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Measuring Walkability: Development of an Automated Sidewalk Quality Assessment Tool

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Introduction

Sidewalks are a critical part of sustainable transportation systems. Good quality pedestrian infrastructure supports walking as a viable mode choice and encourages healthy physical activity. Presence and quality of sidewalks have been found to be significant predictors of perceived safety and general satisfaction in the pedestrian environment (Landis et al. 2005). In a recent study of mode choice and street network characteristics in 24 California cities, street features such as on-street parking, bike lanes, and sidewalk presence were associated with less driving (Marshall and Garrick 2010). Mode shifts to walking (and other non-motorized forms of transportation) are associated with increases in physical activity, improved health, (Woodcock et al. 2009) and potential decreases in vehicle miles traveled, roadway congestion and vehicle emissions. Additionally, sidewalks are recognized under the Americans with Disabilities Act of 1990 (ADA) as a vital part of accessible transportation infrastructure designed to improve the quality of life of persons with disabilities.

Planners recognize the benefits of providing high-quality pedestrian infrastructure for accessibility, safety, and quality of life, but often lack the data necessary to support and encourage the implementation of sidewalk improvement projects. In part, this is because developing sidewalk inventories and gathering sidewalk condition data is extremely time-consuming and costly. At the local, regional, and national levels, the lack of pedestrian-scale data has also presented a barrier to robust pedestrian transportation modeling (Pratt et al. 2012) and the assessment of Americans with Disabilities Act (ADA) regulatory compliance (USGO 2007). Although local agencies are required to develop ADA Transition Plans and may be legally responsible for inadequate infrastructure maintenance, it is often a challenge for jurisdictions to collect data necessary to measure and assess compliance. Sidewalk presence, width, and surface condition are several of the pedestrian-scale data sources needed to accurately plan accessible pedestrian facilities and prioritize new infrastructure investment. To support the cost-effective collection of data that can be used to assess sidewalk quality, researchers have developed an Android-based system that operates in a tablet to automatically generate spatial sidewalk inventories, evaluate sidewalk quality, and prioritize sidewalk repairs.

Literature Review

Safe and accessible pedestrian infrastructure design is guided by the implementation of the Americans with Disabilities Act (ADA) through federal regulatory requirements, as well as state and local laws and regulations. Recent studies indicate additional factors beyond regulatory compliance may play a role in predicting walkability, sense of security, and convenience of the pedestrian environment. Although methodologies for sidewalk inventory and assessment are still emerging, local agencies have utilized GPS/GIS-based surveys, level-of-service models, and other techniques to support pedestrian planning, regulatory code compliance and asset management.

Pedestrian Accessibility Guidelines

The Americans with Disabilities Act of 1990 (ADA) established requirements for transportation access to public facilities and buildings, including access to public transportation. The ADA Accessibility Guidelines (ADAAG) for Buildings and Facilities provides design specifications for pedestrian infrastructure. The aim of ADA design standards is to enable safe transportation for disabled persons to public facilities. These standards also help to build an environment where the pedestrian infrastructure promotes safety, mobility, and accessibility for all users. The ADAAG standards relating to “accessible routes” and curb ramps are applicable to the pedestrian-traveled way. For example, ADAAG specifies specific widths, surface conditions, grades and cross-slopes for “accessible routes” (Quiroga and Turner 2008).

Along with tying into safety, health, and accessibility issue, sidewalk quality has legal implications as well. Pedestrian infrastructure is legally considered part of the “public right of way” and local governments can be liable for physical injury resulting from inadequate maintenance of infrastructure. Recent court decisions indicate that sidewalks are covered by ADA requirements, that municipalities are responsible for removing barriers to reasonable accessibility, and that the definition of roadway “alterations,” which triggers ADA upgrades, includes pavement resurfacing projects *Barden v. Sacramento* (2002) and *Kinney v. Yerusalim* (Lautt 2011).

The U.S. Access Board (2002) published a design guide addressing accessibility for pedestrian facilities. Design considerations include sidewalk width, presence of passing areas, running-slopes, cross-slopes, and ramps presence and design. The Accessible Right-of-Way guidelines require a minimum “continuous clear width” to allow sufficient space for persons with disabilities to travel. The minimum “clear width” is three feet; however walkways less than 5 feet wide must provide sufficient passing spaces every 200

feet. The guidelines establish a maximum running-slope for wheelchairs to travel safely at 5% (except where roadway slope exceeds 5%), with running slope not to exceed roadway slope. Additionally, the Access Board's design guide identified cross-slopes greater than 2% as a barrier to accessibility. Appropriate cross-slope is an access issue both in the sidewalk environment and at driveway crossings (Proposed Accessibility Guidelines 2011). Guidelines also recommend minimum clear width and clear lengths, as well as a "level and stable" surfaces, at transit boarding areas. Generally, sidewalk pavement should be "stable, firm and slip-resistant," and certain construction materials are not recommended for safety reasons. Design guidelines also specify maximum changes in level to ensure a continuous path of travel (Proposed Accessibility Guidelines 2011).

Accessibility design guidelines and technical specifications provide a framework for assessing pedestrian conditions. However, traditional sidewalk data collection methods are time-consuming and resource-intensive for public works departments. New methods are emerging to streamline the sidewalk assessment process and aid agencies in developing their ADA transition plans and planning for pedestrian facilities. The Georgia Tech system looks beyond a simple compliant/non-compliant determination by collecting detailed sidewalk inventory data and performing automated quality assessment for the segments monitored. Both of these elements are needed for pedestrian activity and infrastructure planning.

Pedestrian Infrastructure Assessment and Indices

Recent studies have examined the relationship between perceived walkability and sidewalk quality, mostly relying on non-quantitative pedestrian facility assessment criteria. Sidewalk width, a buffer between sidewalk and street, and presence of amenities are predictors of pedestrian travel, perceived safety and quality of the pedestrian environment (Marshall and Garrick 2010, Landis et al. 2005, Kockelman et al. 2001). In developing pedestrian indices, previous studies have incorporated survey data or objective-built environment measures to assess the relationship between the physical condition of the pedestrian environment and perceived pedestrian comfort or quality of service. For example, the Irvine-Minnesota Inventory Tool included 162 items in a field observational audit instrument to assess built environments in terms of pedestrian comfort and accessibility (Day, Boarney, Alfonzo & Forsyth, 2006). However, the authors noted that the length of the survey may be time-consuming for a comprehensive inventory over a large area. Effective sidewalk width, pavement condition, and material composition were important variables for sidewalk accessibility in a 2008 index based on perceived importance to wheelchair users (Ferreira and da Penha Sanches 2008). A review of 25 pedestrian indices also identified objective

variables for measuring walkability, included sidewalk presence, sidewalk width, running slope, and presence of a buffer between the sidewalk and motor vehicle traffic (Meghelal and Capp 2011).

Traditional methods of sidewalk inventory are often time and cost-prohibitive, particularly for large-scale implementation. A literature review of 29 cities' efforts at pedestrian and bicycle data collection of bike and pedestrian facilities found a variety of methodologies used ranging from user surveys to facility inventory and spatial analysis (Schneider et al. 2005). According to these case studies, bike and pedestrian data collection can provide evidence of changing travel patterns, identify locations for infrastructure improvements, evaluate new infrastructure needs, and facilitate bicycle and pedestrian planning. Approaches for cost-effective data collection included use of volunteer or intern labor and use of GPS technology. Some data collection efforts can be institutionalized so that an ongoing effort persists.

Although pedestrian activity data and facility inventories are not new to the field of transportation, many inventories do not include quantitative analyses of infrastructure conditions. In 1999, the Federal Highway Administration published a report on a Sidewalk Assessment Process to assess ADA compliance. The Sidewalk Assessment Process was piloted in several cities, and involved physical evaluation of sidewalk widths and slope measurements, among other qualities (Khambatta and Loewenherz 2011). Recently, local governments utilized GPS, GIS software, and PDAs for pedestrian data collection. For example, University of Oregon researchers collected data on sidewalk width and condition using GPS units (Schlossberg 2006). A review of ADA compliance inventories at state Departments of Transportation found several innovative studies that incorporated new technologies for infrastructure asset management (Quiroga and Turner 2008).

In cooperation with the Federal Highway Administration, the City of Bellevue (Washington) completed a sidewalk and curb ramp inventory for an ADA transition plan (Quiroga and Turner 2008). The City of Bellevue found traditional inventory methods to be prohibitively costly, and piloted a prototype of an inertial profiler system to accurately collect slope data while realizing a 70% cost savings (City of Bellevue 2009).

A review of best practices in pedestrian infrastructure demonstrates the potential of emerging technologies for accurate and cost-effective asset management. Quantitative inventories of sidewalk and curb ramp infrastructure assist in ADA compliance efforts, and municipal repair prioritization designed to increase safety and walkability. However, current gaps in literature and practice indicate a need for development of a replicable, objective, cost-effective system to assess pedestrian infrastructure quality.

Research Objective

The objective of the research has been to develop and deploy a low-cost system that can be used to automatically assess sidewalk quality and that can be deployed by agencies on a large scale. This sidewalk assessment system takes prior studies of national accessibility design standards into account in identifying the indicators that are most important in assessing pedestrian infrastructure. Survey data and measurements from the physical environment identified as best practice in the literature are utilized in the development of a sidewalk quality index rating. A premise of the research is that sidewalk inventories developed through volunteer data collection efforts and use of advanced technology would be beneficial to control costs associated with developing pedestrian infrastructure databases.

The research team is currently calibrating the automated sidewalk quality assessment system for deployment in spring 2013. In consultation with expert stakeholders via survey responses, the research team is developing the sidewalk quality index and field-testing the system. The Android App, SideWalk Sentry™, runs on a Toshiba Thrive tablet. The App records video, GPS, accelerometer, and gyroscope data. When attached to a manual wheelchair and rolled along the sidewalk, the App automatically records the video and collects the data necessary to identify sidewalks that may need of repair or reconstruction. This data collection system is low-cost due to the use of a standard, manual wheelchair (approximately \$200 per wheelchair), tablet devices (approximately \$200 per tablet) and volunteer and student labor for field work. Prior studies have demonstrated that the use of mobile devices such as PDAs and volunteer labor to be cost-effective in sidewalk data collection. Additionally, the use of manual wheelchairs as a data collection vehicle is significantly less costly than a Segway (as used in City of Bellevue, 2009). Additionally, the use of an Android application for data collection likely reduces the time needed for field data collection when compared with an audit instrument. In order to validate these automated field data, a survey instrument is used to compare sidewalk data from the Android app with expert sidewalk quality ratings. The data collection in the Atlanta metro area will provide a baseline for municipal and regional sidewalk inventory, which is necessary to identify and prioritize infrastructure repair, maintenance, and new construction.

Sidewalk Quality Index Development

To test the implementation of a sidewalk assessment system in a large jurisdiction, researchers collected pilot data in the City of Atlanta, Georgia.

Despite the automobile-centric reputation of the Atlanta metropolitan area, about 4% of Atlanta city residents walk to work and nearly 13% commute by transit (American Community Survey 2010). The Federal Highway Administration has identified Atlanta as a Pedestrian Safety Focus City due to its relatively high rate of pedestrian fatalities (Redmon et al. 2012). Pedestrian incident data within the City of Atlanta indicates a large number of pedestrian incidents within particular corridors in the city, such as along Peachtree Street and Peachtree Road in the central business district (see Figure 1).

Figure 1: Density of pedestrian crashes in the City of Atlanta (Source: City of Atlanta Office of Planning)

The City of Atlanta estimates a total sidewalk network of approximately 2,158 miles (City of Atlanta 2008, City of Atlanta 2010); however, the exact length and current state of good repair estimates are somewhat uncertain. The 2008 State of the City's Infrastructure report estimated that 18% of the sidewalk network to be deteriorated and the City of Atlanta Public Works Department estimates that the pedestrian infrastructure repair backlog totals around \$153 million. The City of Atlanta has faced litigation from the U.S. Department of

Justice under the Americans with Disabilities Act for non-compliant sidewalks and curb ramps (U.S. Department of Justice 2009). Injury lawsuits related to deteriorated sidewalk facilities have cost the City of Atlanta millions of dollars in the last few years, much more than is spent on sidewalk repairs (McWilliams 2012). Recent court decisions also indicate that local jurisdiction may be litigated under ADA due to inadequate maintenance of the public right-of-way. These driving forces led the Atlanta City Council to recently convene a Sidewalk Task Force to research public policy issues associated with sidewalk maintenance, pedestrian facility funding, and pedestrian safety. Stakeholders interested in sidewalk quality and assessment in the City of Atlanta include local, regional and state agencies, non-profits, community groups and residents. Several expert stakeholders have noted the outstanding need for a complete inventory of Atlanta's pedestrian facilities prioritize repairs and future infrastructure.

Data Sources and Methodology

Sidewalk condition and presence of obstructions have been identified in national accessibility guidelines and recent pedestrian research as significant for pedestrian safety, mobility and quality of life. Hence, the basic research approach calls for field data collection of sidewalk width, pavement surface condition, presence of curb ramps, and presence of obstructions within the public right-of-way using the Android tablet application. The App-equipped tablet is attached to the base of a wheelchair and the user simply walks the chair and attached tablet along any desired route (See Figure 2). SideWalk Sentry™ records video, GPS location, accelerometer, and gyroscope data. The video and vibration data are processed, weighted, and analyzed to identify the sidewalk sections that may be in need of repair or reconstruction. Robust stakeholder engagement is being undertaken during system development, and will continue through deployment, to ensure that the system will obtain useful data and that the results will inform pedestrian facility and asset management activities at the local, regional, and state levels.

Figure 2: Researcher demonstrates data collection system (Source: Virginia Highland Civic Association)

In consultation with transportation planners and stakeholders, the research team is conducting a sidewalk quality survey to obtain expert sidewalk ratings on sidewalk quality for a sample of more than 40 sidewalk segments. The sidewalk segments represent a range of sidewalk parameters, including width, pavement type, surface quality (roughness, discontinuities, gaps, etc.), grade, and number of obstructions. The objective was to create a sample of sidewalks representing the wide array of conditions encountered in Atlanta. Sidewalk segment selection was based upon stakeholder input, previously planned and programmed pedestrian facility improvements, and crash incident data. Specifically, sidewalk segments were selected that were located near public transit stations, schools, parks and high-density areas. These sample sidewalk segments are located in geographically and economically diverse locations throughout the City of Atlanta. Figure 3 shows the 40 block-length segments used in the expert sidewalk survey, based on raw GPS data and incorporating example screenshots of video data.

Figure 3: Sidewalk Data Collected for Survey

The stakeholder sidewalk quality surveys will provide the link between stakeholder stated preference related to sidewalk quality and quantitative indicators from the SideWalk Sentry™ App for use in statistical analysis. To develop the Sidewalk Quality Index ratings, the research team will correlate quantitative parameters and qualitative ratings to identify key indicators of sidewalk quality and develop a composite sidewalk quality index score. The team will use cluster analysis for the statistical linkage between observed parameters and expert ratings. When the algorithms are complete, sidewalks can be automatically graded using the data collected by the sidewalk App.

State and local transportation agency staff and volunteers from PEDS (a local pedestrian advocacy group) will participate in initial testing of the survey instrument and provide feedback. More than 100 stakeholders and sidewalk experts have participated in the survey this spring. Stakeholder focus groups will also be conducted in order to gather input on important sidewalk quality and walkability parameters to consider during index development and future sidewalk data analysis.

Research Results to Date

The research team has collected the field data for more than 40 sidewalk segments across the City of Atlanta and has deployed the quality evaluation survey to more than 100 national transportation experts and stakeholders to obtain baseline sidewalk quality expert ratings (for more detailed information on the results of the sidewalk quality survey, see Grossman et al., 2013, forthcoming). This sidewalk quality data collection system is complete and has been field-tested in Atlanta. Once the final sidewalk quality indices are complete, the system will be deployed throughout the City of Atlanta and the Atlanta metropolitan area. The system should serve as a model for data collection and sidewalk assessment for any major metropolitan area.

The results of field data collection and post-processing have identified values for sidewalk quality parameters, such as effective sidewalk width, density of pavement cracks, and presence of stationary obstructions for each segment in the 40-segment sample. Expert survey results will identify individual and relative ratings for each sidewalk segment, and provide information on the specific sidewalk characteristics that were critical to the determination in each case. Statistical analysis of survey results will identify the sidewalk quality parameters that are most significant for grouping the sidewalk quality ratings. Further analysis will develop a model to predict sidewalk quality ratings based on quantitative parameters obtained from field data. These analyses will determine the relative importance of various sidewalk quality parameters, and provide a

basis for rating and ranking sidewalk segments throughout the Atlanta metropolitan area.

The research team has attended multiple public meetings regarding the issue of sidewalk maintenance and funding options in the City of Atlanta, which provided information on current challenges, existing policies and potential stakeholder priorities. Members of the research team have participated in Atlanta City Council Sidewalk Task Force, including attending general meetings and subcommittee meetings. The full Sidewalk Task Force includes city staff from Public Works and Planning, elected officials, and pedestrian advocates. The research team has also presented and demonstrated the research project at numerous neighborhood planning unit meetings, to city staff, and to staff at the Atlanta Regional Commission.

The results of the Sidewalk Quality Index will be integrated into an online mapping interface and made available to stakeholders to inform pedestrian planning, project prioritization and asset management. Project results will be presented to stakeholders and practitioners to ensure that the research product is easily accessible and ready for implementation.

Conclusion

The sidewalk assessment ratings developed through this project can provide a baseline for municipal and regional sidewalk inventories, influencing transportation decision-making and improving quality of life and public health. The research team anticipates that the sidewalk assessment system will gain widespread national application. Future research will focus on verification of the Sidewalk Quality Index results by expanding the field dataset to an entire neighborhood or jurisdiction, and the team hopes to conduct follow-up surveys with stakeholders to evaluate how composite index ratings compared to their initial qualitative assessment. Future research and analysis will likely investigate the relationships between sidewalk quality ratings and land use, street network characteristics, and socioeconomic and demographic characteristics.

Based on the established sidewalk quality index ratings, local agencies may identify an appropriate repair and planning prioritization process. The dataset established by this research provides a baseline for widespread pedestrian infrastructure inventory and analysis, with applications to pedestrian research, modeling, and planning practice. The development of low-cost, automated evaluation tools will help to address current challenges in prioritizing infrastructure improvements, fostering walkable and livable cities and suburbs.

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