IDEA

Innovations Deserving
Exploratory Analysis Programs

Transit IDEA Program

Comprehensive Wayfinding for All

Final Report for
Transit IDEA Project 91

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January 2022

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Comprehensive Wayfinding for All

IDEA Program Final Report
(Stage 1)

Transit IDEA Project T-91

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Transportation Research Board
The National Academies of Sciences, Engineering, and Medicine

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In fact, Capital Metro, as a whole, deserves significant recognition for making this project possible. They were on-board at the very beginning of the project, partnering with TTI and the Taskar Center for Accessible Technology; contributing their time, data, and talent to the project team; and purchasing and installing some of the Bluetooth® low-energy beacons for the testing phases of the project.

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- The City of Austin.
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- The American Council for the Blind, Austin Chapter.
- The Texas School for the Blind.
- The Metropolitan Transit Authority of Harris County (Houston METRO).

It takes a group of dedicated, invested individuals to make any complex, innovative project work. And, although the final product was not completed, the accomplishments and lessons learned along with way would not have been possible without all those listed above.

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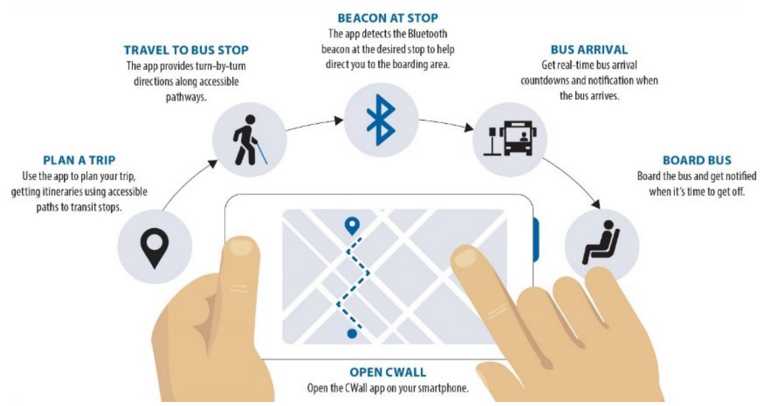
EXECUTIVE SUMMARY

In partnership with the Capital Metropolitan Transportation Authority (Capital Metro) and the Taskar Center for Accessible Technology (TCAT), the Texas A&M Transportation Institute (TTI) led a project that aimed to develop an iOS-based smartphone application to provide trip planning and navigation assistance to members of the mobility-impaired (MI) and blind or low-vision (B/LV) communities. The project and app, called *Comprehensive Wayfinding for All* (CWall), was funded by the Transit Ideas Deserving Exploratory Analysis (IDEA) program and started in the summer of 2018. Although the CWall app could be used by anyone, the goal was to provide MI and B/LV users with assistance for the following activities (see Figure 1):

FIGURE 1 Overview of the proposed use of the CWall app.



- Planning a trip that involves walking and/or walking and fixed-route transit. Walking legs of the trip would be routed along accessible pedestrian pathways if needed.
- Locating a bus stop by combining the phone's GPS-based position and the known Bluetooth® low-energy (BLE) beacon installed at each bus stop. The BLE beacons would help the user, especially B/LV users, find the actual stop location and provide confirmation that the user is at the correct bus stop.
- Providing real-time fixed-route transit information in an accessible format, so a user can know the predicted arrivals of a desired bus and receive a specific alert when the user's bus is arriving.
- Providing step-by-step trip assistance that encompasses all of the features above plus alerts for when to get off the bus. This trip assistance would help guide a MI or B/LV user from the trip origin, to the correct bus stop, onto the correct bus, off the bus at the correct stop, and to the final destination.

The goal of the project team was do accomplish all of these app functions using free, open source data sets and development approaches so that the final CWall app could be easily scaled and used by any region that wanted to set up the application. Figure 2 displays the CWall data and technology integration model.

FIGURE 2 CWall data and technology integration model

However, although the project team made several significant steps forward, the project was halted at Stage 1 (the halfway point of the project) due to technical challenges that were insurmountable given the project's budget and goal to keep all development open. Although the CWall app's functions were never fully developed, the project team did have several accomplishments:

- The team confirmed with members of the MI and B/LV communities that the CWall app, in concept, served a currently unmet need and would be helpful for navigating and using a city's pedestrian and transit networks.
- The team, with the help of TCAT, digitized the pedestrian networks in a portion of downtown Austin and at Tech Ridge Park and Ride into OpenStreetMap.
- The team established an app server with supporting data fetch processes to pull OpenStreetMap and Capital Metro's GTFS-Static data sets for use in the app.
- The team completed the app's user account creation and management function.
- The team completed the app's trip planning function, routing users along pedestrian and transit networks.

Although the CWall product was not completed, the project was still beneficial to the industry through several lessons learned, listed below and discussed in more detail in the Conclusions section of this report.

- Free, open-source engines for pedestrian network routing <u>and</u> pedestrian wayfinding do not exist.
- Data standards for pedestrian network data are not commonly used.
- Data regarding intersection characteristics relevant to MI and B/LV travelers are not standardized or publicly available.
- Real-time information about pedestrian pathway closures and accessible detours is lacking.
- The CWall app (or similar app) would help fill a real, current need in the MI and B/LV communities.

Although there are many apps and technological aids available to members of the MI and B/LV communities, there remains a need for an app like CWall (or that goes beyond CWall) to make the traveling experience of members of the MI and B/LV communities much more seamless—improving personal freedom, mobility, and quality of life.

SECTION 1. INTRODUCTION

In partnership with the Capital Metropolitan Transportation Authority (Capital Metro) and the Taskar Center for Accessible Technology (TCAT), the Texas A&M Transportation Institute (TTI) led a project that aimed to develop an iOS-based smartphone application to provide trip planning and navigation assistance to members of the mobility-impaired (MI) and blind or low-vision (B/LV) communities. The project and app, called *Comprehensive Wayfinding for All* (CWall), was funded by the Transit Ideas Deserving Exploratory Analysis (IDEA) program and started in the summer of 2018. The CWall app would aid MI and B/LV users in traveling to and locating bus stops, obtaining real-time transit information, and receiving alerts for when to board and get off buses.

However, although the project team made several significant steps forward, the project was halted at Stage 1 (the halfway point of the project) due to technical challenges that were insurmountable given the project's budget and goal to keep all development open (preferably using existing open source code and platforms). Details about the accomplishments and the technical challenges encountered are provided in the remainder of this report.

The CWall app was never tested with actual users, because app development did not reach a stage in which user testing could begin. Because this is the final report for an incomplete IDEA product, the report will discuss both the original *concepts* (what CWall was *going to be*) and the actual *accomplishments* (what was actually done to date). Language about the CWall concepts will be discussed in terms like *would* and *could.*

After this introduction, this report is divided into several sections:

- Section 2: IDEA Product.
- Section 3: Concept and Innovation.
- Section 4: Investigation.
- Section 5: Potential Implementation.
- Section 6: Conclusions.

SECTION 2. IDEA PRODUCT

Nineteen percent of the U.S. population, approximately 56.7 million people, have some form of disability (*1*). The unemployment and poverty rates for people with disabilities are 13 percent and 25 percent, respectively, and 29 percent of people with disabilities report that a lack of adequate transportation is a significant problem in accessing jobs. Public transit is a vital part of the transportation options available to people with disabilities; however, taking a transit trip often presents its own set of challenges. The Accessible Transportation Technology Research Initiative (ATTRI) studied the transportation challenges of people with disabilities and identified barriers to using transit, user needs when taking transit, and the most common issues with technology (*2*) (see Table 1).

TABLE 1 Transportation challenges of people with disabilities according to ATTRI.

Top Identified Barriers	Top Identified User Needs	Top Identified Issues with Technology
• Lack of or inaccessible signage, maps, landmark identifiers, and announcements	• Amenity Information (e.g., restroom and shelter)	• Training to use and awareness of new technology
• Navigation difficulties (do not know when to arrive, transfer time, or distance)	• Real-time transportation information	• Affordability
• Inconsistent accessible pathway infrastructure	• Safety, security, and emergency information	• Performance quality (especially long-distance travel and rural areas)

Source: (*2*).

Transit still has a long way to go before it fully meets the identified needs of people with disabilities, but addressing these needs can help improve the freedom, mobility, and quality of life of people with disabilities.

EXISTING CHALLENGES

For many travelers, especially those in the MI and B/LV communities, using fixed-route transit can be a challenge, and barriers may be encountered at any point of a transit trip—from planning a trip through arriving at one's final destination. For example, a traveler may encounter transit maps and schedules that rely on sight, pedestrian pathways that are not accessible or temporarily closed, bus stops and boarding areas that are hard to locate, no accessible real-time bus arrival information, and buses that do not provide audio announcements when they arrive at the bus stop. Although more and more transit agencies are geocoding bus stop locations, bus stop coordinates are not always accurate, and navigation apps that rely on a global positioning system (GPS) are not always precise in determining a person's (or the bus stop's) location. As more technological solutions are developed, fixed-route transit will become easier to use, and users will have improved mobility and freedom by using fixed-route transit more often. This benefits both the rider and public transit agency by decreasing the overall cost of traveling by avoiding expensive Americans with Disabilities Act (ADA) paratransit, transportation network companies (TNCs), or taxis.

EXISTING SOLUTIONS

As Bluetooth® and other wireless and mobile technologies become more widely used by the public, these technologies can be leveraged to build solutions that aid transit riders with disabilities. For example, Bluetooth can be used to create a positioning system that helps riders, especially B/LV riders, navigate their environments and locate points of interest. A study in Sweden used Bluetooth to create a positioning system that could be integrated into new apps and services (*3*). A study in 2016 proposed an updated methodology using Bluetooth low-energy (BLE) beacons to simulate positioning in three dimensions. This method yielded a higher positioning accuracy rate than the existing two-dimensional triangulation method (*4*). Bluetooth technology integrated with way-finding apps and services can be fine-tuned to assist transit riders with visual impairments.

A few recent studies have specifically researched ways to use smartphone apps to aid transit riders with visual impairments. For example, a 2017 study looked at developing a "public transit assistant." The research team used Wi-Fi access points at bus stops and inside transit vehicles both to notify passengers at bus stops when vehicles were arriving and to notify passengers on buses when their buses were approaching their destinations (*5*). Several other apps, such as BlindWays and BlindSquare, provide way finding for people with visual impairments. These apps rely on comprehensive point-of-interest databases and maps, GPS, or even crowdsourced knowledge to provide users detailed information about their environments and pathways to reach their destinations (*6*, *7*).

New data sets for accessibility information are also being created to improve transportation accessibility. TCAT is spearheading OpenSidewalks, a database of sidewalk and pedestrian pathway data that supplements OpenStreetMap data. TCAT aims to create a standard data structure for sidewalk representation and provide tools for individuals to contribute to the sidewalk database (*8*).

The goal of the CWall app was to do what no other app or solution currently does: provide sidewalk-level navigation assistance along accessible paths to and from transit stops and provide helpful assistance during any trip with both pedestrian and transit legs (or parts). CWall would leverage existing technology and data and would use users' smartphones instead of custom-built devices.

ORIGINAL CWALL CONCEPT

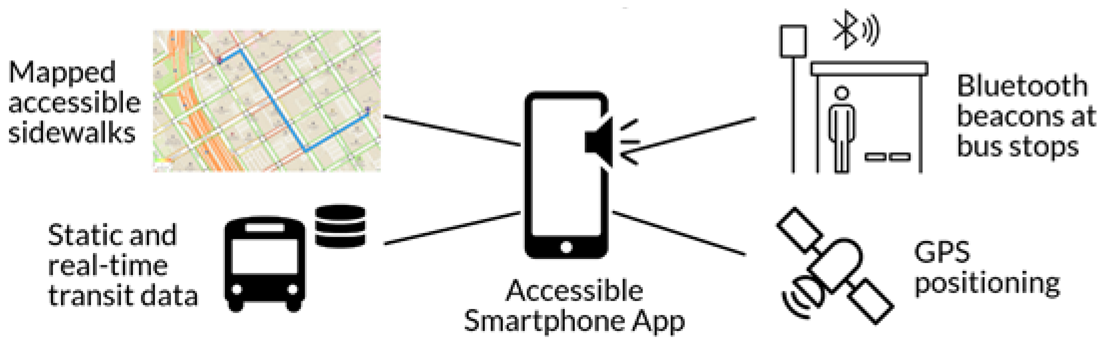
CWall would be a fully integrated accessible trip-planning and wayfinding smartphone app that could address several of the ATTRI-identified challenges for using fixed-route transit by providing:

- Bus stop finding: Users would be guided to the precise boarding location of a desired bus stop. CWall would use Bluetooth® low-energy (BLE) beacons installed at stops to achieve better-than-GPS bus stop locations. The CWall app focused on finding bus stops (as opposed to train stations—either above or underground), because bus stops are much more difficult to find and there are many more of them.

- Real-time transit information: Users would receive real-time estimated arrival times for desired routes; trip itineraries would contain the latest information to reflect any stop or route closures or detours.
- Trip planning: Users would enter an origin and destination and receive walking and transit trip itineraries along accessible pathways using sidewalk level data. The app would use pedestrian pathway and transit data, combined with user preferences and needs, to rank and present trip itineraries.
- Pedestrian wayfinding: Users would be directed along accessible pedestrian pathways with turn-by-turn instructions customized for pedestrian networks.
- Trip assistance: Users would receive comprehensive guidance along an entire transit trip, including all of the functions described above in addition to receiving notifications when it was time to get off the bus.

CWall would integrate several existing data sources and technologies (Figure 3) and go a step above currently available solutions by combining sidewalk-level (not merely street-level) accessibility information and navigation assistance with real-time transit data, bus stop locations, and GPS information. Figure 4 displays the steps in a typical CWall use case.

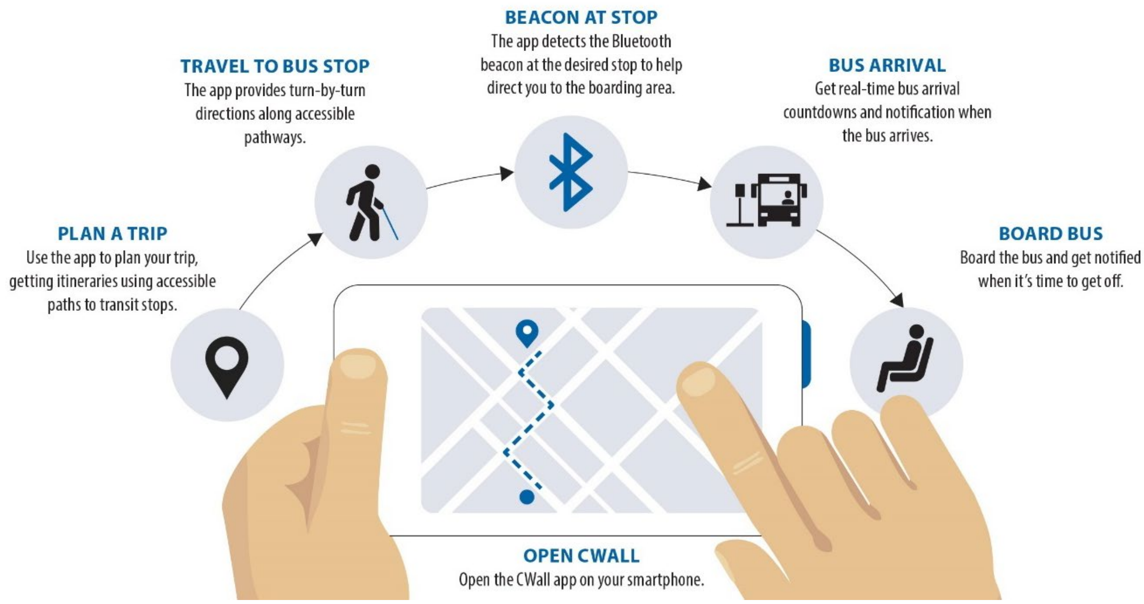
FIGURE 3 CWall data and technology integration model.



The proposed data sources or standards supporting the app's functions are below:

- *Pedestrian pathways:* Accessed from OpenStreetMap.
- *Static transit data* (i.e., routes, stops, and schedules)*:* The static General Transit Feed Specification (GTFS-Static) data from the relevant transit agency(ies).
- *Real-time transit data* (i.e., predicted arrivals as well as delays, closures, or detours)*:* The agency's real-time data feed either through the agency's application programming interface (API) or its GTFS real-time (GTFS-RT) feed.

FIGURE 4 Overview of the proposed use of the CWall app.



POTENTIAL FOR APPLICATION TO PRACTICE

The CWall app would have several potential benefits for users and transit agencies.

CWall could provide an integrated tool for users to improve the accessibility of their cities and transit. For many users, MI or B/LV travelers, CWall would help make fixed-route transit easier to use. As fixed-route transit becomes easier to use, users would have improved mobility and freedom by using fixed-route transit more often—all while decreasing the overall cost of traveling by avoiding expensive ADA paratransit, TNCs, or taxis. Although CWall specifically targets users with disabilities, the app could also benefit users without disabilities by reducing the learning curve of taking transit and making the sidewalk and transit network easier to understand and use.

CWall would benefit transit agencies by helping shift passengers with disabilities onto fixed-route transit. Because ADA paratransit is more expensive per passenger trip than fixed-route transit, any shift in passenger travel from paratransit to fixed-route transit helps transit agencies control and potentially reduce operating and capital costs associated with operating paratransit service. Also, the CWall app would be built using relatively inexpensive and scalable technology (i.e., BLE beacons) and open data sets (e.g., transit data APIs and OpenSidewalks). Upon completion, the CWall appl source code would have been available using existing standards in open-source development.

Lastly, CWall could make the transit network easier to use for anyone, helping to attract and retain new riders with and without disabilities.

SECTION 3. CONCEPT AND INNOVATION

This section provides more detail about the CWall concept app, including, as conceived, the app's functions, what data sources and technologies would be used for each function, and what the user experience would be like. This section describes each of the CWall app's desired functions, including:

- User Account Creation and Management.
- Bus Stop Finding.
- Real-Time Transit Information.
- Trip Planning.
- Pedestrian Wayfinding.
- Trip Assistance (a combination trip planning, wayfinding, bus stop finding, and real-time transit information).

After these functions are described, this section also discusses what additional functions or features could be beneficial but were not included in the original development plan.

USER ACCOUNT CREATION AND MANAGEMENT

The CWall app would allow users to create an account by creating a unique username (optionally an email address) and password. Each account would be associated with the user's profile, which would include the properties shown in Table 2. These desired profile properties were identified during development; however, not all properties were given the same priority during the project (the priorities are also shown in Table 2).

TABLE 2 User profile properties.

Property Title	Priority	Description	Use in CWall
First name **Last name**	High	(optional) The user's first and last name.	Would be used in various app screens for personalized messages. Also would be used for communication with users.
Email	High	The user's email address	Would be used to register and confirm the account. Also would be used for communication with users.

Property Title	**Priority**	**Description**	**Use in CWall**
Saved addresses	Low	(optional) Stored addresses associated with a user's frequently used origins or destinations.	Multiple saved addresses would be allowed. Each could be named by the user (e.g., "home," "work," "doctor"). Saved addresses would be available during trip planning. Addresses typed in during Trip Planning could also be saved.
Travel preferences	See individual preferences	(optional) A series of fields related to personal travel needs / preferences.	These travel preferences determine how the user's trips are planned and what level of wayfinding assistance is provided. The preferences were: • *Use wheelchair accessible routes:* (high priority) would force itineraries to use wheelchair-accessible pedestrian routes (on/off). • *Visual impairment assistance:* (low priority) would provide more frequent and descriptive instructions to the user (on/off). • *Walk distance limit:* (high priority) would allow the user to set a maximum distance that he or she is willing to walk (slider/input). • *Haptic feedback option:* (low priority) would allow user to turn haptic feedback (vibration cues during Trip Assistance) on or off.

The app would also support:

- Logging in.
- Logging out.
- Changing or resetting the password.
- Resetting travel preferences.
- Deleting the account.

BUS STOP FINDING

One of the functions of the app would be locating (and providing basic guidance to) a desired bus stop. In this function, the user knows what stop he or she wants to travel to and is generally comfortable with the street network. However, the user is seeking assistance to make sure he or she (a) is heading in the right direction and (b) has actually found the correct bus stop.

The Bus Stop Finding Function would rely on the phone's GPS and compass data for phone location and the relative position of the desired bus stop. Bus stops and their locations would be contained in the relevant GTFS-Static data set. An additional table that associates a BLE beacon ID with each bus stop would provide the app with what specific BLE beacon the phone should be searching for.

The function would work like this:

- The user would open the app and select *Find a stop*.
- The app would determine the nearest five bus stops and would present them as a list.
- The user could select to search by location or by route.
  - Searching by location: There would be a text input into which the user could input a stop ID, an intersection, or an address. Based on the input, the app would present the most relevant stops.
  - Searing by route: There would be a text input into which the user could input a route number or name. Based on the input, the app would present the nearest stops on that particular route.
- Once the user selected the desired stop, the user could ask for a trip plan to the stop or could ask to be told how far away and in what direction the stop was.
- If the user requested a trip plan, the app would launch the Trip Planning Function using the user's current location as the origin and the desired stop as the destination. (See the Trip Planning Function for more details.)
- If the user requested the stop's distance and direction, the user would start walking toward the stop.
  - The app would provide corrective or confirmatory statements depending on whether the user was heading in the right direction. The app would provide updates about the distance to the stop along the way.
  - As the user gets closer to the stop, BLE detection would take over and would begin seeking the BLE beacon associated with the desired stop. Once the BLE beacon is found, the app would update the distance estimate using a combination of GPS and BLE beacon signals.

    - When the user arrives at the actual stop location (within 5-to-10 feet), the app would notify the user that they had arrived and would then ask if the user wanted real-time transit information for a particular route. If so, the app's Real-Time Transit Information function would launch (more details are provided in the section describing the Real-Time Transit Information Function).

REAL-TIME TRANSIT INFORMATION

This app function would provide users with real-time transit information for fixed-route transit modes. In this function, users receive either next arrivals at a single bus stop or next arrivals for a single route and stop combination.

Bus stops, their locations, and routes serving the stops would be contained in the relevant GTFS-Static data set. Real-time transit information would be contained in the relevant transit agency's real-time data feed, typically provided through a custom API or through a real-time data standard like GTFS-RT.

The function would work like this:

- The user would open the app and select *Real-time info*.
- The app would determine the nearest five bus stops and would present them as a list.
- The user could select to search by location or by route.
    - Searching by location: There would be a text input into which the user could input a stop ID, an intersection, or an address. Based on the input, the app would present the most relevant stops.
    - Searing by route: There would be a text input into which the user could input a route number or name. Based on the input, the app would present the nearest stops on that particular route.
- Once the user selected the desired stop, the user could receive all next arrivals (for all routes) or could select a specific route for which to receive next arrivals.
- Arrival information that was based on scheduled (not real-time) data would be flagged as *scheduled*.
- The next arrival information would update regularly (e.g., every 30-to-60 seconds).
- The user could also request to be notified when a bus on their desired route was arriving. If selected, the app would only provide notifications of the estimated arrival time for that route and would provide a special notification when the bus was arriving at the desired bus stop (based on real-time arrival data).

TRIP PLANNING

Another app function would help users plan trips. This function is essential to the core innovation of the CWall app, because trip planning would provide itineraries (trip plans) that utilize the pedestrian network, street network (if needed), and fixed-route transit network. In particular, if users' travel preferences were set to require wheelchair-accessible pathways, itineraries would only include routes that are wheelchair accessible. Granted, "accessible" was minimally defined in this project, requiring only two characteristics to be considered accessible by the app:

- The presence of a sidewalk or similar hard-surface pedestrian pathway.
- The presence of curb cuts or similar ramps that would connect elements of the pedestrian pathway together.

The pedestrian network (including pathways and curbcuts) would be contained in OpenStreetMap, using OpenSidewalks data standards. The street network would be contained in OpenStreetMap. The transit network would be contained in the relevant GTFS-Static data set. Current route or stop closures would be contained in the relevant GTFS-RT data set. Of particular importance in this part of the application is the routing engine. The project team researched several routing engine options and found that the *Navitia* routing engine to be open source, free, and capable of routing along a pedestrian network from OpenStreetMap. (This was true as of the time of the project; however, technologies and offerings in the trip planning space change rapidly.)

The function would work like this:

- The user would open the app and select *Plan a trip.*
- The app would prompt the user for an origin. Options would include:
  - The user's current location (determined by GPS).
  - Picking from a list of saved addresses (part of the account profile).
  - Inputting an address or point of interest (POI).
- The app would prompt the user for a destination. Options would include:
  - The user's current location (determined by GPS).
  - Picking from a list of saved addresses (part of the account profile).
  - Inputting an address or point of interest (POI).
- The app would prompt the user for the trip time. Options would include:
  - Depart at:
    - Now.
    - A selected date and time.
  - Arrive by a selected date and time.

- The user's travel preferences would be used when generating itineraries; however, a menu button would allow the user to change travel preferences for this specific trip.
- Using a routing engine, the app would then display up to three itineraries using the pedestrian, street, and fixed-route transit networks (including both scheduled and real-time information to account for possible stop or route closures or detours). Itineraries would be sorted based on total travel time (including all legs of the trip).
- The app would present the user with a summary of each itinerary, describing each in terms of the total time, walk time, and a list of transit routes used. If there are any data uncertainties for generated itineraries (e.g., absence of a pedestrian network), the itinerary would be flagged to notify the user of this issue.
- A user could view the details of each itinerary, including full step-by-step instructions.
- The user could then select *Start trip* to begin the trip. Starting the trip would launch the app's Trip Assistance Function.

PEDESTRIAN WAYFINDING

Pedestrian wayfinding would be the app's function that provides users with enroute trip instructions during the pedestrian legs of a planned trip. This function would help users navigate the pedestrian and street networks by providing prompts that help users stay on the appropriate path to their destinations.

Pedestrian wayfinding would begin when the user selects a trip itinerary that includes one or more pedestrian legs (e.g., walking to a transit stop, between transit stops, or from a stop to a final destination). The Pedestrian Wayfinding Function would rely on the phone's GPS and compass to determine the user's location and direction of travel. If the user is traveling to a bus stop, then, the Bus Stop Finding Function would take over when the user was in close-enough proximity to detect the stop's BLE beacon.

The function would work like this:

- The user starts a trip by selecting an itinerary from the Trip Planning Function and selecting *Start trip*, which launches the Trip Assistance Function. If the trip's first leg contains is on the pedestrian network, the Pedestrian Wayfinding Function would be used.
- The app determines the user's location and direction using GPS and determines what prompts to give the user to orient them in the correct direction. The app continually monitors the user's location and direction to determine if a correction needs to be given.

- The app would contain a set of standardized audible prompts that provide the user with information leading up to and at trip nodes. (Nodes are places in the trip when the user changes from one element of the network to another element.) Examples include:
    - Turn to 12 o'clock to walk north on St. Paul street for 500 feet.
    - In 100 feet, turn left to 9 o'clock to walk west on 2nd Street.
    - Turn left to 9 o'clock to cross St. Paul street when it is safe. This intersection has a curb cut.
    - Continue walking west on 2nd Street for half a mile.
    - Your destination, the 2nd Street and Lamar Avenue bus stop, is on your left.

Additionally, the project team wanted to build haptic feedback cues into the app, causing the phone to vibrate in unique ways as prompts for specific changes in direction. For example, the app could produce:

- One long pulse to prompt the user to continue straight.
- Two short pulses to prompt the user to turn left.
- Two short pulses, a pause, and then two more short pulses to prompt the user to turn right.
- Five long pulses to indicate destination arrival.

As should be clear, the number of potential unique prompt styles (both audible and haptic) is large. However, it is in this function that the research team encountered its main obstacle to completing the project. At the time of writing this report, there was no free, open source wayfinding engine that could accept a Navitia-generated route along a pedestrian network and automatically generate the needed prompts. The project budget was not significant enough to develop this function internally.

TRIP ASSISTANCE

Trip Assistance would be an umbrella function that utilizes each of the functions above in addition to a disembark alerts function. Trip Assistance would provide the user with step-by-step enroute guidance along all legs of a planned trip.

In an itinerary that involves both pedestrian and transit legs, the function would work like this.

- The user starts a trip by selecting *Start trip*.
- The Pedestrian Wayfinding Function would help the user head in the right direction to get to the first bus stop.
- As the user neared the bus stop, the Bus Stop Finding Function would help the user locate the actual stop location using BLE beacon detection.

- Once the user arrived at the stop, the Real-Time Transit Information Function would provide real-time arrivals for the needed route and would notify the user when his or her bus was arriving.
- Once the user was on board the correct bus, the app would track the user's location and would provide notifications when his or her bus stop was approaching.
- Once the user alights the vehicle, the Pedestrian Wayfinding Function would take over and would help the user navigate to either the final destination or the next bus stop, whichever applies.

POTENTIAL ADDITIONAL FEATURES AND FUNCTIONS

During development, the project team had the opportunity to discuss the app's specifications with potential users and with representatives from the City of Austin and Capital Metro. During these discussions, several additional helpful features and functions were identified that were outside of the scope of this project but could prove useful in any future application seeking to provide similar assistance to the MI and B/LV communities. These additional features and functions included:

- Sidewalk closures and detours.
- Intersection / street crossing information.
- On-demand transit options.

Sidewalk Closures and Detours

Members of the MI and B/LV communities that are planning or taking trips that contain pedestrian legs can often be frustrated by finding out last minute that a sidewalk is closed—this is especially problematic if a person who is B/LV finds out by encountering an unexpected sidewalk blockage. Sidewalk closures can add delay to trips, requiring people to backtrack and take alternate routes. If the alternate route is not wheelchair accessible, then, a person with a wheelchair or mobility device may encounter additional frustration by having to take an even longer alternate path.

Adding real-time information about sidewalk closures and accessible detours could greatly benefit users by helping them avoid closed sidewalks and providing them with itineraries that take closures into account. However, there currently is no commonly used data specification or process for sidewalk closures and detours, and local jurisdictions would need to develop processes to keep any provided data set up to date. The AggieMap application (https://aggiemap.tamu.edu/map/d) does actually include a layer of construction zones and sidewalk closures that is used in trip planning; however, this application is limited to use at Texas A&M University.

Intersection / Street Crossing Information

Members of the MI and B/LV communities that are planning or taking trips that involve crossing a street (usually at an intersection) might find additional information about the intersection useful both when determining whether to take the trip and when actually crossing the intersection. Based on discussions with potential users, several key features of intersections could provide useful:

- Whether there is a pedestrian crossing signal.
- Whether there is a *marked* pedestrian crosswalk.
- The number of lanes to be crossed and whether those lanes are one- or two-way.
- Whether there is a right turn slip lane and pedestrian "pork chop." (A "pork chop" is a small pedestrian island formed when there is a right turn slip lane.)
- Whether there is a pedestrian island located at the mid-point of the crossing.
- The typical level of traffic at the intersection at a given time of day.
- Real-time information about the status of the signals at the intersection.

On-Demand Transit Options

During the course of the project, more and more general-public on-demand transit options were launched. On-demand transit refers to public transit operations that allow users to request and schedule trips with very little notice (e.g., less than an hour). These on-demand options were part of transit agencies' offerings but were operated by many different types of transportation providers: the transit agencies themselves, a transit agency contractor, or a TNC or taxi company. Because these on-demand options often connect to fixed-route transit or fill coverage gaps where fixed-route transit is not operating, they are becoming an important additional source of mobility for the MI and B/LV communities. The team did not incorporate on-demand transit into the CWall app; however, future work should carefully consider on-demand transit as another key part of the transit network.

SECTION 4. INVESTIGATION

This section describes the steps taken during the CWall project and includes:

- A chronology of the project.
- A discussion of accomplishments and unfinished work.

PROJECT CHRONOLOGY

This section provides a chronology of the project, from execution through the decision to terminate the project at Stage 1. Main phases of the project include:

- Execution, kick off, and project planning.

- Stakeholder engagement.
- Mapping and validation of pedestrian networks.
- App development.
- Seeking alternative approaches.

June 2018 – August 2018: Execution, Kick Off, and Project Planning

The project was fully-executed in June 2018. There were three different "teams" involved in the project:

- Core Team: Comprising TTI, Capital Metro, and TCAT, the Core Team were the central project executors and would be doing the actual *work* of the project.
- Technical Team: A technical group of key people who provided data, development, or other technical inputs. The team included:
    - TTI.
    - Capital Metro.
    - TCAT.
    - City of Austin (ADA Program and Public Works Department).
    - The Metropolitan Transit Authority of Harris County (Houston METRO).
- Participatory Design Team (PDT): A group of potential users and local stakeholders to help ensure CWall was aligned with actual user needs.

The Core Team began project planning discussions, and held a project kick off meeting on August 14, 2018 to introduce team members, set roles and expectations, and to establish next steps. The Technical Team then met on August 17, 2018 to introduce members to the purpose, scope, and timeline of CWall; to discuss team member roles and involvement; and to discuss preliminary technical items like needed data and hardware.

Another important kickoff step in the project was obtaining data from Capital Metro and the City of Austin. Capital Metro provided access to its GTFS-Static and GTFS-RT feeds, and the City of Austin provided a geospatial information system (GIS) layer of sidewalks and curb cuts in downtown Austin.

September 2018 – October 2018: Stakeholder Engagement

TTI developed a two-page, accessible CWall fact sheet (see Figure 5) that was sent to representatives from several organizations who represent, train, or advocate for people with disabilities (see Table 3).

FIGURE 5 CWall fact sheet.

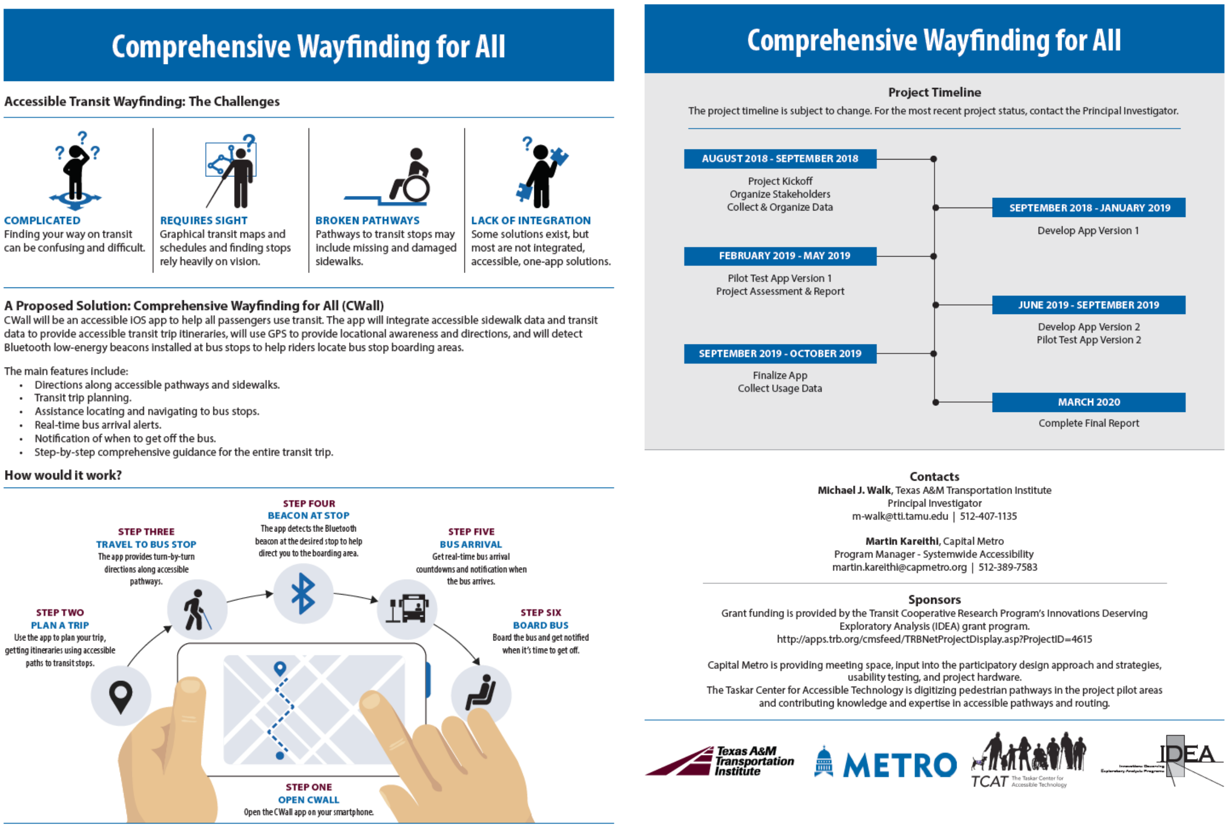


TABLE 3 List of stakeholder organizations invited to be in the PDT.

Invited Organization Name	Website
Mary Lee Foundation	https://www.maryleefoundation.org/
American Council for the Blind, Austin Chapter	http://acbaustin.org/
Criss Cole Rehab Center for the Blind	https://www.twc.texas.gov/jobseekers/criss-cole-rehabilitation-center
National Federation of the Blind of Texas, Austin Chapter	https://www.nfbtx.org/chapters-austin.php
ADAPT of Texas	http://adaptoftexas.org/
AISD Project Search	https://projectsearch.azurewebsites.net/ (general site, not specific to the Austin Independent School District [AISD])
Texas School for the Blind	https://www.tsbvi.edu/

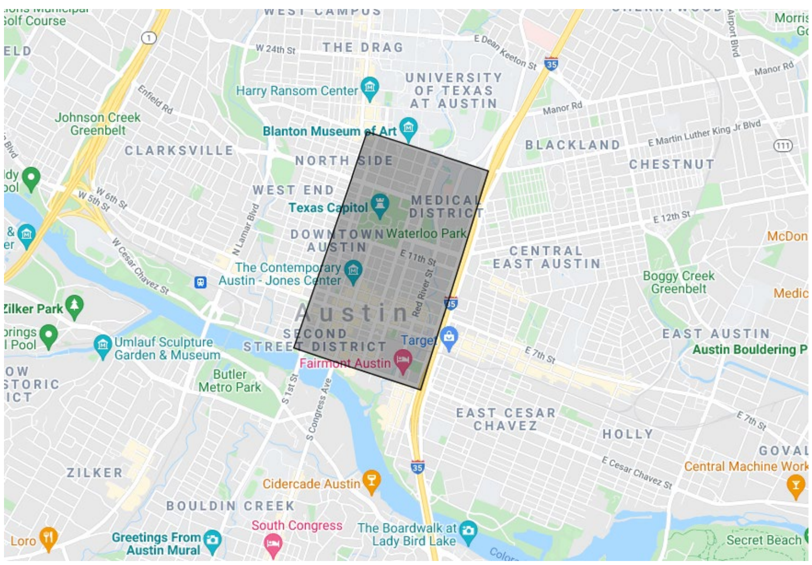
The PDT kick off meeting was held on October 16, 2018 at Capital Metro's headquarters. Five representatives from three stakeholder organizations were able to attend in person or virtually. During this kick off meeting, the Core Team received excellent feedback about the proposed CWall app's functions. The meeting also confirmed the Core Team's understanding that the CWall app would fill a currently unmet need for people in the MI and B/LV communities.

November 2018 – April 2019: Mapping and Validation of Pedestrian Networks

The CWall project included two different zones in which the team would have tested the CWall app:

- The Downtown Zone: A zone in the Austin central business district bounded by Martin Luther King Jr. Blvd. to the north, Interstate 35 to the east, Cesar Chavez St. to the south, and Guadalupe St. to the west (see Figure 6). The zone was chosen for its high density of streets, bus routes, and trip origins and destinations.

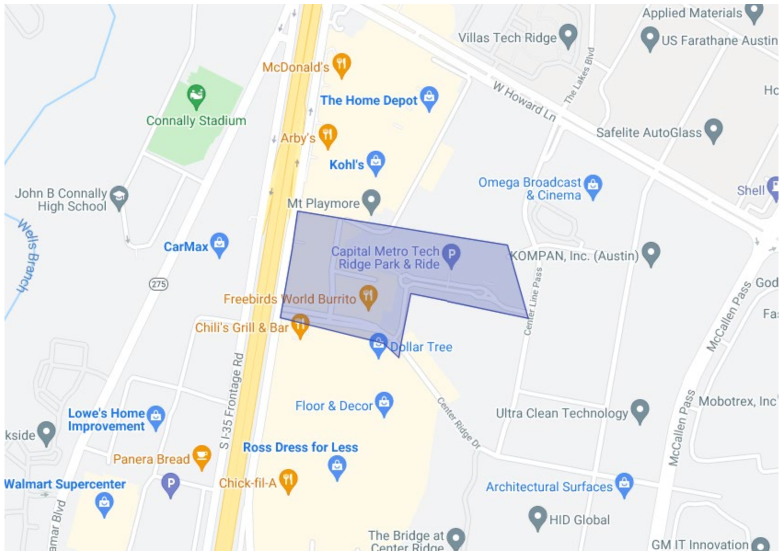
FIGURE 6 Downtown pilot zone area.



Source: Google Maps.

- The Tech Ridge Park and Ride Zone: A zone in northeast Austin at a bus transfer center and park and ride (see Figure 7). The zone was chosen as a test case for using CWall at a transfer center with multiple bus bays.

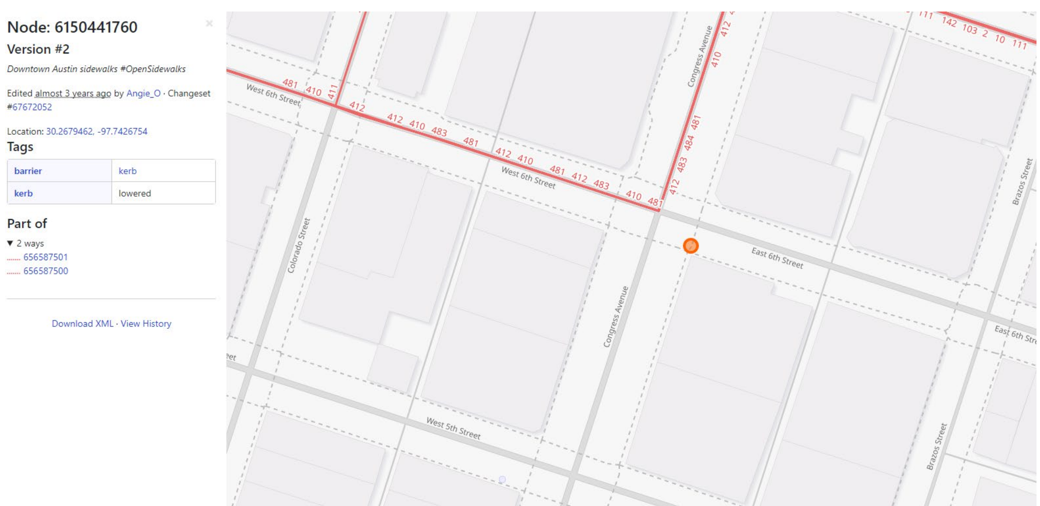
FIGURE 7 Tech Ridge park and ride zone area.



Source: Google Maps.

To test the app in these zones, the project team needed to digitize each zone's pedestrian networks in OpenStreetMap using the OpenSidewalks data standard. The curb cuts and pedestrian pathways were mapped by TCAT. Figure 8 shows a zoomed in section of the OpenStreetMap transport layer with the "footways" shown (dashed lines) and with a node (i.e., connection) between footways highlighted. In this case, the node has a curb cut, making this an accessible connection between the two footways.

FIGURE 8 Screen shot of digitized pedestrian network in OpenStreetMap.



Source: OpenStreetMap.

TTI and Capital Metro performed field verification of the pedestrian network data by visiting several actual locations in the zones and determining if OpenStreetMap correctly represented the actual pedestrian infrastructure. Figure 9 includes several pictures taken during the field verification process.

FIGURE 9 Pictures from pedestrian network field verification.

January 2019 – July 2019: App Development

During the months of January to July 2019, the entire Technical Team held meetings every other week to check in on progress and discuss technical details and questions. During this period of time, TTI was working on developing an alpha version of the CWall iOS app, and Capital Metro was procuring BLE beacons to use during app testing.

During app development, the following was accomplished:

- Setting up an app server to support the CWall app, including storing user accounts and transport network data.
- Setting up processes to obtain and cache Capital Metro GTFS data on the app server.
- Setting up processes to obtain and cache OpenStreetMap data on the app server.
- Setting up scripts to pass a trip request off to the Navitia routing engine and receive back itineraries.
- Creating usable app screens for creating an account, setting travel preferences, and requesting itineraries.

The alpha app was deployed on the iOS app testing framework called *TestFlight* and was distributed to team members with iPhones for preliminary testing. TTI began developing testing protocols to use during small group testing.

However, in July, the TTI development team reached an impasse when developing the pedestrian wayfinding function: no free, open source engine existed that (a) would accept an itinerary from Navitia and (b) could provide users with prompts during pedestrian wayfinding. The CWall budget did not include enough funding to develop its own wayfinding engine.

August 2019 – October 2021: Seeking Alternative Approaches

Once the impasse was identified, the TTI team worked to identify alternative approaches to continue the project. Several options were explored that sought to identify both (a) a software development team capable of building the wayfinding engine and remaining app functions and (b) additional funding to support the additional work. The TTI team talked with private app developers with commercial transit planning apps, with foundations and other non-for-profits, and with staff within TTI and Texas A&M University. Although virtually every party expressed significant interest in the app and its purpose, no additional funding was found to support continued development. TTI and the IDEA program jointly decided to cease work on the project at Stage 1.

SUMMARY OF ACCOMPLISHMENTS AND UNFINISHED WORK

Although the CWall app's functions were never fully developed, the project team did have several accomplishments:

- The team confirmed with the PDT that the CWall app, in concept, served a currently unmet need and would be useful to MI and B/LV communities.
- The team, with the help of TCAT, digitized the pedestrian networks in the Downtown Austin Zone and Tech Ridge Park and Ride Zone into OpenStreetMap.
- The team established an app server with supporting data fetch processes to pull OpenStreetMap and Capital Metro's GTFS-Static data sets.
- The team completed the user account creation and management function.
- The team completed the trip planning function.

However, several unfinished aspects of the CWall app and project remain:

- The following app functions were not completed:
  - Bus stop finding (including the use of BLE beacons at stops).
  - Real-time transit information.
  - Pedestrian wayfinding.
  - Trip assistance.
- The CWall app was never tested with actual users; therefore, no data about the app's actual usefulness or resulting improvements to personal mobility were ever collected.

SECTION 5. PLANS FOR IMPLEMENTATION

Because the CWall product is currently unfinished, there are no concrete plans for implementation; however, interest in the CWall concept remains high among stakeholders, including Capital Metro. The lessons learned through the CWall project to date would greatly benefit any future development of CWall or a similar product.

The code used for this project is available on GitHub in the following code repositories:

- ttitamu/cwall-explorer.
- ttitamu/cwall-server.
- ttitamu/cwall-app.

SECTION 6. CONCLUSIONS

Although the CWall product was not completed, the project was still beneficial to the industry through several lessons learned, discussed below.

- **Free, open-source engines for pedestrian network routing <u>and</u> pedestrian wayfinding do not exist.**

  There are free options available for creating multi-modal trip itineraries (e.g., OpenTripPlanner and Valhalla); however, these options do not treat the pedestrian network any differently than the street network and would, in fact, route pedestrians along streets that do not have sidewalks. The team used Navitia as a routing engine that supporting routing along pedestrian networks. However, Navitia, and other routing engines do not have an wayfinding engine that would provide prompts custom-built for pedestrian networks (e.g., "cross to the west side of 3rd Street using the cross walk"). This was the major development hurdle that caused the CWall project to stall at Stage 1.
- **Data standards for pedestrian network data are not commonly used.**

  Although there are projects underway (e.g., the Mobility Data Specification and OpenSidewalks), there is no uniformly recognized and nationally used data standard for pedestrian networks. The project team used the OpenSidewalk standard when digitizing the pedestrian networks in the pilot zones; however, this data had to be *created* for the project. Local jurisdictions that manage sidewalks and other pedestrian infrastructure often keep their pedestrian network data in shape files or other formats tied to specific GIS software. This will be a challenge to any application that uses pedestrian network data.

- **Data regarding intersection characteristics relevant to MI and B/LV travelers are not standardized or publicly available.**

  During discussions with the PDT, the project team learned that the characteristics of intersections were a key factor in trip planning and decision making. If users had to cross an intersection that was too challenging, they were less likely to take the trip using walking plus transit.

  Several aspects of an intersection can make it more or less challenging to cross—especially for a member of the MI or B/LV community. For example, the number of lanes to cross and whether there is a right turn slip lane can greatly change the difficulty of safely crossing an intersection. These intersection properties are likely known and available in various databases or inventories; however, there is no standard representation for this data. Future work should look into ways to represent and consider intersection characteristics during trip planning and wayfinding.
- **Real-time information about pedestrian pathway closures and accessible detours is lacking.**

  During discussions with the PDT, the project team learned of the frustrations experienced by members of the MI and B/LV communities when they encounter unanticipated pedestrian pathway closures. Pedestrian pathways can be closed for many reasons—from long-term construction projects to short-term utility work. However, pathway users are rarely notified in advance. A closed pathway can add significant uncertainty to the trip and can be a real barrier to even successfully completing the desired trip if the user is unfamiliar with alternative pathways. Future work should look into ways to represent and consider pedestrian pathway closures during trip planning and wayfinding.
- **The CWall app (or similar app) would help fill a real, current need in the MI and B/LV communities.**

  Although there are many apps and technological aids available to members of the MI and B/LV communities that each contain one or some of the functions in the CWall app concept, none currently have all of the CWall app functions in one place. Of course, technological developments will continue, and perhaps in the near future, there will be something close to the CWall app available in the marketplace. Until that time, there remains a need for an app like CWall (or that goes beyond CWall) to make the traveling experience of members of the MI and B/LV communities much more seamless—improving personal freedom, mobility, and quality of life.

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