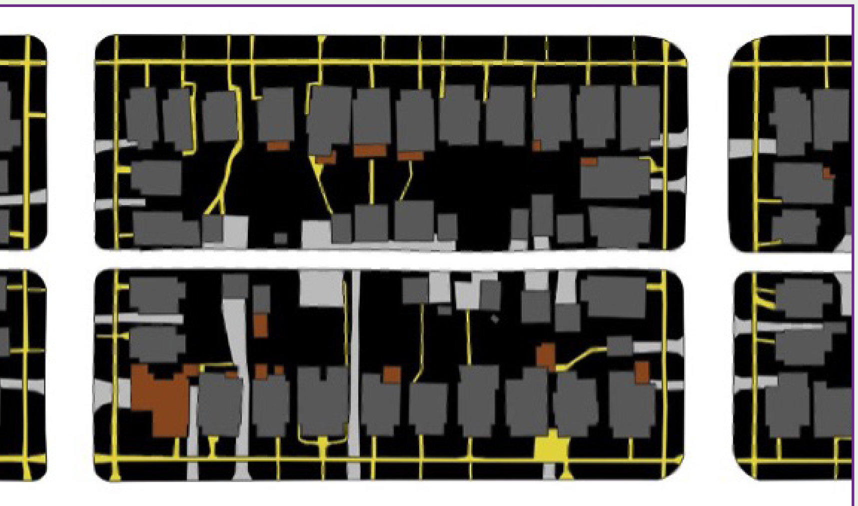
Exploratory Advanced Research Program

Sidewalk Mapping for Pedestrian Navigation

Workshop Summary Report

EXPLORATORY ADVANCED RESEARCH



U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank Highway Research Center

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16. Abstract On October 19 and 20, 2022, the Federal Highway Administration's Exploratory Advanced Research Program held a workshop on sidewalk mapping to complement the findings of the program's "Mapping and Navigation for Pedestrians with Disabilities" white paper. This paper, included in this summary report's appendix, identified the need to define the role of government in this research area. It also recommended an investigation of replicable data collection methods. The workshop focused on research needs for sidewalk mapping as well as the roles of various stakeholders who can impact the deployment of sidewalk mapping technologies.		
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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.755	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
ounces		28.35	grams	g
pounds		0.454	kilograms	kg
short tons (2,000 lb)		0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
foot-candles		10.76	lux	lx
foot-Lamberts		3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
poundforce		4.45	newtons	N
poundforce per square inch		6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lbs)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbfin²

*SI is the symbol for international System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (revised March 2003)

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WORKSHOP BACKGROUND

On October 19 and 20, 2022, the Federal Highway Administration's (FHWA) Exploratory Advanced Research (EAR) Program held the "Mapping and Navigation for Pedestrians with Disabilities" workshop to complement the findings of the program's "Mapping and Navigation for Pedestrians with Disabilities" white paper. The workshop focused on research needs for sidewalk mapping as well as the roles of various stakeholders who can impact the deployment of sidewalk mapping technologies.[(1)] The white paper, included in this summary report's appendix, identified the need to define the role of government in this research area, and it also recommended an investigation of replicable data collection methods.

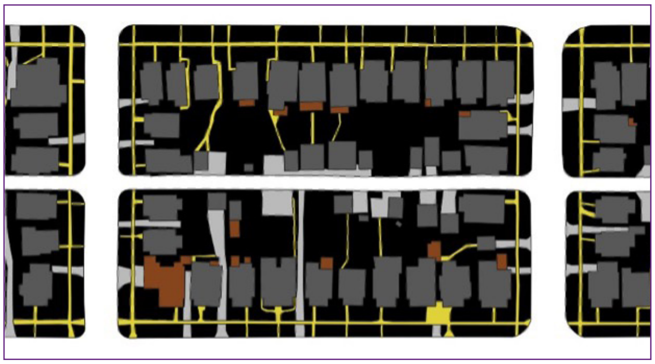
The workshop featured the following presentations:[(1)]

- Dr. Wesley Marshall (University of Colorado Denver).
- Dr. Yochai Eisenberg (University of Illinois Chicago) and Chu Li (University of Washington).
- John Eastman (city of Austin, TX).

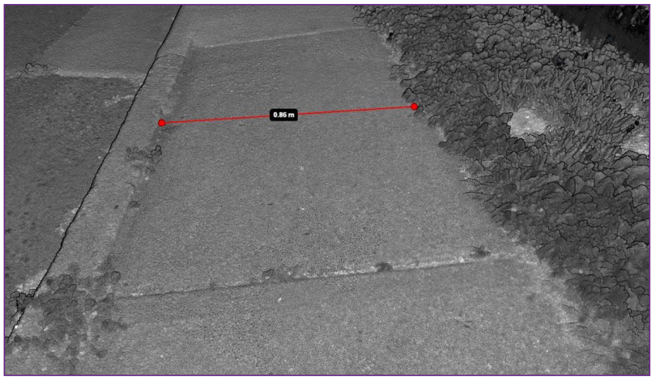
KEY TAKEAWAYS

The workshop had the following takeaways:[(1)]

- Accessible and connected sidewalks are essential for quality of life. Workshop attendees agreed that accessible sidewalks are important for improving transportation equity and mobility for all, including individuals with disabilities and older adults. Moreover, the connectivity of sidewalks is a necessary component to consider in sidewalk mapping activities.
- Standards for condition ratings and individual data elements related to sidewalk infrastructure are critical to data sharing and investment. Participants indicated that communities and academics often develop their own ratings because there is no standard guidance. Standard ratings would make it easier to improve pedestrian access across jurisdictions and provide much-needed direction for jurisdictions with limited capacity. No standards currently exist that allow communities to link data effectively across geographies.
- Data collection technologies for sidewalk infrastructure vary widely in sophistication and maturity. In addition, the potential for artificial intelligence (AI) and machine learning to enhance these technologies exists, particularly in the area of crowdsourced data. The advancement of these technologies could make this data collection faster and more cost efficient.
- Policies governing sidewalk infrastructure and data collection would benefit from Federal coordination and streamlining. Such guidance can provide a path forward for communities interested in improving sidewalk infrastructure and make data collection and sidewalk improvement processes more accessible to jurisdictions with fewer resources.
- Sidewalk obstruction data are critical to understanding sidewalk accessibility, but the methods for gathering these data are limited. Obstructions such as benches, bus shelters, fire hydrants, and streetlights can significantly impact the useful width of sidewalks and compliance with the Americans with Disabilities Act (ADA) standards.[(2)] The development of new methods to account for static obstructions during data collection and analysis would improve the use of sidewalk accessibility findings.



© 2022 Marshall & Coppola. **Figure 1. Image. Identifying sidewalks within planimetric data.[1]**



© 2022 Marshall & Coppola. **Figure 2. Image. Sidewalk width captured from LiDAR point cloud data.[1]**

PRESENTATION 1—WHERE THE SIDEWALK BEGINS: QUANTIFYING SIDEWALKS VIA REMOTE SENSING

(DR. WESLEY MARSHALL, UNIVERSITY OF COLORADO DENVER)

Dr. Marshall described several related research activities focused on measuring fundamental aspects of sidewalk availability, including sidewalk width.[1] This research focused on light detection and ranging (LiDAR) and planimetric (the horizontal distance between points) data collection techniques.[3] Images from the presentation can be seen in figure 1 and figure 2.

Dr. Marshall's presentation had the following major points:[1]

- LiDAR technology can measure sidewalk width as well as sidewalk lips and slopes. Tools from private firms can collect this information, but it can take upward of 20 min per scan. By contrast, Marshall's team found that LiDAR data collected from smartphones are useful for gathering width data, and collection is much faster. Additional research is underway regarding smartphones' accuracy in collecting lip and slope data.
- The team used planimetric data to assess sidewalk availability and reached out to cities across the United States to inquire about existing planimetric data. The analysis included data provided from 16 cities.
- Static obstructions are generally not accounted for in planimetric data, which is a weakness of using this type of data to measure sidewalk availability. Static obstructions can considerably impact the clear width of sidewalks and compliance with ADA standards as well as other width guidelines.[2]
- A study of sidewalk data from Cambridge, MA, found that the number of ADA-compliant sidewalks in the city is cut nearly in half when accounting for static obstructions.

Presentation 1 Question and Answer (Q&A) Session

Question: The smartphone LiDAR looks impressive. Can you extract data from it? What does the data look like?

The data are point cloud data and were collected from a handheld smartphone.

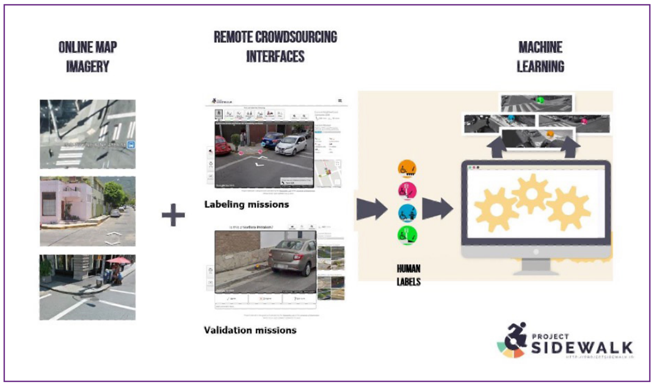
PRESENTATION 2—CROWD+AI TOOLS TO MAP, ANALYZE, AND VISUALIZE SIDEWALK ACCESSIBILITY

(DR. YOCHAI EISENBERG, UNIVERSITY OF ILLINOIS CHICAGO, AND CHU LI, UNIVERSITY OF WASHINGTON)

Dr. Eisenberg discussed the role of crowdsourced data in addressing a critical gap in sidewalk accessibility: Data about sidewalk locations, conditions, and obstructions are not collected by many cities. Additionally, for these data, there are no standardized formats. Images from the presentation can be seen in figure 3 and figure 4.[1]

The presentation included the following major points:[1]

- ADA lawsuits, among other factors, could influence interest in collecting sidewalk data to inform sidewalk investments.
- Gaps in planning limit the responsiveness of some governments to ADA requirements.[2] Dr. Eisenberg and his colleagues found that very few communities have an ADA transition plan. Among the 401 government entities reviewed, only 54 had an ADA transition plan readily available. Out of these 54 plans, only 7 met all the minimum criteria. Communities with a transition plan generally had better accessibility than those that did not.
- Traditional sidewalk audits are often costly and time consuming. Additionally, the use of the data is generally restricted, limiting analysis and utility for wayfinding applications.
- Project Sidewalk addresses common sidewalk data collection and analysis concerns by using existing online map imagery, crowdsourcing condition/ obstruction labeling and validation activities, and applying machine-learning techniques to assess sidewalk conditions.[4] The project has been deployed in 10 cities in North America and 2 in Europe. The project has collected more than 700,000 condition labels and 400,000 validations. The availability of online map imagery limits the project.
- Project Sidewalk data can find trends in sidewalk conditions in a particular community. Several cities have used the data to develop improvement plans.
- The research team plans to conduct cross-regional studies regarding sidewalk infrastructure, mobility, and equity in the future. For example, the research team will compare curb issues across cities as well as evaluate the correlation between pedestrian accidents and relevant Project Sidewalk data.[4]



© 2022 Project Sidewalk. **Figure 3. Image. The Project Sidewalk crowdsourcing workflow showing potential map imagery input datasets, the crowdsourcing workflow, including labeling and validation missions, and how these human labels are used to train machine-learning algorithms.[4]**

© 2022 Project Sidewalk. **Figure 4. Image. Project Sidewalk user interface for labeling sidewalk accessibility using streetscape imagery.[4]**

- Accessibility data has several interconnected uses, including route planning and wayfinding, community planning and investment activities, and advocacy efforts.

Presentation 2 Q&A Session

Question 1: For Project Sidewalk, how are crowdsourcing volunteers recruited?[1]

Volunteers are generally recruited through local networks, often from disability service organizations.

Question 2: How can sidewalk data collection be scaled so that data do not end at the city limits?

Technologies are available. However, it is a matter of data standardization as well as political, legal, and funding considerations. In response to potential ADA challenges, some cities have proactively deployed data collection technology.[1] Existing ADA lawsuits have also generated new sidewalk data collection efforts. Community engagement efforts can also provide motivation. However, data collection capacity on a regional scale is an issue.

PRESENTATION 3—CITY OF AUSTIN SIDEWALKS AND GEOGRAPHIC INFORMATION SYSTEM (GIS)

(JOHN EASTMAN, CITY OF AUSTIN, TX)

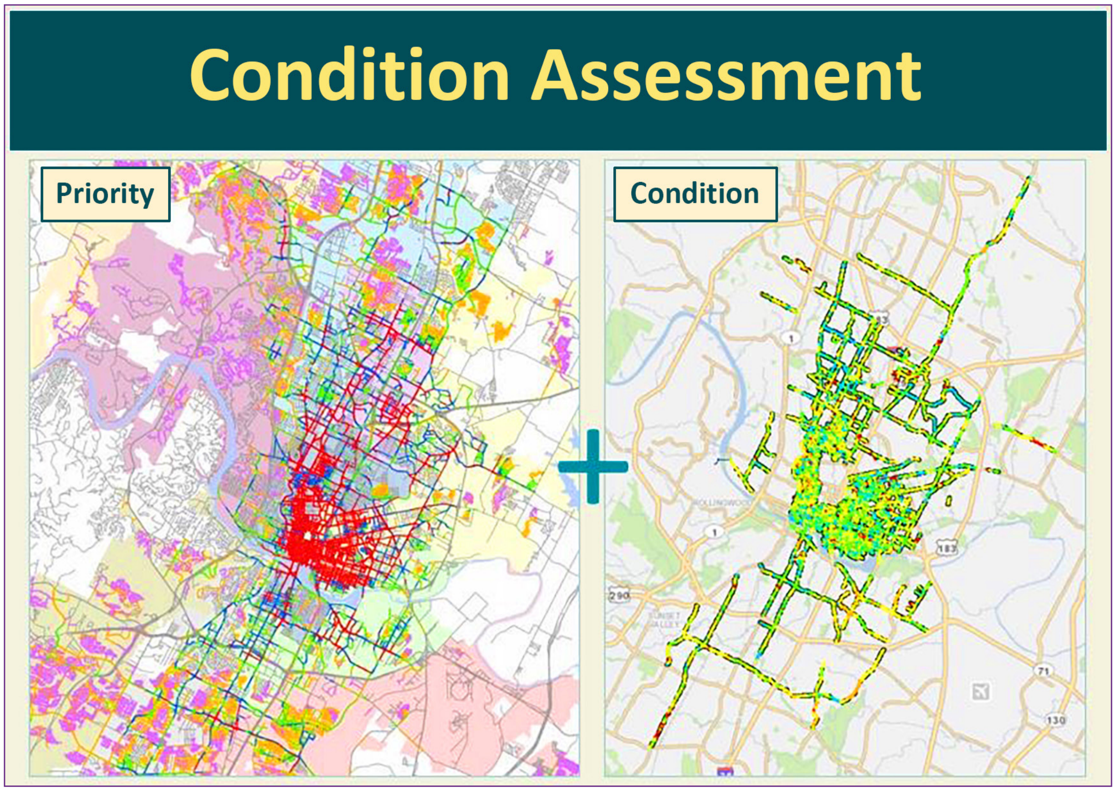
Mr. Eastman described various strongly supported policies in the city of Austin, TX, that allow the city to invest in moving toward a complete and well-maintained pedestrian network. In particular, an established ADA transition planning process that included sidewalk condition ratings has improved coordination across the city government and communication with the public. Images from the presentation can be seen in figure 5 and figure 6.[1]

© 2022 City of Austin. **Figure 5. Image. City of Austin, TX, sidewalk condition data collection.**[1]

The presentation had the following major points:[1]

- Transit riders heavily rely on a strong pedestrian network. Many of Austin's transit riders do not have the option to arrive at transit options using a vehicle, and many riders have mobility impairments.

- ADA transition planning for sidewalks in 2009 and 2016 has supported Austin's sidewalk improvement efforts, including the use of GIS. Sidewalk centerlines and curb ramp points are the primary data layers used. The city developed these layers based on the 2009 plan.[5] At the time, the city used GIS to determine where to allocate limited resources.



© 2022 City of Austin. **Figure 6. Image. City of Austin, TX, citywide sidewalk prioritization and condition assessment maps (2022).[1]**

- Equity-focused prioritization metrics and condition data are used to inform sidewalk improvements. The city uses an equity-based approach in sidewalk investment decisions.
- Public-facing data are made available through a website to keep neighborhoods informed of upcoming and completed sidewalk improvements.
- Coordination with other capital improvement programs has amplified the impact of the sidewalk improvements.
- Sidewalk condition ratings ("excellent," "good," "marginal," etc.) were developed by a consultant, as there was no standard option available. The city required these ratings as part of the 2016 plan. This plan included using GIS to determine the location of functionally deficient sidewalks as sites of potential improvement. These data have been used directly by maintenance crews.[5]
- The city led public awareness campaigns to inform property owners of their sidewalk maintenance responsibilities (e.g., clearing vegetation).[5]

Presentation 3 Q&A Session

Question 1: How does the city of Austin, TX, update sidewalk absence?

The city actively links development service performance data. High school interns update maps combined with satellite imagery and driveway permit data points. The city of Austin, TX, has a full-time GIS specialist in the sidewalk team to interface with the mapping layers.[1]

GENERAL WORKSHOP DISCUSSION Q&A

Question 1: What do researchers need from a partner to pilot a technology?

Researchers need multiple jurisdictions to get different perspectives on design, sizes, and context. The municipality, affected communities, and other parties must collaborate, and all parties need to know how the data will be used. Some communities want to know where there is a need for sidewalk improvements, and some do not. Researchers must be willing to integrate other types of data and be open to data sharing. Some communities are not comfortable with data sharing.

Question 2: From a public agency perspective, what is the motivation for working with a research team on testing new technology?

Public agencies are motivated to use new technologies when they provide safe pedestrian access at an efficient cost or when the data allow us to communicate more effectively with our stakeholders.[1]

Question 3: How can smaller cities and rural areas effectively deploy these technologies?

- Increasing the capacity of smaller cities and rural areas to deploy these technologies through agencies pooling resources or allowing State or county agencies to deploy technologies for cities or regions as a whole.
- Creating a more simplified and standardized approach for ADA transition plans.[1] Some who work in small towns have never heard of an ADA transition plan. For pavements, there is a simple methodology and approach. A template that tells people how to collect the data that they need, explains how to measure it, and describes how to lay it out is critical. Scale for the methodology also needs to be considered. Communities of 50,000 people have different needs than communities of 500,000.
- Using tools and data standards for monitoring. Often, staff will create a document or spreadsheet with these improvements, making it difficult to tell where these improvements are.

Question 4: What is the private sector's role in deploying these technologies?

- Legal risk may be pushing much of the sidewalk mapping work.
- Technologies are available, but the extent to which Government can or should leverage those technologies or point entities in their direction has not been defined.
- The private sector plays a prominent role, but there should be data standards that companies must follow.

This white paper was developed in June 2021.

INTRODUCTION

FHWA’s EAR Program funds longer term, higher risk research with a high payoff potential. In 2012, the EAR Program funded three related projects on assistive wayfinding technologies for visually impaired users.(6) In support of the EAR Program, the Volpe Center (Volpe) coordinated a technology demonstration across the three projects in 2016 and subsequently completed a state of-the-art practice scan in 2017 to assess the opportunities for additional research. Both of these activities contributed to technology development in wayfinding and navigation as well as in pretrip and concierge services by FHWA’s Accessible Transportation Technologies Research Initiative program.(7)

Wayfinding and navigation technology research and development have been proceeding rapidly since the 2016 demonstrations and the 2017 scan.(7) Both commercial providers and public agencies are collecting more spatial data than ever at increasingly higher resolutions. Advances in communication systems, machine learning, and sensor technology have also been contributing factors. Volpe developed the “Mapping and Navigation for Pedestrians with Disabilities” white paper to assist the EAR Program in assessing the state of emerging technologies for pedestrian mapping and wayfinding. As part of developing this white paper, Volpe will also coordinate with key stakeholders to identify government roles in research and development as well as potential next steps for the EAR Program.

NAVIGATION FOR PEDESTRIANS WITH DISABILITIES OVERVIEW

Modern smartphones equipped with Global Position System (GPS) receivers, navigation applications, detailed maps, and point-of-interest databases have made it easy to plan and navigate pedestrian routes that are accessible for many but not all users. These tools help outline potential routes from a user’s current place to a desired location. Typically, navigation applications can adapt their functionality according to various attributes, such as traffic congestion and method of travel. Still, until recently, they have emphasized vehicle-based rather than pedestrian navigation.

Some populations require more specialized data for safe navigation. People with sensory, mobility, and/or cognitive conditions may face additional challenges in safe wayfinding as pedestrians in indoor and outdoor environments. New technologies provide an opportunity to address existing data gaps for safe pedestrian navigation for all users.

Current applications of indoor/outdoor pedestrian wayfinding and navigation assistance usually calculate the route to a destination based on the shortest or fastest path from the origin. Typically, outdoor wayfinding and navigation via mobile phone use established mapping interfaces created by private firms. However, these mapping applications may not always provide up-to-date maps, and they may not provide relevant features to all pedestrian users. Mobile applications dedicated to wayfinding in indoor environments have been preliminarily developed by private companies acquired by Esri™. Such applications have been piloted at San Francisco International Airport in 2014 and Penn Station in New York City in 2018.(8) These systems use low-energy wireless technology “beacons” and wireless network hot spots to help guide smartphone users through routing by voice in a mobile application.

Numerous findings in cognitive science show that the ease of use and communication of route instructions depends on factors other than the length of the route, such as the number and complexity of decision points.

INTENDED AUDIENCES

The intended audience for this research topic is public agencies that own and operate transportation facilities, such as roads, trails, transit stations, and airports. Other audiences include transportation professionals, information technology professionals, and researchers interested in finding ways to advance the collection of data valuable to pedestrian navigation and wayfinding. There are potential opportunities for data collection applications in almost every aspect of pedestrian navigation. The use of cooperative automation to assist in mapping out pedestrian features (e.g., stairs, steep inclines, ramps, etc.) focuses on new approaches that reduce the manual burden of data collection and increase automation or application of data. These new approaches may help alleviate obstacles to the widespread deployment of more accurate and useful pedestrian-focused map attributes and layers. These methods are either being privately tested or are being piloted by public agencies and the government to cost-effectively collect pedestrian navigation and wayfinding data in support of future infrastructure and policy efforts.

UNDERSTANDING USER NEEDS

Drivers are generally able to rely on dedicated vehicle navigation systems and mobile phone applications to reach their destination, whereas pedestrians are often a secondary audience for mapping and navigation providers. Although popular navigation tools provide pedestrian routes to destinations, suggested routes are not optimized for pedestrians with disabilities. People with disabilities often encounter numerous challenges when traveling independently, and understanding these challenges is essential to recognize when collecting wayfinding data.[1] For instance, obstacles, such as stairs, steep inclines, missing ramps, blocked curb ramps, or poor walking surfaces make sidewalks uncomfortable or even inaccessible to people with mobility disabilities.[(9)] The specific wayfinding needs of users with disabilities can vary depending on a person's type of disability as well as personal preferences.

Due to the likelihood that a single obstacle could make a complete trip impossible for a pedestrian with disabilities, there are significant obstacles for people to find accessible routes.[2] For example, in a recent study, interviewees with a visual disability stated that they might call ahead for directions to a destination. However, these directions were often given by a sighted respondent and frequently inadequate for a visually impaired traveler. Interviewees noted that, as a result, they typically would seek information from other visually impaired friends or trainers who understand helpful landmarks and routes to follow.[3]

Despite the availability of GPS-based information systems, pedestrians with disabilities still have unmet needs in terms of navigation. While regular and well-known routes generally work well, wayfinding breakdowns are possible. Rerouting and reorientation around obstacles are difficult activities without visual cues. Unfamiliar routes are difficult because of the lack of mental maps or accommodations.[3]

LANDSCAPE OF CURRENT DATA COLLECTION PRACTICES AND APPROACHES

Collecting accurate sidewalk and associated contextual pedestrian data is an ever-evolving practice that is a key element in providing pedestrians with disabilities the ability to travel independently. The following section highlights the type of data being collected and their collection process. It covers several data collection practices and approaches, including examples provided to Volpe from the University of Washington and Atlanta Regional Commission during a wayfinding-focused ITS4US Complete Trip Deployment Program meeting in April 2021.[4]

Data Collection Methods

Municipalities may encompass hundreds to thousands of miles of sidewalk networks which vary in condition. To best serve pedestrians with various disabilities, multiple variables about the physical environment must be captured to allow for effective trip planning and safe navigation. The data collection process depends on the resources available to the data collectors. Satellite imagery is often used to identify roadways with paralleling sidewalk systems to capture a base map. Sidewalk networks can also be constructed using parcel-level land use and roadway centerline data. These data are typically incomplete; onsite mapping fills the gaps in the satellite imagery, parcel, and roadway data.

Once a map is established, manually pushing a wheeled device is the most common method of collecting the characteristic sidewalk data. These devices can be equipped with various data collection tools, such as cameras, gyroscopes, GPS, or LiDAR. Georgia Tech has used such a device to map Atlanta's sidewalk system, where data and video are collected by attaching an application-equipped tablet to a standard wheelchair and walking it along any desired route.[(10)]

According to the Georgia Tech Center for Transportation Operations and Safety, once the sidewalks have been video recorded by the wheeled device, general-public volunteers, undergraduates, and graduate students review the video and code the sidewalk manually. These manual adjustments took roughly 1,200 h to complete for the city of Atlanta, GA.[5]

Researchers at the University of Washington have taken a similar approach, but employed machine-learning software to identify particular sidewalk characteristics. This system uses a convolutional neural network (CNN) computer vision tool that has helped to semiautomate and make less labor intensive these data collections.[3] However, some data, such as curb ramp data, are generally entered manually.

Sidewalk delivery robots have been identified as a potential way to further automate the sidewalk data collection process. Additionally, LiDAR drones could streamline the data collection process. However, due to the high cost of LiDAR drones, this method is too expensive for many municipalities.[6]

Type of Data Collected

The needs of a particular pedestrian with a disability vary depending on their preferences and abilities. The city of Seattle, WA, and University of Washington have partnered to create the open-source tool OpenSidewalks, housed on OpenStreetMap.[(11)] From an initial scan, these partners have developed a significant, open-source pedestrian navigation tool. Table 1 highlights the data this project has collected in Seattle.

The Taskar Center for Accessible Technology (TCAT) at the University of Washington has developed a GitHub data schema where anyone can insert data into OpenStreetMap to create pedestrian maps and analyses.[12,13] The University of Washington team stated that there are six active OpenSidewalks collections underway in Redmond, WA; Bellevue, WA; Austin, TX; Korfu, Greece; Padova, Italy; and Milan, Italy.[7] Although much of the data collected is related to the navigation of sidewalks, OpenSidewalks also provides the opportunity to code the location of indoor elevators and the hours of operation of such elevators. Moreover, recent literature provides relevant analysis on the current extent of municipality-level collection and maintenance of accessibility data.[14]

REVIEW OF SPECIFIC DATA COLLECTION ENTITIES AND/OR EFFORTS

OpenSidewalks (System in Development)

The aforementioned data architecture, OpenSidewalks, is a notable example of remote collection. The effort, currently being developed by TCAT, seeks to make pedestrian infrastructure, like sidewalks, of "equal consideration in an open, routable

Table 1. The table shows three phases of data creation for different layers of sidewalk data.[1]

Phase I Fundamental Pedestrian Layer	Phase II Primary Pedestrian Features	Phase III Application Specific
Footways: • Sidewalks • Crossings (best crossing locations) • Footway links (paths that go through curb ramps) • Curb lowered/raised • Outdoor stairs/escalators • Outdoor ramps/ wheelchair ramps • Publicly accessible buildings with elevators (interior or exterior) • Connection of all components to represent a connected transportation graph layer	• Footpath surface information • Elevation information • Cross slope (cross grade) • Surface type • Large surface interruptions • Sidewalk width **Shoring:** • Tree lined • Grass lined • High curbed • Curb present • Other separators **Pedestrian corners and pedestrian signalization:** • Crossing type • Indicating pedestrian crossing time • Signals indicating to traffic that pedestrians are crossing • Are there accessible pedestrian signals? • Sidewalk bulbs • Pedestrian islands • Lit corners	**Transit stops:** • Node location • Footway link to the rest of pedestrian transportation network • Complexities specifying the actual path to getting to the transportation stop, including going underground, etc. • Amenities and descriptors of the stop • Entrances to public buildings and amenities

transportation network from which we can ask a variety of important questions. This means collecting a connected network of path types with detailed attributes like width, surface composition, steepness, and shared traffic."[11]

AccessMap (Available in Seattle, WA; Bellingham, WA; and Mt. Vernon, WA)

AccessMap serves as an example of an open-source data collection method. This mobile application prioritizes pedestrian-mobility data and "provides customized accessible sidewalk and footpath routing directions" based on a "personal mobility profile."[15] The application layers multiple forms of pedestrian needs and preferences for travel and allows for automated route functionality. AccessMap answers the question: How do I get from point A to point B in a nonmotorized mode given my specific needs and preferences? For example, AccessMap identifies the best path for users by allowing them to alter their route based on their preferences for steepness. Figure 7 provides a representation of AccessMap and how pedestrians can use it for trip planning.

Esri (System is a Commercial Product)

Esri's ArcGIS is a GIS and geodatabase management company that uses mobile applications and remote sensing technology to collect and store mapping data via the cloud.[14] ArcGIS allows developers to upload a basemap and join it with other basemaps or additional GIS layers as they are packaged by other sources. In addition to basemaps, ArcGIS can use geodatabases, which present building assets in relation to real-world environments. This function can enhance the understanding of pedestrian needs within the built environment. The datasets stored by Esri can be cross-referenced with existing geotagged data to suit the mapping needs of the user. Esri's remote sensing data collection

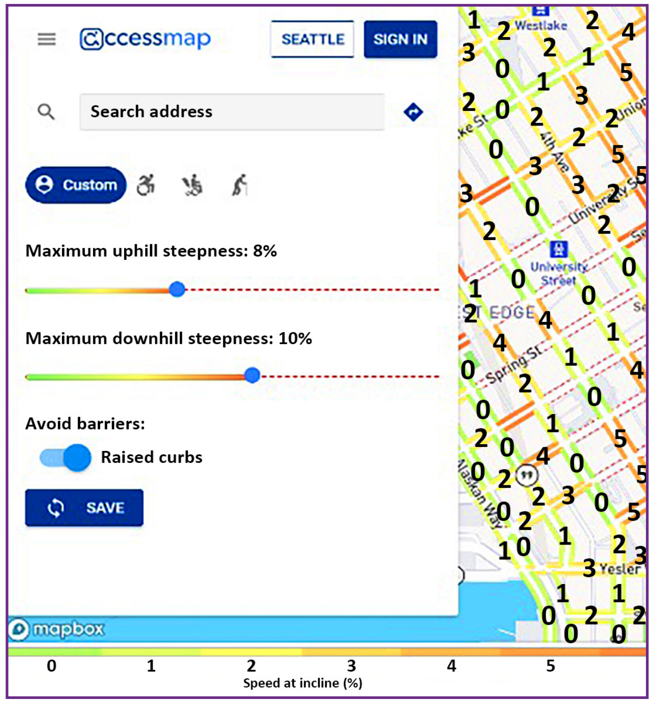


Figure 7. Screenshot. AccessMap—the interface to Seattle's sidewalks.

capabilities include LiDAR technology, which can be later paired with existing datasets.[16] For instance, users can download elevation data from the U.S. Geological Survey (USGS) and create three-dimensional imagery of an area that LiDAR has scanned.[8] These data allow individuals to generate a point cloud to color code and classify different features. This technology also allows for analyzing elevation data within a specific area. These data would enable users to identify certain routes with high levels of incline and decline.

SideGuide (System in Development)

SideGuide is a large-scale sidewalk dataset that offers the opportunity to help people with disabilities. SideGuide was generated through data acquired from smartphone cameras and a ZED stereo camera. To validate SideGuide, a prototype trained with SideGuide data was developed to aid people with disabilities by informing users of their proximity to an obstacle. The prototype recognizes target objects on the sidewalk, and it predicts the distance to each object and the average distance within the object region.[17]

RECOMMENDATIONS

This paper reviewed current practices and innovative technology development of data collection for pedestrian navigation and wayfinding tools that help people with disabilities. It is a starting point for discussing the application and feasibility of using collective information for transportation safety data. Rather than capture the entire universe of active research and development in this field, the authors of this white paper only focused on some uses of these applications for transportation agencies in collecting pedestrian navigation and wayfinding data. For example, this paper did not discuss how the rise in automated vehicles will likely coincide with the rise in people with disabilities traveling independently. Additionally, there are aspects of the collected information that are not addressed in this paper, such as how the public can be persuaded to participate in the collection and transmission of data for these technologies.

Academic efforts, like the University of Washington's and Georgia Tech's ITS4US awards, have demonstrated the ability to partner with transit agencies, universities, and the private sector to make strides forward in accessible pedestrian navigation.[6] In the future, these dynamic relationships can create innovative and novel approaches, making wayfinding and pedestrian navigation data collection efforts easier and more efficient. Moving forward, it will be important to build on these dynamic relationships while also continuing to balance innovation with the public good.

In an increasingly urbanized United States, identifying replicable data collection methods will remain important for providing an equitable pedestrian network. As a result, scaling up pedestrian navigation and wayfinding technologies should be considered. In May 2021, FHWA developed a pedestrian and object detection request that identified research groups in the academic, public, and private sectors theorizing, developing, or working with approaches for gathering data (e.g., video, image, computer vision, camera) to use in intelligent transportation systems.[18]

Based on the initial exploration detailed in this paper, collective pedestrian and wayfinding applications may provide a tremendous opportunity for agencies to collect data effectively and implement infrastructure improvements that enhance the safety of people with disabilities.

NOTES:

1. Wayfinding is a process of following a path or route between an origin and destination that becomes extremely difficult for people with disabilities.[19]

2. The complete trip concept reflects the understanding that a person's travel comprises a chain of steps beginning with an often-spontaneous decision to make a trip through to planning an itinerary; traversing the built environment and its transportation networks (with or without a vehicle); and navigating streets, intersections, facilities, stations, and stops to their destination safely, efficiently, and carefree.[20] The complete trip is the realization that if any part of the trip-making chain is broken, the trip cannot be completed, and an opportunity is lost.

3. This information was shared with the ITS4US Complete Trip team during a pedestrian navigation information session in April 2021.

4. The ITS4US Complete Trip Deployment Program is a program that aims to solve mobility challenges for all travelers with a specific focus on underserved communities, including people with disabilities, older adults, low-income individuals, rural residents, veterans, and limited English proficiency travelers.[21] This program will enable communities to build local partnerships, develop and deploy integrated, replicable mobility solutions, and help to achieve complete trips for all travelers.

5. This information was shared with the ITS4US Complete Trip team during a meeting in February 2021.

6. This insight was gained from a discussion with the Georgia Tech and University of Washington ITS4US teams in April 2021.

7. The locations of active OpenSidewalks collections were shared with the ITS4US team in April 2021. Additionally, OpenSidewalks data collection is slated to begin soon in Los Angeles, CA; Quito, Ecuador; Sao Paulo, Brazil; and Santiago, Chile.[22]

8. USGS data do not include sidewalk-specific data but rather a three-dimensional image of an area that may have identifiable sidewalks.

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To take advantage of a broad variety of scientific and engineering discoveries, the EAR Program involves both traditional stakeholders (State department of transportation researchers, University Transportation Center researchers, and Transportation Research Board committee and panel members) and nontraditional stakeholders (investigators from private industry, related disciplines in academia, and research programs in other countries) throughout the research process.

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EXPLORATORY ADVANCED **RESEARCH**

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