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Project Title

Pedestrian Infrastructure and ADA Compliance: Leveraging Advances in Spatial Technologies

University

University of Colorado Denver

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Research Needs

When it comes to historic Civil Rights legislation, many overlook the Americans with Disabilities Act (ADA) of 1990. While the ADA principally prohibits discrimination against people with disabilities, it also mandates the removal of barriers that would prevent equal participation in public life. For persons with disabilities, a lack of proper sidewalks and curb ramps often sits at top of the list of transportation-related barriers. As Lawrence Carter-Long, Director of Communications at Disability Rights Education and Defense Fund, said: "If you're trying to get across the street and there are no curb cuts, six inches might as well be Mount Everest" (Carter-Long 2021)

What are cities doing to improve their sidewalks and curb ramps? Given the ever-expanding list of cities ending up on the losing side of ADA lawsuits, they have not been doing enough. As of late 2020, more than 142 government agencies have been named in such lawsuits (ADA Solutions 2020). The lawsuits include larger cities such as Portland, Oregon, which committed $113M to sidewalks and curb ramps in order to settle a class-action lawsuit as well as Los Angeles, which committed $1.3B to settle theirs. It also includes smaller cities such as Colorado Springs and Cedar Rapids, Iowa.

More than 30 years after passage of the ADA, why are cities still failing to provide such fundamental infrastructure? Many would blame a lack of funding, but it is impossible to know how much money is needed until we know the extent of the problem. Recent research by Eisenberg et al. reviewed more than 400 government agencies for ADA transition plans (Eisenberg, Heider et al. 2020). Less than 6% of these government agencies had collected data on the state of their curb ramps, and only 2% of them had information about their sidewalks. Without baseline data on sidewalks and curb ramps, we cannot even begin to work towards fixing the problem and fulfilling the promise of the ADA.

Unfortunately, there has long been a lack of comprehensive sidewalk and curb ramp data. Some cities, however, have started to collect planimetric spatial data from high-resolution aerial imagery. Such remotely sensed data is helping us move towards city-scale data where we can systematically consider factors such as sidewalk presence and width with respect to ADA standards. In a previous Mountain Plains Consortium project (#579), we acquired planimetric data to identify problematic areas in Denver. This included highlighting, for instance, Denver's overreliance in some neighborhoods on "Hollywood" sidewalks, which are only 18" wide with sloped curbs. Although the city officially considers this a sidewalk, it does not meet ADA accessibility standards.

What we learned in MPC project #579 was that even though this planimetric data is an important step forward over the historically subjective and time-consuming manual methods, it generally does not provide us information about static obstructions in the sidewalk, nor anything about sidewalk condition in general, including cracks, gaps, lips, and bumps. It also does not tell us much about curb ramps. In other words, planimetric data only allows us to consider a fraction of the possible ADA sidewalk and curb ramp problems. Putting us on a path towards accessible infrastructure requires the ability to objectively and consistently measure our sidewalks and curb ramps over large areas.

This project seeks to leverage advances in LiDAR to fill this data gap. Light Detection and Ranging (LiDAR) is a sophisticated, precision-mapping technology that measures the distance to an object by illuminating the object with pulsed laser light and measuring the reflected pulses with a sensor. LiDAR has long been either overly expensive or too sparse of a point cloud density to be practical for pedestrian infrastructure purposes. Today, high-density LiDAR is becoming more commonplace and is actually standard issue on higher-end iPhones and iPads (Figure 1 depicts a CU Denver student testing out this functionality, using an iPhone, as well as the accompanying output). Our first objective is to see if we can collect high-quality LiDAR data with an iPhone. This will include comparing the resulting data against planimetric data and, via equipment gifted by Trimble Inc., against high-end mobile LiDAR data.

The second objective is to use the LiDAR data to create a map of ADA sidewalk and sidewalk ramp issues and compliance. We will again compare the iPhone data to high-end mobile LiDAR data in an effort to see how well the iPhone LiDAR data performs and whether such data could be crowd-sourced and stitched together to create larger area, citywide maps. The resulting ADA maps will also be integrated into both a web-mapping and mobile-mapping application that could be used by city personnel or by persons with disabilities seeking accessible travel routing.

Since most sidewalk-related LiDAR data is collected from cars equipped with LiDAR sensors instead of along the sidewalk, such data collection technique may not be able to access the necessary data needed to quantify sidewalks and ADA accessibility issues. These issues may be exacerbated in areas with parked cars, street trees, and other street furniture. They may also be problematic when the sidewalk are set back or at a higher elevation. We will compare the two methods.

Lastly, ADA compliance of sidewalk and ramp infrastructure has long been a reactive undertaking. When combined with the difficulty cities seem to have in collecting sidewalk infrastructure data, the result is an underwhelming status quo of problematic sidewalk infrastructure with little or no chance of improvement. There is a need to explore easily obtainable built environment data against sidewalk infrastructure data to identify what factors are significantly associated with ADA compliance issues. The results could help cities without sidewalk infrastructure data to locate areas of potential concern that should be prioritized. It could also give cities insight into what designs may lead to future sidewalk issues.

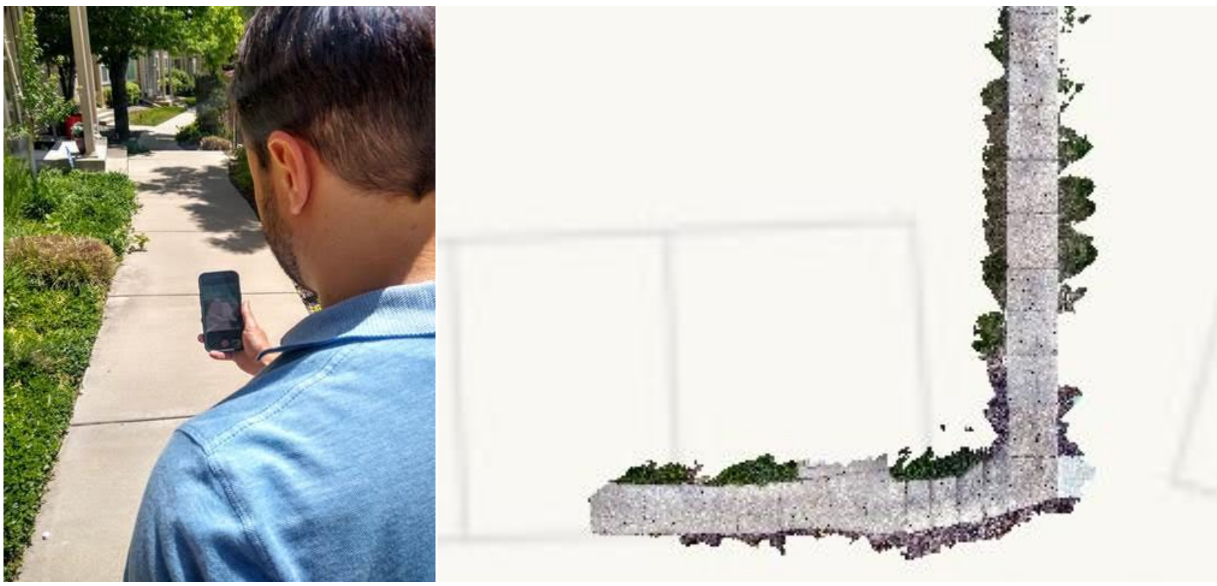

Figure 1 – Test of iPhone LiDAR Data Collection

Research Objectives

The key steps for this project are the following:

1. Conduct literature review;
2. Investigate current LiDAR technologies;
3. Collect mobile LiDAR data using iPhone;
4. Collect mobile LiDAR data using Trimble equipment;
5. Compare sidewalk metrics from planimetric data to on-the-ground LiDAR sidewalk infrastructure data collection;
6. Compare our ability to measure sidewalk issues from the sidewalk versus the street and consider how this differs by different possible occlusion issues (such as on-street parking);
7. Develop ADA accessibility maps;
8. Explore built environment data against sidewalk infrastructure data to identify what factors are significantly associated with ADA compliance issues;
9. Integrate ADA accessibility maps into GIS for online or mobile phone mapping applications;

10. Advance knowledge by carrying out analyses to answer our research questions;
11. Advance policy and practice with respect to building more accessible cities;
12. Advance education through the hand-on training of students; and
13. Build an evidence base by disseminating findings through publications and presentations.

Research Methods

With respect to sidewalk data, much of the existing data collection efforts are primarily based on field audits (Brownson, Hoehner et al. 2009, Harvey, Aultman-Hall et al. 2015) such as that depicted in Figure 2. Such audit-based approaches tend to be highly labor and time intensive. Before being sent into the field, potential auditors typically need to be recruited and trained. Then, data collection for each street segment can range between 3 and 20 minutes depending on the approach and issues faced (Brownson, Hoehner et al. 2009). Thus, collecting data at the citywide scale, or even for multiple cities, is beyond the ability of most governmental organizations. Moreover, larger audits can lead to issues of inter-observer reliability and face problems of subjectivity (Park 2008, Harvey and Aultman-Hall 2016).

Figure 2 – Manual Sidewalk Data Collection Efforts

Over the last few decades, however, GIS-related technologies have increasingly improved our capacity for asset management and our ability to efficiently and objectively manage our transportation infrastructure. Light Detection and Ranging (LiDAR) is one of these technologies. Unfortunately, this has yet to involve data collection for sidewalks and/or curb ramps at a broad scale or in a manner that cities can easily and inexpensively conduct. When properly collected and analyzed, LiDAR has the potential to be an efficient and objective approach for measuring ADA issues related to sidewalks and curb ramps. LiDAR also has the ability to be integrated into a GIS platform that can easily be used by professionals as well as in web or mobile-mapping applications that would be more accessible to the general public.

In this project, we will evaluate both iPhone and high-end mobile LiDAR collection methods (such as the Trimble MX7 or LiBackpack DGC50) for sidewalk and curb ramp data collection. While mobile LiDAR data collection is still relatively new to market, its ability to quickly and easily create survey-quality data is helping exponentially increase its popularity. As a result, the technology is evolving to the point where the cost is dropping well below that of expensive aerial LiDAR. Moreover, sidewalk issues would often be occluded from aerial LiDAR due to street trees, roof overhangs, etc. Mobile data also tends to be much denser than aerial data, often exceeding 2,000 points per square meter (as opposed to a pulse density of 8 points per square meter with Quality Level 1 data). Accordingly, handheld and/or backpack mobile LiDAR is better suited for measuring sidewalks and curb ramps in ways that aerial or car-based mobile LiDAR cannot compete. This project will be at the forefront of utilizing mobile LiDAR for objectively quantifying ADA issues with respect to sidewalk and curb ramps.

With respect to data processing, we will primarily rely on Merrick and Company's MARS® LiDAR software, in part because it has the ability to pair the LiDAR data view with Google StreetView. This facilitates presenting the LiDAR data on one computer screen and Google StreetView's identical location on the second computer screen, as shown in Figure 3. This MARS®/Google StreetView dual visual setup and pairing can assist in terms of accurate and seamless classification of, for instance, static obstructions in the sidewalk.

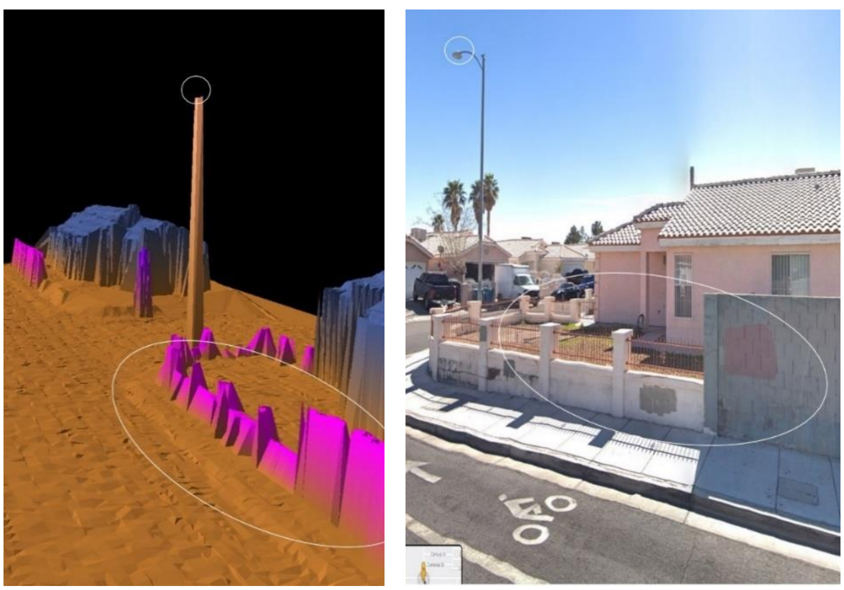

Figure 3 – MARS® LiDAR Processing Software and Google StreetView Dual Visual Pairing

Site selection will be determined in order to test the ability of the LiDAR options to identify various types of ADA compliance issues such as clear width, slope, lips, and gaps. For instance, the ADA, most recently revised in 2010, states that an accessible path of travel must be provided (Mahoney, 2012). The ADA defines an accessible path of travel as an unobstructed pedestrian passage for approach, entrance, exit, and connection on sidewalks (Mahoney, 2012). Within Chapter 4, ADA Standards for Accessible Design, the current standard clear width for accessible routes is 36 inches (although it would increase to 48 inches if the guidelines proposed by the US Access Board are approved by the Department of Justice) (USAB, 2011a). Sidewalks less than 60 inches should have a passing space of at least 60 inches every 200 feet (and the passing space could include driveways). The ADA defines trip hazards as any vertical change over ¼-inch. Sidewalk slopes should be less than 1:20, while curb ramps must be less than 1:12 and at least 36 inches wide. The proposed project will test the ability of the LiDAR to identify all of the aforementioned ADA compliance issues. We will field verify compliance using tools such as electronic levels and assess the assessment ability of each LiDAR option. We will also document the methods to do so.

After working with the LAS file format data in the MARS® LiDAR software, we will export the data to GIS with the goal of creating an ADA compliance map. Figure 4 depicts a preliminary example of what this map could look like. We will then web deploy the map and test the usefulness of the map in an existing mobile application that we created for MPC #614 (Learning from the Travel Experiences of Persons with Disabilities: Investigating Navigation Challenges Posed by Infrastructure), as preliminarily depicted in Figure 5.

Figure 4 – Example Map of ADA Compliance Issues

Lastly, we will test our ability to stitch together a mosaic of iPhone LiDAR data from multiple sources. If successful, the idea would be to establish an easy-to-follow data protocol to enable the general public to collect sidewalk and curb ramp LiDAR data in a manner that could allow for the crowdsourcing of a city's network.

We will look to target both academic and practitioner audiences with results of this research. Academic audiences will be reached via conference presentations and peer-reviewed journal papers. Given the universal nature of the subject matter, we also will seek to reach a broader audience via popular press articles.

Figure 5 – Mobile Mapping Application Example of ADA Compliance Issues

Expected Outcomes

The LiDAR-based approaches to quantifying sidewalks and curb ramps that we propose in this project will provide cities with an increased ability to self-evaluate their ADA compliance and violations. This is a key first step in protecting themselves from liability issues. Eisenberg et al. state that: “ADA transition plans are a planning tool required under Title II of the ADA” that should “identify current barriers to physical access, plan for their removal, and designate who is responsible for removing barriers" (Eisenberg, Heider et al. 2020). In a recent popular press article, he expanded upon this by say that these plans should tell us "what percentage of the sidewalks are compliant and what are not" (Berg 2020). The second step would be for cities to show that they are making strides towards fixing these ADA violations. This includes prioritizing problems and investing in improved infrastructure. It also includes tracking progress. Hence, cities could repeat the proposed data collection efforts at regular intervals.

Not only will this work assist cites with asset management of a historically overlooked transportation infrastructure and protect themselves from ADA liability problems, but it will also help real people in terms of improved mobility, accessibility, safety, and access to opportunities. According to the CDC, 13.7% Americans have a mobility-related disability (Okoro, Hollis et al. 2018). This represents more than half (about 53.3%) of those that report any disability. Improvements to sidewalks and curb ramps would also help kids, people pushing strollers, older folks with limited mobility, as well as anyone with a scooter, skateboard, roller skates, or even a need or inclination to walk for either utilitarian transportation or recreational purposes. The expected outcomes of this work will also include:

1. Findings with respect to the hypotheses and research questions
2. Manuscripts for presentation/publication at TRB and other peer-reviewed journals
3. Presentations to academic and policy audiences
4. A new module regarding LiDAR data extraction for a new graduate-level GIS and Transportation course at the University of Colorado Denver

Relevance to Strategic Goals

This project primarily links to the FAST Act strategic goals of preserving the existing transportation system. It will also connect to improving mobility of people and goods, promoting safety, and preserving the environment.

Educational Benefits

This study will provide opportunity for student research in terms of data collection, analysis, and paper writing. It will also be integrated into a new graduate-level GIS & Transportation course being offered in Fall 2021. The resulting data will be made available to students for use in term projects, master's reports, and PhD dissertation.

Technology Transfer

The goal is to disseminate knowledge and findings through personal correspondence, publications, and conference attendance. We will also be sure to collect and organize our data and results in a non-proprietary format so that other researchers can contribute to the work.

Work Plan

Concisely list each of the major tasks or steps in the project. Note that each list item (aka The proposed scope of work is scheduled for a one-year timeframe that will begin with a deeper look into the existing literature and historical approaches to measuring sidewalks and curb ramps. During this time, we will also be evaluating hardware and software options as well as identifying sites that will facilitate testing a broad range of ADA compliance issues. Months 5 through 7 will be dedicated to data collection and evaluation, followed by data analysis. We will then create the web and mobile mapping application before drafting the manuscripts and presentation materials in months 10 through 12. Over the course of the project, this work will be incorporated into lessons for a teaching module within a newly developed graduate-level GIS and transportation course.

Task	Timeline
Literature review	Months 1 – 2
Hardware and software evaluation	Months 2 – 3
Site selection	Months 3 – 4
Data collection and evaluation	Months 5 – 7
Analyze data	Months 7 – 9
Create web and mobile maps	Months 9 – 10
Incorporate lessons into classes	Months 9 – 10
Draft paper and presentation materials	Months 10 – 12

Project Cost

Total Project Costs:	$536,847
MPC Funds Requested:	$268,422
Matching Funds:	$268,425
Source of Matching Funds:	University of Colorado Denver Trimble, Inc. University of New Mexico University of Massachusetts

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