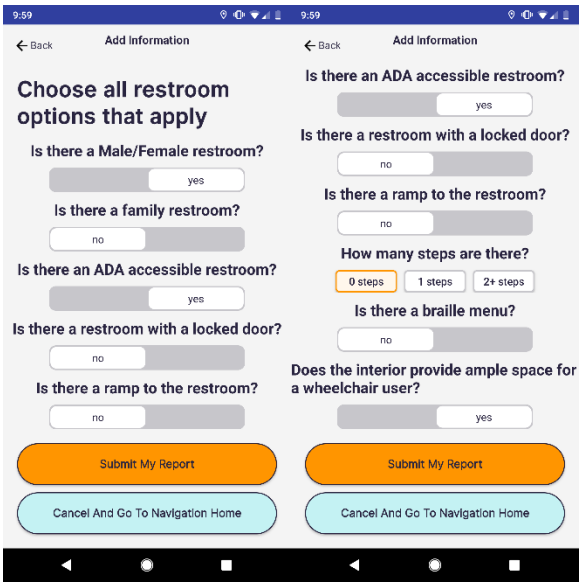

Figure 23: Screenshots of the Indoor Accessibility Reporting Feature (Source: pathVu)

API Features

Routing API

The Routing API (version 1.0) returns a route based on: 1) Starting and ending locations (using latitude and longitude), 2) The pathVu sidewalk network, 3) User route preferences (parameters), and 4) The routing algorithm developed in Phase 1. The sidewalk network schema is described above. User route preferences for the following parameters can be set on a 1 to 4 scale, with 1 being completely uncomfortable and 4 being completely comfortable navigating each parameter: tripping hazards, running slope, cross slope, and roughness. The starting and ending locations, parameter settings, and the sidewalk network data are used in the routing algorithm to return a custom route based on user preferences via the API.

The Routing API provides the ability to identify the type of user: blind/visually impaired, sighted and walking, wheelchair/scooter user, cane/walker user. The API provides default parameter settings for each user type but allows them to be modified through customized preferences. A successful API call will return a route in JSON format. Multiple error responses are described in the API documentation.

Locations API

The Locations API (version 1.3) allows for reporting about hazards, entrances, and indoor accessibility. The API provides the ability to either submit data or request data for a particular area. The primary hazard reporting functionality allows for data to be submitted about hazard type, location, user ID, and image. Hazard types include: tripping hazard, no sidewalk, no curb ramp, construction, and other. The API also allows for hazard data to be returned for a particular area of interest. This information is especially important to help people understand the location of potential hazards on the route. A feature within the app allows for users to be alerted to potential hazards as they approach the hazard.

The Entrance feature provides the ability to report information about building entrance details and their location. Features included in entrance reporting are the address, location of the entrance being reported, user ID, image, ramp, number of steps, and automatic doors. The address helps to identify the building or store to which the report is associated. The location allows for the specific latitude and longitude of the entrance in order to identify which side of the building the entrance is located. The user ID allows for tracking of the person making the report. Images provide additional details about entrances for sighted users. Ramp details specify whether there is a ramp present for wheelchair users. This does not necessarily mean that the ramp is ADA compliant. Further, this feature provides the ability to report whether there are 0, 1, or more than 1 steps. Lastly, data can be reported about whether an automatic door exists. The Entrance feature provides users with the ability to understand the location of accessible entrances and whether they are accessible for their particular needs. For example, an entrance with one step may prove to be impassable for a power wheelchair user, while it is navigable for someone using crutches. Moreover, the user will understand the exact side of the building to enter. It is common, especially in public buildings, for the accessible entrance to be located somewhere other than the main entrance.

The Indoor Accessibility feature provides the ability to report the level of accessibility indoors within a particular point of interest (restaurant, store, building). Indoor Accessibility provides the ability to report data about the address, user ID, image, restroom type, restroom steps, spaciousness, and braille menu. The address, user ID, and image are the same type of information being reported for the features mentioned above. The restroom type allows a user to report or understand the type of restroom present at an establishment, such as male/female, family, ADA accessible, and locked door, or any combination. This allows patrons to understand the restroom options that exist and whether they meet their accessibility requirements. The restroom steps field provides information about the number of steps leading to the restrooms so that people with disabilities understand if they are able to access the restroom within the establishment. The spaciousness field provides a yes/no option as to whether a point of interest is spacious, providing users with information about how easily they can maneuver in an establishment such as for a wheelchair user. Lastly, the braille menu field provides a yes/no option regarding whether a restaurant has a braille menu. This field is important for people with visual impairments who read braille, providing them with an added level of independence.

Users API

The Users API (version 1.4) allows for the creation of user profiles, including usernames, passwords, and settings. This feature allows for user settings to be easily saved and accessed across platforms, reducing the effort needed for users to resubmit their custom settings. This API allows for the creation, updating, and query of user profiles. In order to create a user profile, one must enter a unique username, an email address, and password. Guest user profiles may be created which does not require an email address, username, or password. This API has Sign In capabilities that recall the settings of a specific profile. Sign In options include email and password combinations, Google Account login, or Facebook Account login.

The Users API provides the ability to save a user's favorite points of interest, as well as recent destinations. Recent destinations can be used to quickly access commonly travelled destinations. The Favorites feature can be used for quick access or for alerts. Alerts notify a user as they approach a particular point of interest, alerting the user once they enter a geo-fence surrounding the point of interest. Alerts are specified in Settings. Settings also provides the ability to set a user's user type, pathway parameters, and parameter alerts. User types are the same as those identified in the Routing API: blind/visually impaired, sighted and walking, wheelchair/scooter user, and cane/walker user. Pathway parameters are also the same as those in the Routing API, allowing for custom user comfort settings: tripping hazard, running slope, cross slope, and roughness. Users set their comfort level navigating each of these parameters, and can turn on/off alerts for each parameter. Default settings are set based on the user type but can be updated at any time. The parameter information goes into the routing algorithm when determining the suggested route.

Chapter 7. Project Summary and Lessons Learned

Project Summary

The overall goal of this project was to develop a mobile app that provides pedestrian navigation and directions to people with disabilities based on their abilities to navigate sidewalks and pedestrian pathways. Typical travel apps neither focus on pathway quality nor consider the user's comfort navigate those routes. To that end, AccessPath provides real-time step-by-step directions customized to a user's comfort settings. Each pedestrian has unique abilities and disabilities, and so their routes must be customized to their individualized needs. The app provides the ability to submit reports about hazards, construction, accessible entrances, and the level of accessibility indoors. This enables people with disabilities to contribute data to help others as well as understand important accessibility features about points of interest. The app provides other important features such as favorites, alerts, recent paths, What's Around Me, and VoiceOver/TalkBack compatibility.

Every feature that was integrated into AccessPath was a result of numerous discussions and involvement from people with disabilities. Four focus groups were conducted, one with each of the following disability groups: mobility/wheelchair user, blind/visually impaired, cognitive disability, and hearing impaired. Further, people with disabilities were included from the beginning of the project to identify key design components, such as button size, text size, and screen reader compatibility. In Phase 2, a survey was conducted with people with disabilities to understand which features should be prioritized in future development efforts. This list prioritizing feature development helped to identify the features to be included during Phase 2.

The data that was collected for this project was primarily done with pathVu's proprietary pathMet device, which identifies sidewalk conditions such as tripping hazards, roughness, running slope, cross slope, imagery, and geo-location. pathMet data was collected in Pittsburgh, PA during Phase 1 to serve as a test dataset (60 miles). During Phase 2, pathMet was collected in Washington, DC (50 miles) in order to continue to scale and test in other cities. In order to test scalability in a remote city without pathMet data, sidewalk and curb ramp data was collected in Portland, OR (50 miles) using aerial imagery. This type of data provides only the shortest route compared to custom routes when using pathMet data. Following this project, pilot studies will be conducted in Portland and Washington, DC as a way to continually implement, develop, and test the app.

In order for others to be able to utilize the routing capabilities and algorithms developed as part of this project, an application programming interface (API) was developed. The API has three components: Routing, Locations, and Users. These APIs allow other developers to implement the major components of the AccessPath app, including navigation, reporting, and user comfort settings. This project not only provides a standalone app to be used, but provides future development capabilities that work towards the goal of a Complete Trip.

This project's focus was to provide routes that customized to each user's ability to navigate rather than the assumption that a sidewalk exists and that it is equally navigable for every user. The major accomplishments of this project include:

- Development of Android and iOS smartphone apps that provide accessible pedestrian directions. These apps allow users to identify the best routes for them to travel, submit reports about potential hazards and accessibility features, and receive alerts to hazards along the route, allowing them to be more independent.

- Development and documentation of APIs for use by developers to integrate into future development projects, such as a multi-modal transportation app. The APIs provide pedestrian routing, location and reporting, and user settings services. Pedestrian routes are based on algorithms that consider pathway quality and user settings.

- Data collection was conducted to test and scale the app performance areas. Data was collected in Pittsburgh, PA using pathMet (60 miles), Washington, DC using pathMet (50 miles), and Portland, OR using high definition aerial imagery (50 miles).

Lessons Learned

Following the development activities during this project and continued review by people with disabilities, we have identified numerous lessons learned that will be valuable for future development efforts:

- **Data Accuracy:** The accuracy of data is very important in determining the best route for a user. Using a tool like pathMet helps to guarantee accurate data, however other data collection techniques can be used to help with scalability. For example, open data was used in Portland, OR in order to test remote data collection. It appears as if the data is reliable, but when using open data, it is often unknown as to who created the data and the accuracy of that data. Therefore, it is important to conduct appropriate quality assurance on data especially when it is from a third party source.

- **Crowdsourced Data:** Crowdsourced data can be valuable in the apps ability to scale. In cities, such as Portland, where there is minimal or no data regarding the quality of sidewalks, user-reported data via the app can provide important condition data directly from the users. This data can be used to alert pedestrians to obstructions or even impassable segments such as major hazards or construction. If done correctly, crowdsourcing can quickly scale data collection and thus the value of the app to users. However, the negative of this type of data is that it is subjective. At the time of this report, crowdsourced data does not go into the routing algorithm, only pathMet-type data. This means that only paths with condition ratings in the database are used in determining routes. Crowdsourced data is only used for visualization purposes.

- **Prioritizing Features:** Throughout the development of the app, there was an extensive amount of feedback and suggestions regarding improvements to be made and potential features to add. Although feedback is always welcomed in order to make the app better and more valuable to people with disabilities, this feedback can be overwhelming if not managed properly. For this reason, we developed a prioritized list of features to include in future development efforts. The list developed represents one method of rating features and is not all-encompassing. This list should

be continually updated as part of the development process. However, user feedback should always play a major role in identifying which features to include.

- **Connected Datasets:** Similar to other lessons learned, it is important to have a complete dataset of pathway data within a particular area of interest. This means that the data is comprised of a connected map of sidewalks, crosswalks, pathways, curb ramps, and similar data to create a network. If data is created neighborhood by neighborhood, then the navigation will only work within each neighborhood and not the larger city. Therefore, it is important to connect neighborhoods together and create complete datasets to add the most value.

- **Testing Protocols:** Testing the app with end users should be a continuous part of the development process. First, it keeps the end users involved so that you are developing a tool that will be usable and desired by the end user. Second, it will reduce the amount of re-development or fixes when the user does not like something. It will also ensure that app features perform properly. The testing protocol should be clearly identified in order to understand what is being tested, how it will be tested, and how it will pass or fail. This will help the developer understand whether the features meet the design specifications.

- **Don't Underestimate Bugs:** Bugs are problems in the development of the app. Bugs can be big or small. It is easy to get lost in the development process and fail to address bugs. It is important to continually test on multiple phone models with a number of end users. Bugs will often occur even after small changes. Do not assume that the app works on every phone if it is successful on one phone or platform.

- **Accessibility Features:** Even while focusing on the development of an accessible app, it can be easy to overlook accessibility features that are important. For this reason, it is important to keep end users continually involved in the development process. Like other features, accessibility needs to be prioritized in order to understand which features to implement first. Every feature cannot be developed from day one, but it is important to develop a systematic approach for reaching full accessibility and total inclusion of all users.

- **Documentation and Planning:** Throughout the development process, we noticed that there was often confusion about how a feature was going to be implemented and how it would be tested. In this app, we were dealing with the development of two native apps, an API, and building the appropriate GIS databases to meet the project needs. At times these various components were done in parallel, which can be positive for productivity but difficult for troubleshooting. Consequently, when changes were made to one component, it could potentially break the other ones if something went wrong. Our lesson learned here is to develop a more thorough plan and documentation, not only at the beginning but throughout the development process. Create test versions so that features can be tested properly, minimizing risks of problems. By having a thorough and documented plan at the beginning, one can more easily keep track of issues and how to test. This planning and documentation also help to keep everyone on the same page so that it is clearly identified what is being developed and how it is being implemented.

- **Keep the Conversation Focused:** During focus groups, our approach was to initially ask generalized questions and listen to participants in order to give them an opportunity to share their thoughts. This is often a good method to receive quality feedback that you might not have received by asking more focused questions. However, the focused questions add value

throughout the conversation in order to narrow down and understand in more detail what participants are thinking. Although the concept of asking general questions can be extremely valuable, it is important to make sure the conversation stays focused. Sometimes participant feedback can get off topic or too futuristic. For example, when developing our pedestrian navigation app, participants sometimes talked more about driving apps because that is what they know. Our recommendation is to have generalized questions, follow up with specific questions and have some ready, keep the conversation focused, and document everything, even the minor details, so that you do not forget anything.

Future Development

This report has presented numerous possibilities for future development efforts, features to consider, accessibility components, and methods of scaling. All aspects should be considered when deciding how to proceed following this project. To start, additional pilot testing with end users should be conducted in order to identify bugs to be fixed to optimize performance. As a result, our team will be conducting pilot projects in Portland, OR and Washington, DC.

Beyond the pilot projects, this project opens up opportunities to achieve the ultimate goal of ATTRI, which is to help people with disabilities to take the Complete Trip. This app alone does not address this topic completely; however, it is a piece of the puzzle that will facilitate accessible pedestrian travel. Future development could include integration of additional pieces of the Complete Trip puzzle, including indoor navigation, transit accessibility, street crossings, multi-modal travel, and similar. Through the use of the AccessPath API, developers and researchers have the ability to continue to build upon the success of this project, integrate other technologies, and improve transportation for people with disabilities.

As a suggested next step to achieving the Complete Trip would be to incorporate other ATTRI projects or similar beneficial technologies into one app/product. Each project addresses a significant step in fulfilling the Complete Trip, such as this project that serves as the intermediate step in every part of the process. Everyone is a pedestrian at some point in the trip. However, this project does not address the issue of accessible transit, indoor navigation, nor fully addresses the needs of people with cognitive and hearing disabilities. The integration of these technologies could begin to validate more fully the Complete Trip and its value in helping individuals, especially those with disabilities, navigate the physical environment safely, independently, and accessibly.

Appendix A: Focus Group 2

This section shows the results of Focus Group 2. The list below is divided into two categories of questions: general app and pedestrian navigation questions. The major questions that were asked are presented under each category in italics. The participant responses and further explanation and clarification are provided under each question. These responses include suggestions for possible design improvements for future phases. The results are summarized in the Focus Group 2 Discussion section above.

General Mobile App Usage Questions

1. *What mobile apps do you use on a daily basis? Do you use any navigation apps?*

    - **ezRide Pittsburgh**: Participants use this to understand arrival and departure times of transit options in the city. Transit is an important component for the participants and they would like to see it integrated in future versions.

    - **Facebook**: Participants use this to stay connected with friends and family, and for their social media interests.

    - **Waze**: Participants use Waze to understand the hazards along the route. They like the ability to view route information ahead of time and the ability to contribute data to others using the app.

    - **Google Maps instead of Apple**: Participants said that they will use Google Maps instead of Apple because they can trust it more. Trust is an important attribute that participants often referenced during the discussion. AccessPath should be built so that users can trust it.

    - **New York Transit App**: Similar to the ezRide Pittsburgh app, participants said that when they travel, they like to use another city's transit app, such as the New York Transit app. Participants often take public transportation, and understanding the arrival/departure time information helps them stay on schedule.

2. *Do you have any frustrations when using your favorite apps?*

    - **"Getting asked to rate an app when in a crisis"**: Participants expressed frustration when constantly asked to rate an app, especially when the notification occurred during a critical time during their life. Participants expressed interest in contributing ratings, but in a way that would not interfere with their daily lives. They sometimes become anxious if their routine is interrupted by unnecessary notifications.

    - **"The repeated same question that does not help"**: Participants dislike when an app is confusing and continually provides the same question or answer to a problem. It is important to

express content in a way that is easily understood and directly relates to the problem. This will prevent people from becoming anxious and frustrated.

- **"Apps that open up into undesirable modes"**: Participants want an app that opens to the exact screen that they use often. They do not want to fumble through screens in order to find what they are the right location. In order to find the solution for this, testing should be conducted to establish the correct screen that users would like to view when opening the app.

- **Automatic updates**: Participants said that they would like to be in charge of when an app updates. If an app updates, that means something is new in the app. If they are unaware that something new has occurred, then they may become anxious and frustrated when opening the update unknowingly. Although this is often controlled in the phone settings, it is something to be aware of during development.

3. *What is important to you about how an app works, the experience of the app?*

- **"Colors and Photos are important"**: Participants expressed interest in having controlled and purposeful use of colors and photos in the app. They commented that "the majority of the population are visual learners." Thus, the app interface should be designed in a way where the visual content has meaning. The colors should match what is typically seen in other apps and should be consistent through AccessPath. Photos should be used to help people understand what is going on, whether through training or when depicting sidewalk problems. Visual content and reminders are very important.

- **"Simplified linear experience"**: Similar to Focus Group 1, participants want a simplified design. They want the design to be as linear as process so that it is easy to follow and one screen directly follows another. The app should also be simple with little clutter and a clean design. Too much content on the screen could cause confusion and result in anxiety for users.

- **User-friendly**: The app should be user-friendly. It should flow correctly. It should be easy to use. It should be responsive. It should be reliable and trustworthy. Participants said that this is one of the most important features. If it is not user-friendly and they cannot trust it, then they will not use an app.

Pedestrian Navigation Questions

4. *When you travel locally, where do you go?*

- **Work**: Participants said that they most often travel to work. They are typically coming from the suburbs to downtown to get to work. They take transit when they travel to work and walk a short distance from the bus stop to the building.

5. *Do you travel the same routes routinely? How often?*

- **Yes, very often**: Participants expressed that it is very important that they travel the same routes with which they are familiar. They do not often divert to different routes, even crossing to the other side of the street. A change in route or timing can cause increased anxiety for the users. If there is a change it their route quality, such as the existence of construction, it would be very valuable

for them to know this ahead of time. Understanding if there is a change of course in advance would decrease their anxiety and make them feel much more comfortable. Participants expressed interest in having a feature that would show their recent paths.

6. *Can you tell us what's frustrating about your current navigation process?*

   - **"Not understanding the right direction…. not understanding current direction"**: Participants expressed that one of their biggest frustrations when navigating is getting lost or turned around and not knowing the correct direction to travel. This is a common them among Focus Group 1 and 2 participants. Knowing one's current direction and which direction to travel is invaluable. If someone started walking in the wrong direction, they would quickly become anxious and could potential enter into a dangerous situation if they are at a different location than they are expecting.

7. *Are there any accessibility barriers you see when traveling?*

   - **"Paint on the sidewalks"**: Participants expressed concerns about painted sidewalks that are wet. For example, they said that painted curbs become slippery when wet. Although they have learned to avoid stepping on these areas, they can cause them to slip and fall.

   - **Obstructions on the sidewalk**: Participants said they often encounter obstructions along the route. They hate when those obstructions cause them to travel along a different route and change their plans. They would like to know about these conditions prior to starting their trip.

8. *How can ACHIEVA benefit from an app like* AccessPath*?*

   - **"Important for the staff to prepare for the journey with a patient"**: Staff at ACHIEVA often take walks with their patients around the nearby area. A pre-trip planning feature in AccessPath would allow them to view the route ahead of time to prepare for the conditions ahead. This is especially important around this time since there is a lot of construction going on near the office. Each staff member has an iPad or tablet and could have AccessPath installed.

   - **"A learning tool… a comfort level… increase independence within a community"**: Staff participants expressed that AccessPath could be used as a learning tool for their patients in order to teach them how to navigate sidewalk and intersections safely. They can review the routes ahead of time in a safe environment through pre-trip planning. Then, they can teach them how to safely maneuver in the community by training them on the app. This will ultimately improve their independence and comfort navigating on their own.

   - **"Increased level of safety"**: The number one concern of staff is patient safety. An app like AccessPath could improve staff and patient knowledge about safe routes, thus improving their safety when travelling.

   - **"Won't feel alone and stuck out there winging it"**: Staff feel that a pedestrian navigation like AccessPath would help to empower their patients. They expressed that their patients sometimes feel like they are "winging it" and AccessPath would complement their abilities and provide that support so they do not feel alone. A valuable feature to include would be a "share my route" feature so that staff could be aware of their patient's location.

- **"Routine is a big part of feeling independent. Do not want to have to relearn again"**: Staff reiterated the importance of routine for their patients. Routine means that the route will be the same and they do not need to learn a new route. If their patients have a routine, this means that they can have increased independence.

9. *What assumptions would you have about an app that proposes to help you navigate sidewalks more successfully?*

    - **Simplicity**: Participants want the app to be simple, similar to what was discussed above. They also want to be able to complete tasks with only one or two button clicks.

    - **Send ETA or location**: Participants want to be able to share their ETA (estimated time of arrival) and current location with friends and family. This will help guarantee their safety and know that the person arrived safely.

    - **Get notified of obstructions**: Participants would like notifications of some type to obstructions in their path. They are most interested in obstructions that will divert them to a different path. These notifications should alert them prior to taking their trip.

    - **Simplified and unique iconography**: Participants would like different obstructions to have unique, but simple, icons. This is valuable so that they can easily identify a particular obstruction type by viewing the icon on the map. The icons should be simple so that it is not confusing and the screen remains uncluttered.

    - **Wheelchair accessibility routes and different route options**: For users who also use a wheelchair, staff would like to see the app display different route options based on user type. They would like to understand which routes are wheelchair friendly and which are not. This also allows our participants to have a backup plan in case of a closed path.

    - **Nearby points of interests**: Participants would like to understand the location of nearby points of interest. This information is important because it can help them navigate by using the landmark as a point of reference. It also is important because they would like to find certain points of interest.

    - **Crowdsourcing and group integration**: Participants were enthusiastic about the idea of crowdsourcing. The like the concept of a community effort to contribute information to help someone else. This allows them to be actively involved in what information is being used in navigation.

    - **Weather**: Participants want to know what the weather is like prior to leaving their house. They want to know if it is raining, if they need a warm coat, and similar weather updates. At times, they can become flustered if they do not take the appropriate weather gear.

    - **Customizable Experience**: While participants want the app to be simple, they also want a customizable experience unique to their abilities. They want to have the ability to turn on/off settings and adjust which routes they travel based on their unique settings.

- **Pre-trip planning**: Users want the ability to do pre-trip planning and do a virtual walk through of the route prior to taking the trip. This allows them to become familiar with the route ahead of time. If there is an obstruction on the route, they would know that a different route should be taken. They would be willing to take a longer route if there are too many obstructions, but the data needs to be accurate.

- **Redirect back to the route**: Participants said that they would want the app to be able to redirect them back to the suggested route if they accidentally went off course. They want to be re-oriented with the correct route if they lose their place along it. Similarly, they want the route to recalculate if they go off course too much. However, they may not want the route to recalculate automatically.

- **Simplified directions and instructions**: Similar to other comments regarding simplicity, the directions and other app instructions should be design to be simple. Participants suggested a maximum of three instructions at a time, however fewer is preferred.

- **Upcoming direction**: Participants want to know ahead of time what the next turning direction will be when navigating. This feature is similar to other navigation apps when it alerts the user of the upcoming turn. The directions should be read a few times along that segment.

- **Emergency button**: Participants want to be able to contact someone quickly in the event of an emergency. They referred to it as a panic button at times. This will improve safety, especially in the case where someone is travelling alone.

- **Locate family restrooms and accessibility**: Participants want to know where family restrooms and other accessibility amenities are located nearby. This will provide them with improved independence and mobility.

10. *What concerns would you have with using an app that proposes to help you navigate sidewalks more successfully?*

    - **Negative travel experience**: Participants expressed concerns in the event that there was a negative travel experience. They said that a negative travel experience may cause fear, which could prevent them from using the app in the future.

Appendix B: Focus Group 3

Possible Future App Features

Below are the nine AccessPath features that the Focus Group 3 participants identified as top features to be considered in future versions of the app. A description of the nine features is provided. Table 5 shows how the six participants ranked their priority. A rating of one shows the highest priority, while a nine shows the lowest priority. The average rating for each feature is provided in the Table as well.

A. ***Points of interest indoor accessibility***: This feature will allow users to understand the accessible features about a particular point of interest, such as a restaurant or store. These features could include information about the entrance (is there a step), restroom, width of aisles, automatic doors, typical loudness, braille availability, and more. It would allow users to submit this information via the reporting feature in the app. Similar to current features in the app, it would allow sighted and non-sighted users to submit information through a guided progression.

B. ***Crossing signal details***: This feature would allow users to view additional information about crossing signals at crosswalks and intersections. It will provide information regarding timing, crosswalk type, button signal type, existence of audible feedback, subjective safety rating, and more. This data could be crowdsourced through the app's reporting feature or reported by a trained technician. Certain features, such as the existence of an audible signal, can easily be reported by app users, while details about timing would need to be reported by a technician in the field.

C. ***Bus stop and transit details***: This feature would allow users to view additional information about the accessibility features of a bus or transit stop. For example, users could understand if there is a shelter, wheelchair accessibility in the shelter, whether the bus typically can access the curb, audible cues, benches, and more. This information could be crowdsourced from the user or aggregated from open-sourced data, such as transit agencies or local government websites.

D. ***Multimodal***: This feature would integrate additional modes of transportation into the wayfinding algorithms. It would include modes such as bus routes, transit routes, bikeshare, and other similar transportation modes. The resulting suggested route or routes would take into account every transportation mode. The suggested route could be made up of multiple components such as walking and bus. For example, the resulting route may start by telling the user to walk to the bus stop, take the bus from point A to B, then walk from B to the destination. The current version of the app only considers the walking portion of this example trip and is one-dimensional in that sense. The user may have the option to choose the shortest route, least transfers, and other similar options that match their accessibility and comfortability requirements.

E. ***What is around me?***: This feature would allow the user to search for nearby points of interest. This data could come from 3rd-party APIs, such as Google or Yelp, or crowdsourced through the reporting feature in the app. This feature is useful for two primary reasons: 1) It allows users to orient themselves to their surroundings for improved navigation and awareness. The user could

potentially ask the app what is nearby, whereas the app will tell the user the points of interest in each direction. Similarly, some people navigate best by using landmarks as reference points. 2) Users are interested in searching for places that they would like to go. They would like to know what places are nearby.

F. ***Incorporating Yelp, Uber, and other APIs***: Users would like additional information and capabilities from other apps and companies. By incorporating these APIs into the app, users can get the best from each app through their API to add to the complete trip. Some APIs are free, while others cost money. The cost of the API and the importance to the user will determine which ones are implemented first.

G. ***Gamifying/Incentivizing crowdsourced reports***: Users said that they felt that more people would submit crowdsourced reports if there was an incentive for reporting or if there was a game-like element to it. They would like to encourage as much data to be reported, resulting in a better navigation experience. This could be done through a point system, where people earn points for submitting reports. Further, people could be incentivized through payment or prizes (e.g. gift cards) for submitting a certain number of reports.

H. ***Accessible entrances***: This feature would show the exact location of the accessible entrance. Typical navigation apps typically show the location of the building, but not the accessible entrance. This feature would show the exact side of the building where the accessible entrance is located. This information would be crowdsourced through the app.

I. ***Share my route***: This feature would allow the user to share their route with friends and family who have the app. The friend would be alerted when the user arrives at their destination. This would also be helpful when scheduling to meet so that the other person knows when the user will arrive.

Table 5: User-prioritized rankings of nine app features (1-highest priority, 9-lowest priority)

Feature ID	WC user 1	WC user 2	WC user 3	WC user 4	Visually impaired user	Caregiver	Average
A	4	2	1	1	6	7	3.5
B	6	3	3	6	1	5	4
C	8	4	8	3	3	3	4.8
D	9	6	7	5	4	2	5.5
E	3	5	5	4	2	1	3.3
F	5	9	4	7	7	9	6.8
G	2	8	6	9	9	4	6.3
H	1	1	2	2	8	6	3.3
I	7	7	9	8	5	8	7.3

Appendix C: Focus Group 4

Appendix C shows the questions and responses from participants shown as bullet points under each question. The content within the parentheses following each response shows the primary disability type(s) that provided the response. “D” represents the deaf individual. “H” represents the hard-of-hearing individual. “DB” represents the deaf-blind individuals. “A” represents all individuals.

General Questions and User Responses

1. *What challenges do you have navigating pedestrian paths?*

    a. ***Intersections:*** The challenge for people with hearing disabilities at intersections is understanding when it is safe to cross the street. Users need to constantly look each direction to make sure there are no cars coming and that it is safe to cross the street. The dangers of intersections are, by far, the most important challenge to address.

        i. Users said that the presence of a crosswalk signal is helpful, but it can still be unsafe to cross the street if a car runs a red light. (A)

        ii. Intersections can also cause challenges if the person with a hearing disability does not see that the crossing signal has changed to “Walk” since they depend on sight for everything. (A)

        iii. Users said that they prefer to cross at intersections where there is a leading “Walk” signal for pedestrians because it gives them time to enter the intersection before cars. (A leading “Walk” signal means that the pedestrian signal turns to “Walk” before the vehicle traffic signal turns green.) (A)

        iv. It is important to understand the location and type of crosswalk signals in order to understand the safest crossings for them. The type of signal refers to the existence of a signal, whether it has a numbered countdown to cross the street, whether there are audible cues (for those with hearing), whether there is a leading “Walk” signal, or any combination of these attributes. (A)

        v. Crossings near curves in the road are difficult since people with hearing disabilities cannot hear cars coming and cannot see the car due to the curve in the road. (D, H)

    b. ***Emergency vehicles:*** It is difficult for people with hearing disabilities to know when emergency vehicles are approaching unless they are looking in the exact direction. Users would like a feature that alerts them when emergency vehicles are approaching. If possible, users would like this feature to notify them of the direction of the approaching vehicle and its distance from them. This would allow the person to look up, find where the vehicle is coming from, and ensure that they do not cross the street if it is nearby. One

focus group participant shared a story of almost getting hit by an ambulance at an intersection because the crosswalk signal showed “Walk”, and as she started walking into the street an ambulance quickly passed her. (D, H)

c. ***Restaurant ordering:*** Users with hearing disabilities said that they sometimes have difficulty ordering food at restaurants because of communication challenges with restaurant employees. Since many times people with hearing disabilities do not communicate verbally and restaurant employees often do not know sign language, there can be poor communication between individuals. As a result, participants said that they often go to restaurants that have online menus, pre-ordering apps, or some other automated ordering method in order to avoid these communication difficulties. Participants would like to understand which restaurants have these features so that they can make an educated decision on which restaurant they prefer. Although, at first glance, the restaurant ordering capabilities may not appear to affect the pedestrian trip, this information improves the person’s complete trip to/from their destinations. (D)

d. ***Poorly lit routes:*** Routes that are dark or with poor lighting can make it difficult for people with hearing disabilities to navigate since they depend on their sight. In these cases, they cannot see where they are, what is around them, or where sidewalk ends. Similarly, one participant stated that poorly lit areas can make her feel unsafe because of difficulty seeing potential crime and/or predators. (D, H)

e. ***Pavement unevenness:*** This comment was given primarily from participants who are deaf-blind, but has shown to be a common theme across many users with disabilities. Users would like to be aware of or be notified of upcoming uneven pavement or tripping hazards. Uneven pavement can cause them to trip and fall, presenting a dangerous environment for users. By being aware of such conditions ahead of time, users can be aware and approach more cautiously. People who have hearing disabilities often have balance issues as well, and so being aware of uneven pavement can help them navigate safely. (A)

f. ***Communicating with others:*** Communication is often a challenge for people with hearing disabilities since they often communicate through nonverbal means. They often rely on third party apps or notepads in order to communicate with others in a nonverbal way, such as when they are using public transit. Adding a feature in the app that facilitates communication would help users navigate more easily and care-free, especially when using public transit. (A)

g. ***What direction to go once I exit the building:*** Similar to previous focus groups, people often have trouble understanding which direction to travel after exiting a building. This is especially a problem for people who are deaf-blind, those with visual impairments, or those who use entrances that are different from the main entrance. However, this challenge may apply to people with or without disabilities. Users have said that a feature that describes which direction to travel, including upcoming landmarks, would be helpful. (A)

h. ***House numbers, knowing where you are:*** This comment was given primarily from the participants who are deaf-blind. It can be difficult to know exactly where you are as you walk down the sidewalk. It is difficult to know at which house number you are standing or

walking beside and when one building ends and the other begins. Incorporating a feature that addresses this challenge is important to help users create a mental map prior to travelling. (DB)

2. *How do you currently navigate?* (The following results are primarily from non-sighted users.)

    a. **Mental map:** Creating a mental map prior to taking a trip is the most reliable method. Users will plan out their trip ahead of time and memorize the directions so they understand what to expect and when to expect it. This helps them to be prepared for the upcoming trip. Current tools that participants use include: Google Maps, MapQuest, and their own memory from previous trips. When using tools like Google Maps or MapQuest, participants will enter their starting and ending locations. After the tool returns the suggested route, they will memorize the route and turn-by-turn directions prior to taking the journey. If the user has sight, they will use Google StreetView to get a street-level view of the route. (A)

    b. **Objects along the route:** Users will often use the following objects to help understand where they are and how far to the next object: street lights, crossing signals, poles, garbage cans, and tables. When people with visual impairments travel a familiar route, they often use unique objects and textures to guide them along the route. These objects and textures act as “mile markers” along the route, reminding them how far they have traveled and how far they have yet to travel. (DB)

    c. **Landmarks:** Users often use landmarks and points of interest to navigate. For people with visual impairments, this is very helpful to help orient them to their location and the distance to the next step of the process. Landmarks are also useful visual cues for people with hearing disabilities. (A)

    d. **Count steps:** Many people with visual impairments will count steps to understand when it is time to turn or move on to the next step. Counting steps allows the user to know exactly how far to the next turn and removes the inaccuracies of GPS. (DB)

3. *What apps do you like to use?*

    a. **Google Maps:** Users use Google Maps for driving, walking, and biking directions. Users have expressed difficulties with Google Maps for inaccurate sidewalk data and everything focused on audible feedback. (A)

    b. **Microsoft Translator:** Microsoft Translator is a free, personal translation app for 60+ languages, to translate text, voice, conversations, camera photos and screenshots. You can also download languages for offline translation for free to use when you travel. (D)

    c. **Google Live Transcribe:** Live Transcribe is an accessibility app designed for the deaf and hard of hearing, and usable by anyone. Using Google's state-of-the-art automatic speech recognition technology, Live Transcribe performs real-time transcription of

speech and sound to text on your screen, so you can more easily participate in conversations going on in the world around you. You can also keep the conversation going by typing your response on the screen. (D)

d. **Note apps:** Users sometimes use the smartphone's built-in note-taking app to type messages back and forth with others in order to facilitate communication. Users said that they will often use apps like Microsoft Translator, Google Live Transcribe, or a note-taking app when communicating with those who work in public transit. These communication tools could be possible tools to integrate into AccessPath for improved communication with public transit operators or others encountered during the user's trip. (D)

4. *What accessibility features are most helpful?*

   a. **Captioning*:*** One of the most important accessibility features for people with hearing disabilities is that all things done audibly are captioned and/or represented visually on the screen. Just as people with visual impairments need audible cues, people with hearing disabilities need visual cues. Since people with hearing disabilities often cannot hear audible cues, captioning is their way of understanding what is going on in the app. (D, H)

   b. **Easy to read/see*:*** Apps that are easy to read and navigate through reduce the visual cognitive load for people with hearing disabilities. Since they depend on their eyes for most things, it is best to ease the dependence on one's eyes. This is also valuable for users who are deaf-blind since they have little to no sight, depending on the user. Features that could help reduce the load on one's sight include, color contrast, zooming abilities, bigger fonts, and a dark mode. (D, H)

   c. **Haptic feedback:** To assist with limiting the visual and cognitive load, users have said that haptic (vibration) feedback is very useful. Although it can be difficult to discern smartphone haptic vibrations from vehicle-transmitted vibrations in heavily trafficked areas, these haptic alerts and notifications would help users be aware of upcoming turns, obstacles, or when their stop is approaching when riding public transit. Users have suggested that creating a standard method of haptic feedback would be useful, such as short vibration for a left turn and a long vibration for a right turn. These haptic alerts are an alternative way of communicating through the app. If a user with a hearing disability is not looking at the app, they will not know what the app is showing. Thus, haptic feedback provides a way by which a user will know what the app is showing/telling and limit missed cues. (A)

5. *If the app could do [blank], I would use it every day.*

   a. Favorite locations: Users would like the ability for the app to store their favorite locations, and ideally it would be done automatically similar to other navigation apps. Further, they would like to be notified to their upcoming favorite locations, and would like the ability to turn these notifications on/off. Having a feature of favorite locations makes it

easy for people to find their favorite destinations limits the cognitive load for users. Further, favorite location notifications help people with visual impairments orient themselves along their route as they pass each favorite place. (A)

b. **Distance walked:** Users would like the app to have some activity monitoring, similar to other apps. This feature would include the distance walked each day, calories burned, and other similar metrics. In addition, users would like to understand the number of bad sidewalks that they have avoided through use of the app. Users would like to view these personal data through a personal portal. Since users would be using the app for walking and pedestrian navigation, they would like all of their walking metrics all from one app. (D, H)

c. **Pull in Google to understand what time something closes:** Users would like Google Places data to be incorporated into the app so that when they search for a destination, they can view the menu, see what time it closes, and understand other information that Google typically shares. Participants expressed the desire for these capabilities so that they do not need to use multiple apps to find this information. They want the ability to understand as much as they can about a location in order to make an educated decision as to whether they want to travel there. (A)

d. **Alternate routes:** Users would like alternate route options based on safety, preference, or distance traveled. Users prefer to take different routes on different days depending on what they are doing or where they are going. By having multiple route options, they can choose to take the shortest path on a cold day or scenic route on a nice day, for example. (A)

Appendix D: Feature Prioritization List

Feature Definitions

This section provides a description of the features listed in the participant survey. For each feature, there is a lettered identification (ID), short feature name, and a description of that feature. The ID and name will be used to cross-reference in other sections of this report. Two versions of each feature are described. Version 1 describes a basic version of the feature, while Version 2 describes the feature with more capabilities. The intended methodology for implementation is that Version 1 would be added to the app before Version 2 because the level of effort needed for development is significantly less than Version 2. After users have had an opportunity to test Version 1, Version 2 should be implemented.

A. ***Indoor Accessibility***: This feature will allow users to understand the accessible features about a particular point of interest, such as a restaurant or store. These features could include information about the entrance (is there a step), restroom, width of aisles, automatic doors, typical loudness, braille availability, and more. It would allow users to submit this information via crowdsourcing. This feature does not mean that the data exists, but rather that the capability of crowdsourcing this data exists in the app.

   a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

   b. ***Version 2***: Version 2 will implement these points of interest into the routing algorithm based on quality of this point of interest. Users will also be able to choose to navigate to these points of interest.

B. ***Crossing Signals***: This feature would allow users to view additional information about crossing signals at crosswalks and intersections. It will provide information regarding timing, crosswalk type, button signal type, existence of audible feedback, subjective safety rating, and more. This data could be crowdsourced through the app or reported by a trained technician. This feature does not mean that the data exists, but rather that the capability of crowdsourcing this data exists in the app.

   a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

   b. ***Version 2***: Version 2 will implement these points of interest into the routing algorithm based on quality of this point of interest. Users will also be able to choose to navigate to these points of interest.

C. ***Transit Accessibility***: This feature would allow users to view additional information about the accessibility features of a bus or transit stop. For example, users could understand if there is a shelter, wheelchair accessibility in the shelter, whether the bus typically can access the curb, audible cues, benches, and more. This information could be crowdsourced from the user or aggregated from open-sourced data. This feature does not mean that the data exists, but rather that the capability of crowdsourcing this data exists in the app.

a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

b. ***Version 2***: Version 2 will implement these points of interest into the routing algorithm based on quality of this point of interest. Users will also be able to choose to navigate to these points of interest.

D. ***Multimodal***: This feature would integrate additional modes of transportation into the wayfinding algorithms. It would include modes such as bus routes, transit routes, bikeshare, and other similar transportation modes. The resulting suggested route or routes would take into account every transportation mode. The suggested route could be made up of multiple components such as walking and bus. The user may have the option to choose the shortest route, least transfers, and other similar options.

a. ***Version 1***: Version 1 would use a basic custom version to prototype and test the multimodal concept and functionality.

b. ***Version 2***: Version 2 will implement Google Maps API and other APIs for scalable multimodal navigation.

E. ***What is Around Me?***: This feature allows the user to search for nearby points of interest. This feature is useful for two primary reasons: 1) It allows users to orient themselves to their surroundings for improved navigation and awareness. The user could potentially ask the app what is nearby, whereas the app will tell the user the points of interest in each direction. Similarly, some people navigate best by using landmarks as reference points. 2) User are interested in searching for places that would like to go. They would like to know what places are nearby.

a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

b. ***Version 2***: Version 2 will be more interactive, allowing users to ask the app what is nearby, list the nearby points of interest, and choose to navigate to the one the user chooses.

F. ***Yelp***: This features allows the user to review Yelp points of interest and ratings.

a. ***Version 1***: Version 1 will only incorporate the API as an added feature and will not interact with AccessPath's routing.

b. ***Version 2***: Version 2 will incorporate the API into the routing algorithm capabilities, working towards multimodal and advanced navigation.

G. ***Rideshare***: This features allows the user to request a rideshare (Uber, Lyft, etc.)

a. ***Version 1***: Version 1 will only incorporate the Uber and Lyft APIs as an added feature and will not interact with AccessPath's routing.

b. ***Version 2***: Version 2 will incorporate the APIs into the routing algorithm capabilities, working towards multimodal and advanced navigation.

H. ***Point System***: Users said that they felt that more people would submit crowdsourced reports if there was an incentive for reporting or if there was a game-like element to it. They would like to encourage as much data to be reported, resulting in a better navigation experience.

   a. ***Version 1***: Users will gain points for submitting reports. They will get badges for being active users.

   b. ***Version 2***: Users may have the opportunity to be paid data collectors based on number of submitted reports, and only after completing training.

I. ***Accessible Entrances***: This feature would show the exact location of the accessible entrance. Typical navigation apps typically show the location of the building, but not the accessible entrance. This feature would show the exact side of the building where the accessible entrance is located. This information would be crowdsourced through the app. This feature does not mean that the data exists, but rather that the capability of crowdsourcing this data exists in the app.

   a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

   b. ***Version 2***: Version 2 will implement these points of interest into the routing algorithm based on quality of this point of interest. Users will also be able to choose to navigate to these points of interest.

J. ***Share My Route***: This feature would allow the user to share their route with friends and family. The friend would be alerted when the user arrives at their destination. This would also be helpful when scheduling to meet so that the other person knows when the user will arrive.

   a. ***Version 1***: Version 1 will send the route via email that can be loaded into a program like Google Maps.

   b. ***Version 2***: Version 2 will send the route via the AccessPath app, text, or other apps, if desired.

K. ***Multiple Route Options***: Similar to other navigation apps, this feature would allow users to select from multiple (2 or 3) options for possible routes to travel. The routes would vary slightly based on distance, time of travel, and accessibility. This allows the user to have options rather than one choice.

   a. ***Version 1***: Version 1 will allow users to choose from two options, shortest route and their custom route.

   b. ***Version 2***: Version 2 will allow users to choose from three options: shortest route, their custom route, and a route in between.

L. ***Redirect and Rerouting***: This feature would direct a user back to the suggested route if it the wander too far off course. This feature would include a rerouting component. It could start by asking the user if they prefer to be redirected back to the route or if they want rerouted completely. The value of this feature is that it will help people who are lost or wander of course

to find their way back on course. If they wish to travel a route different than the suggested one, it is capable of simply creating a new route (rerouting).

a. ***Version 1***: Version 1 will prompt the user, asking them if they would like to be redirected or reroute.

b. ***Version 2***: Version 2 will use artificial intelligence to learn when to redirect and when to reroute.

M. ***Emergency Button***: This feature would allow users to send out an emergency notification or phone call. This capability needs to be carefully implemented to prevent from false emergency calls. The reason for this feature is to allow users to easily and quickly contact a loved one or 911 in the case that they find themselves in an unsafe situation. This feature can be implemented as a strict 911 call or call/notification to a friend or family member.

a. ***Version 1***: Version 1 will open the phone app with "911" ready to dial. This will operate by pressing a button in the app.

b. ***Version 2***: Version 2 will allow users to choose whether to call a friend or 911 for their emergency. It will also have a shortcut method of making the emergency call such as a swiping motion on the screen.

N. ***Family Restrooms***: This feature will allow users to understand the location and level of accessibility of public restrooms. These features could include information about the entrance (is there a step), size, accessibility components, and similar important information. It would allow users to submit this information via crowdsourcing. This feature is similar to other crowdsourcing features previously suggested in the app. This feature does not mean that the data exists, but rather that the capability of crowdsourcing this data exists in the app.

a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

b. ***Version 2***: Version 2 will implement these points of interest into the routing algorithm based on quality of this point of interest. Users will also be able to choose to navigate to these points of interest.

O. ***Extended Crosswalk Time***: Similar to incorporating other APIs, this feature would incorporate Carnegie Mellon University's PedPal project into AccessPath. This feature would allow for the continued improvement of both technologies, working towards the ultimate goal of the Complete Trip. This feature would allow users to understand the locations where PedPal is implemented and use AccessPath to communicate with the PedPal sensors for a seamless, user-friendly process.

a. ***Version 1***: Version 1 will integrate the API into the AccessPath app for use with PedPal sensors. A user will be required to plan a route for integration with PedPal.

b. ***Version 2***: Version 2 will have advanced routing capabilities, such as automatic recognition that the user is near a PedPal intersection without needing to plan a route in the AccessPath app.

P. ***Accessible Parking***: Similar to other crowdsourcing features, this feature will allow users to understand the location, number of spots (total and van accessible), and quality of accessible parking. This data would be crowdsourced by users. This feature does not mean that the data exists, but rather that the capability of crowdsourcing this data exists in the app.

   a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

   b. ***Version 2***: Version 2 will implement these points of interest into the routing algorithm based on quality of this point of interest. Users will also be able to choose to navigate to these points of interest.

Q. ***My Direction***: This feature allows the users to understand the cardinal direction that they are heading and the cross street in that direction. This feature would especially help people with visual impairments re-orient themselves with their surroundings after getting turned around or lost.

   a. ***Version 1***: Version 1 will allow users to understand the cardinal direction in the app by pressing a button in the app.

   b. ***Version 2***: Version 2 will allow users to understand the cardinal direction they are heading and the upcoming cross street.

R. ***Rate My Sidewalk***: This feature will allow users to submit subjective ratings about the quality of sidewalk segments. Similar to other crowdsourcing features, users can select the segment and rate its quality. The ability for users to add an image may be included as well.

   a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

   b. ***Version 2***: Version 2 will implement these points of interest into the routing algorithm based on quality of this point of interest. Users will also be able to choose to navigate to these points of interest.

S. ***Pedestrian Traffic***: This feature would allow users to understand the level of pedestrian traffic on each pathway. This feature would likely evolve over time, starting by showing typical traffic and later evolving to show real-time traffic based on people using the AccessPath app.

   a. ***Version 1***: Version 1 will only show the paths on the map as a separate layer.

   b. ***Version 2***: Version 2 will implement these paths into the routing algorithm based on amount of traffic.

T. ***What Am I Passing***?: This feature will announce points of interest as users walk by those locations. For example, the app alerts the user as they walk past Starbucks. This feature is particularly important for people with visual impairments to orient them to their surroundings. This feature has already been partially implemented, where the user can be alerted to their Favorites as they approach. This added feature will allow users to be alerted to other points of interest already on the map.

   a. ***Version 1***: Version 1 will finalize the implementation of the Favorite alerts capability.

b. ***Version 2***: Version 2 will allow users toggle on/off a feature to be alerted to all points of interest as they travel by.

U. ***Changes to Route***: This feature would alert users to changes along their normal route. This depends on a "normal route" being identified in some way. When a user chooses to travel that route, this feature will identify any changes to the route, such as construction or other obstacles.

a. ***Version 1***: Version 1 will require users to preset a route that they typically travel.

b. ***Version 2***: Version 2 will learn a user's preferred route based on machine learning and artificial intelligence.

V. ***Bus Arrival***: This feature would integrate other tools or APIs to inform users of real-time arrival times. This could integrate with a cities system already in place or integrate a third party API such as Tiramisu.

a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

b. ***Version 2***: Version 2 will implement these points of interest into the routing algorithm based on quality of this point of interest. Users will also be able to choose to navigate to these points of interest.

W. ***Sidewalk View***: This feature would allow users to virtually walk through a route prior to taking the trip in the real world. This feature is a visual journey of the route as shown by pathMet images collected along the route. This feature would start by showing an image of the starting point and announce the first direction. The user would advance through the images, progressing along the route, and the app would announce the set of directions when the user reaches the image where they are supposed to turn or continue. This process continues until they reach their destination or exit the feature.

a. ***Version 1***: Version 1 will only allow users to see the images of a particular route. Directions will not be shown/read.

b. ***Version 2***: Version 2 will add the step-by-step directions to the virtual route. These directions will be read aloud and/or shown on the app.

X. ***Tutorial***: This feature would add a brief app tutorial upon a user's first log in of the app. Further, this feature may include strategically placed help buttons to explain features of the app or terminology (i.e. curb ramp).

a. ***Version 1***: Version 1 will allow a user to watch a short video tutorial.

b. ***Version 2***: Version 2 will implement a tutorial overlaid on the app screens, similar to other app tutorials. Users will receive a step-by-step walk-through for certain features.

Y. ***Legend***: This feature would provide a map legend for the types of data being shown on the map (curb ramps, transit, sidewalks). This helps users understand the types of data being shown.

a. ***Only One Version***

Z. ***Service Animal Restrooms***: Similar to other crowdsourcing features, this feature will allow users to understand the location of commonly used areas as a restroom for their service animal. This data would be crowdsourced by users. This feature does not mean that the data exists, but rather that the capability of crowdsourcing this data exists in the app.

a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

b. ***Version 2***: Version 2 will implement these points of interest into the routing algorithm based on quality of this point of interest. Users will also be able to choose to navigate to these points of interest.

AA. ***App Contrast***: This feature will allow users to modify the color contrast of the overall app as well as the map.

a. ***Version 1***: Version 1 will add the ability to change the map contrast only.

b. ***Version 2***: Version 2 will add the ability to change the app contrast.

BB. ***Outdoor Seating***: This feature will allow users to understand the location of outdoor seating. It would allow users to submit this information via crowdsourcing. This feature does not mean that the data exists, but rather that the capability of crowdsourcing this data exists in the app.

a. ***Version 1***: Version 1 will only show the points of interest on the map as a separate layer.

b. ***Version 2***: Version 2 will implement these points of interest into the routing algorithm based on quality of this point of interest. Users will also be able to choose to navigate to these points of interest.

CC. ***Haptic Alerts***: This feature will add haptic alerts for hazard and favorites alerts. It will also add haptic alerts when a user should make a turn when navigating. The phone will vibrate when a user approaches a hazard, favorite, or the next direction when navigating.

a. ***Version 1***: Version 1 will add vibration when the user approaches a hazard or favorite location. This setting is turned on/off in the Settings menu.

b. ***Version 2***: Version 2 will add vibration alerts for users when they are supposed to make a turn. For example, two short vibrations could mean a left turn and one long vibration could be a right turn.

DD. ***Additional Navigation Capabilities***: This feature would allow the navigation directions to tell you whether you should walk on the left or right side of the road. This helps with navigation capabilities so that users understand which side of the road they should be travelling.

a. ***Only One Version***

User Surveys

There were 34 survey questions that were sent to participants. The first 33 questions were mandatory, while the last question was optional in case participants had additional suggestions. For questions 1-3, participants answered from the lettered options shown below the question. For questions 4-33, participants selected a number between 1-5, where 1 represents “Not important” and 5 represents “Very important.”

Participant Instructions:

AccessPath is a mobile app that provides real-time pedestrian navigation and directions for improved accessibility. Current features of the app include pre-trip planning, real-time navigation, submitting reports about hazards on your route, recent paths, and favorite locations.

The purpose of this survey is to gather feedback from pedestrians to understand how to prioritize which features should be added to the app next.

This is part of a project with the U.S. Department of Transportation. No identifiable information is being collected here. By participating in this survey, you understand that this information and results may be included in reports. Since no names or personal information are being collected, this data will of course remain anonymous.

Directions:

The first three questions pertain to your demographics. For the remaining questions, please rate the following features by their level of importance to you. A rating of 1 means that it is not important, and a rating of 5 means that it is very important. There are 34 questions in total. The last question provides an option to provide additional feedback for features that we missed. This survey should take approximately 10 minutes to complete.

If you are completing for someone with a disability on their behalf, please specify in the "Other" response of the first question.

Thank you for taking the time to complete it!

Survey Questions

1. Specify if you have a disability
    - **a.** Blind or visually impaired
    - **b.** Wheelchair or scooter user
    - **c.** Cognitive disability
    - **d.** Deaf or hard-of-hearing

e. None

f. Other_____

2. How old are you?

a. 18-24

b. 25-34

c. 35-44

d. 45-54

e. 55-64

f. 65+

3. What is your gender?

a. Female

b. Male

c. Prefer not to say

d. Other_____

4. Indoor Accessibility: Understand accessibility features of restaurants and places (i.e. number of steps, restrooms, braille menus)

5. Crossing Signals: Understand the details about the type of crossing signal (i.e. presence of signal, audible, timing)

6. Transit Accessibility: Understand the accessibility attributes about specific transit stops (i.e. steps, shelters, elevators)

7. Multimodal: Your navigation will offer you directions that consider all travel possibilities (transit, walking, driving)

8. What is around me: Understand the points of interest that are within a five block radius

9. Yelp: Adding Yelp capabilities to the app

10. Uber: Adding Uber capabilities to the app

11. Point System: Earn points and virtual trophies for submitting reports in the app

12. Accessible Entrances: Understand the location and side of the building of the accessible entrance

13. Share My Route: Share your route with friends and family, including your estimated time of arrival

14. Multiple Route Options: The app will provide more than one route option

15. Redirecting and Rerouting: The app will redirect you back to your intended route if you stray from it or reroute you if you choose to go a different way

16. Emergency Button: A button that will allow you to get in contact with a family member, friend, or 911 in case of an emergency

17. Family Restrooms: Locate nearby family restrooms, including those that are accessible

18. Extended Crosswalk Time: The app will integrate a technology to extend your time at crosswalks if needed

19. Accessible Parking: Find accessible parking locations, including those for vans

20. My Direction: Understand the cardinal direction you are heading and the upcoming cross street

21. Rate My Sidewalk: Have the ability to rate the quality of entire blocks of sidewalk for improved navigation

22. Pedestrian Traffic: Understand the current amount of pedestrian traffic along sidewalk segments

23. What Am I Passing?: The app will announce and display points of interest as you go by them

24. Changes to Route: Understand changes to your normal route traveled (i.e. from home to work)

25. Bus Arrival: Understand real-time bus arrival information (i.e. how long it will take for the bus to arrive)

26. Sidewalk View: View a virtual route along the sidewalk before taking your trip (similar to Google Street View but from the sidewalk perspective)

27. Tutorial: The app will give you a brief tutorial on how to use it upon opening it for the first time

28. Legend: The map within the app will have a legend describing the map icons

29. Service Animal Restrooms: Understand the location of typical areas where people take their service animals to the restroom

30. App Contrast: Have the ability to change the contrast of different features of the app

31. Outdoor Seating: Understand the location of public seating options along your route

32. Haptic Alerts: The phone will vibrate when it is time for a user to turn on their route or when they pass by a point of interest

33. Additional Navigation Capabilities: The app will tell you whether you should travel down the left or right side of the road, based on your traveling direction

34. Specify any features that we missed here (optional)