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# ASSESSING THE DEGREE OF ACCESSIBILITY OF SIDEWALKS FOR PEOPLE WITH DISABILITIES

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**Abstract:** Federal and state laws require state and local governments to provide and maintain accessibility on their sidewalks to prevent discrimination against people with disabilities. To comply with these laws, state and local governments are required to conduct self-evaluations to identify all non-compliant sidewalks in their right-of-way. The mandatory self-evaluation process includes assessing sidewalks' compliance with a long list of accessibility requirements. This paper presents the development of a novel model to automate the assessment of the degree of accessibility of sidewalks. The developed model enables decision makers to (i) quantify the degree of accessibility of sidewalks, (ii) calculate the overall degree of accessibility of a group of sidewalks to facilitate the ranking and prioritization of their upgrade, and (iii) determine the type of upgrade required to achieve full accessibility. A case study of a small town that includes 864 sidewalks is analyzed to evaluate the model performance and illustrate its unique and original capabilities.

Keywords: - (Sidewalks; ADA; Self-Evaluation; Transition Plan; Assessment; Compliance)

## 1 Introduction

People with disabilities form 18.7 percent of the United States population (US Census Bureau 2012). Providing accessible sidewalks for this significant portion of the population is essential to ensure their independence and active participation in society. Lack of accessible sidewalks force people with disabilities to use streets for transportation increasing the risk of injury and traffic accidents, which hinders their mobility and reduce their participation in programs, services, and activities (PROWAAC 2007). To protect the civil rights of people with disabilities, the United States Congress has passed several statutes to prohibit discrimination against people with disabilities and guarantee their ability to participate in all programs, services, and activities sponsored by state and local governments. These statutes include (1) the Architectural Barriers Act (ABA) in 1968 (42 U.S.C. §§4151 et seq., 1968), (2) the Rehabilitation Act in 1973 (29 U.S.C. § 701 et seq., 1973), and (3) the Americans with Disabilities Act (ADA) in 1990 (42 U.S.C. § 12101 et seq., 1990). Federal agencies such as the United States Department of Justice (DOJ) and the United States Department of Transportation (DOT) are designated by these laws to develop and enforce federal regulations that explain in detail the requirements that must be met to achieve compliance with accessibility laws.

Failure of a number of public agencies to comply with these accessibility laws and regulations has resulted in multiple injuries (Coffey 2014). In addition, public agencies have incurred costly settlements due to non-compliance, including $1.4 billion settlement by the City of Los Angeles in 2015 ("Willits v. City of L.A." 2016), $1.1 billion settlement by California Department of Transportation (Caltrans) in 2010 ("CDR v. Caltrans" 2010), and $50 million settlement by the City of Chicago in 2007 ("Council for Disability Rights v.

City Of Chicago" 2007). These settlements and injuries illustrate the pressing need to improve compliance with accessibility requirements in order to reduce injuries and avoid costly settlements.

Federal laws and regulations require state and local governments to perform *self-evaluation* of their sidewalks to identify non-compliant sidewalks. To perform this self-evaluation process, state and local governments need to measure and document the dimensions, geometry, and conditions of sidewalks in their jurisdiction. In addition, public agencies need to assess the compliance of their sidewalks with accessibility requirements in order to identify any cases of non-compliance. State and local governments are also required to keep their ADA self-evaluations up to date at all times ("2010 ADA Standards for Accessible Design" 2010).

A number of public agencies have developed methodologies and techniques to perform this federally-mandated self-evaluation process. For example, the Sidewalk Assessment Process (SWAP) was developed as part of a study conducted by the Federal Highway Administration (FHWA) to evaluate the accessibility of sidewalks, curb ramps, and other pedestrian facilities (Axelson, Wong, and Kirschbaum 1999; FHWA 2001). Another example is the GIS-based pedestrian audit tool that was developed by Schlossberg et al. (2007) that utilized Geographic Information System (GIS) to document the conditions of sidewalks while requiring surveyors to provide their subjective assessment on whether pedestrian facilities comply with accessibility requirements or not. In 2010, another study sponsored by FHWA piloted a program to implement the Ultra-Light Inertial Profiler ADA system (ULIP-ADA) to capture, process, and document sidewalk dimensions and geometry in a GIS database. This study also required the subjective judgement of human assessors to determine their compliance with accessibility requirements (City of Bellevue 2008; Loewenherz 2010).

Despite the significant contributions of the aforementioned studies, they are incapable of: (1) quantifying the degree of accessibility of sidewalks; and (2) calculating the overall degree of accessibility of a group of sidewalks to facilitate the ranking and prioritization of their upgrade, and (3) determining the type of upgrade required to achieve full accessibility. To overcome these limitations, this paper presents the development of a novel automated model for assessing the degree of accessibility of sidewalks.

## 2 Sidewalk Accessibility Requirements

The aforementioned accessibility laws and regulations specify detailed requirements that must be fulfilled in any sidewalk in order to achieve full compliance and provide people with disabilities with acceptable level of accessibility that guarantees their ability to use the sidewalks independently. The latest enforceable federal accessibility regulations and standards are the 2010 ADA Regulations that includes the 2010 ADA accessibility standards (US Department of Justice 2010). However, the 2010 ADA Title II regulations do not include specific standards for sidewalks. The latest guidelines for sidewalk accessibility is the Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG) that was developed by the United States Access Board (USAB) and published in 2011(El-Rayes et al. 2016). PROWAG is expected to be adopted by the US Department of Justice (DOJ) and the US Department of Transportation (DOT) in their federal ADA regulations. Once adopted, PROWAG will become enforceable standards that must be fulfilled to achieve compliance (El-Rayes et al. 2016).

The degree of accessibility of a specific sidewalk can be determined by comparing the existing conditions and measurement of that sidewalk with accessibility requirements (El-Rayes et al. 2016). When a sidewalk does not meet the minimum accessibility requirements specified in PROWAG, this sidewalks is considered non-compliant with accessibility requirements and inaccessible for people with disabilities (U.S. Access Board 2011). This system of binary classification of sidewalks as compliant or non-compliant is not effective in the process of ranking and prioritizing non-compliant sidewalks to plan their upgrades in order to achieve full compliance (CCRPC 2016; City of Clayton 2014). Non-compliant sidewalks can be further classified as sidewalks with major or minor non-compliances. Sidewalks with major non-compliance are fully inaccessible, while sidewalks with minor non-compliance enable them to be partially accessible. For example, in the case of two sidewalks 0.50 meter wide and 1.10 meter wide respectively, both sidewalks are considered non-compliant because they fail to meet the minimum width requirement of 1.20 meters for accessible sidewalks. However, the 0.50 meter sidewalk is fully inaccessible, while the 1.10 meter sidewalk provides partial accessibility for pedestrians travelling in one direction (PROWAAC 2007).

To overcome this limitation, the present model is capable of quantifying different degrees of accessibility. In this model the degree of accessibility is presented as a percentage from 0% (fully inaccessible) to 100% (fully accessible). The degree of accessibility of a given sidewalk is calculated in the proposed model by identifying the deviation between its existing conditions, geometry, and dimensions, and the minimum sidewalk accessibility requirements in PROWAG including length without turning spaces, width, running slope, cross slope, surface discontinuities, and protruding objects, as shown in Figure 1. The following section explains in detail the process of assessing the degree of accessibility for sidewalks in the present model.

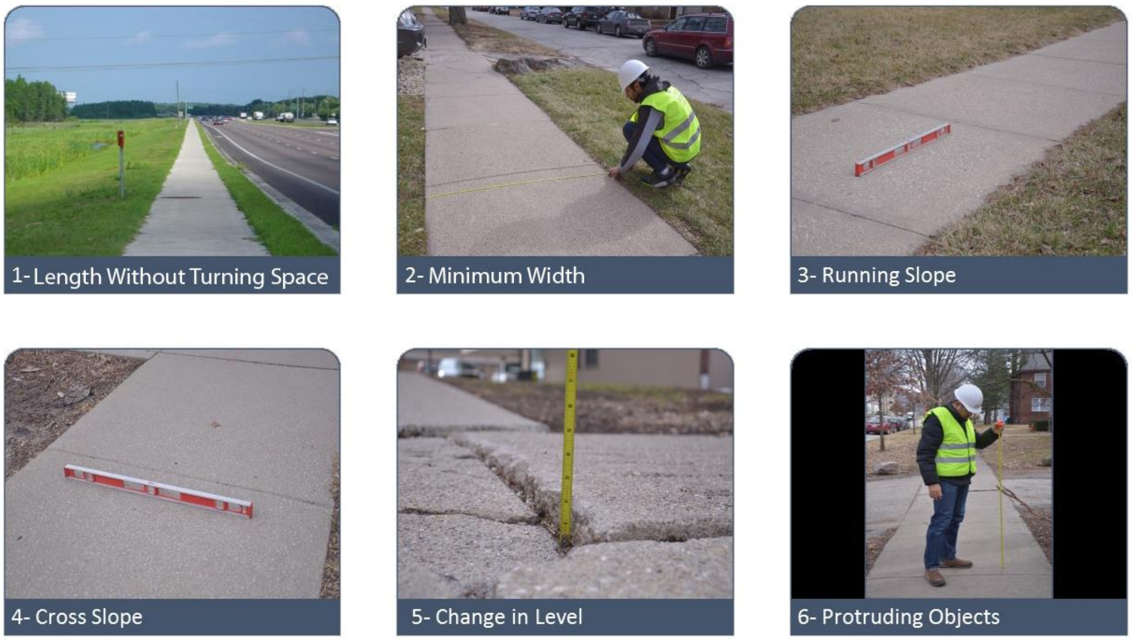


Figure 1: Sidewalk accessibility requirements

## 3 Sidewalk Accessibility Assessment

The sidewalks degree of accessibility (*DOA)* in the present model represents the weighted average of accessibility scores for all sidewalks accessibility requirements. The degree of accessibility is calculated in the present model using equation [1] based on the relative importance weight $W_n$ of each accessibility requirement and its accessibility score $AS_n$. These relative importance weights $W_n$ can be specified by decision makers to reflect the importance of each sidewalk accessibility requirement.

[1] $DOA = \sum_{n=1}^{6} W_n \times AS_n$

Where *DOA* is degree of accessibility, *n* is sidewalk accessibility requirement, $W_n$ is relative importance weight of sidewalk accessibility requirement *n*, and $AS_n$ is accessibility score for sidewalk accessibility requirement *n*.

The accessibility scores $AS_n$ for each accessibility requirement *n* can be determined based on the existing conditions of a sidewalk and the minimum accessibility requirements specified in PROWAG. For example, if a sidewalk is more than 1.2 meters wide, it is considered fully accessible (U.S. Access Board 2011) and will receive a width accessibility score of 100%, while if it less than 0.9 meters wide, it is considered completely inaccessible for people with disabilities (PROWAAC 2007) and will receive a width accessibility score of 0%. However, if the sidewalk width is between 0.9 and 1.2 meters, it is considered partially accessible and it will receive a width accessibility score proportional to its width, as shown in Figure 2-a. The model also enables decision makers to customize accessibility scores for each sidewalk accessibility requirement by creating a utility function that reflects their customized scores, as shown in Figure 2-b. The accessibility scores $AS_n$ for the remaining five sidewalk accessibility requirements are determined using a similar approach to the aforementioned sidewalk minimum width requirement. Federal accessibility requirements from PROWAG are used as upper and lower accessibility limits, as shown in Table 1. For each sidewalk accessibility requirement *n*, if the existing condition of a sidewalk meets PROWAG requirements in the "Full Accessibility" column, it receives an $n^{th}$ accessibility score of 100%, while if it meets the inaccessibility conditions in the "Full Inaccessibility" column, it receives an $n^{th}$ accessibility score of 0.0%. A linear or utility function is used to find accessibility scores $AS_n$ for values between these upper and lower limits.

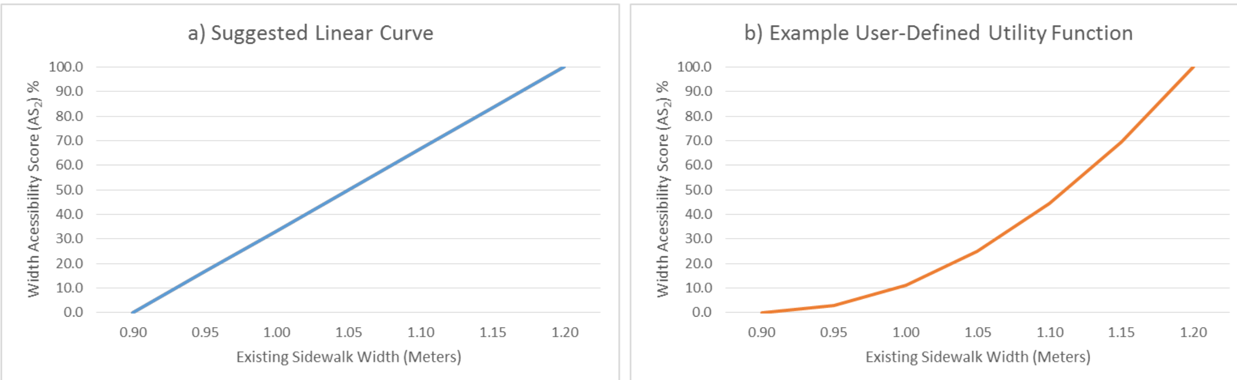


Figure 2: Width accessibility score ($AS_2$)

Table 1: Example table caption

| *n* | Sidewalk Accessibility Requirement | Full Accessibility $AS_n$=100% | Full Inaccessibility $AS_n$=0.0% |
|---|---|---|---|
| 1 | Length without turning space | Less than 60m | More than 90m |
| 2 | Minimum Width | More than 1.2m | Less than 0.9m |
| 3 | Running Slope | Less than 5% | More than 8.3% |
| 4 | Cross Slope | Less than 2% | More than 5% |
| 5 | Change in Level | Less than 13mm | More than 21mm |
| 6 | Protruding Objects | Less than 10cm | More than 15cm |

Quantifying the degree of accessibility DOA for each sidewalk enables decision makers to (1) identify non-complaint and inaccessible sidewalks in their jurisdiction, (2) prioritize and rank non-compliant sidewalks based on their degree of accessibility, and (3) understand the overall conditions of their sidewalk network to support future planning and upgrade decisions. The next section describes the process of aggregating the degree of accessibility for a group of sidewalks based on their geographic location to find their overall degree of accessibility.

## 4 Collective Degree of Accessibility

In most cases, sidewalk upgrade projects do not plan on upgrading a single sidewalk, but rather a group of sidewalks in close proximity to each other or within the scope of a scheduled road resurfacing project (CCRPC 2016). This strategy help municipalities reduce equipment, labor, and material cost by combining several upgrade projects of sidewalks and roadways. The proposed model is capable of aggregating the degree of accessibility DOA for a group of sidewalks to calculate their overall DOA. This collective DOA can be used to compare, rank, and prioritize upgrade projects for different groups of sidewalks based on their degree of accessibility. In the present model, the collective degree of accessibility CDOA of a group of sidewalks represents the weighted average of all DOA of all the sidewalks in this group, as shown in equation [2] by (1) calculating the ratio of each sidewalk length $L_m$ to the total length of all sidewalks $L_M$, (2) multiplying DOA of each sidewalk by the ratio of its length to the total length of all sidewalks, and (3) adding the results of these two steps for all sidewalks in the group to find the CDOA for the entire group.

[2] $CDOA = \sum_{m=1}^{6} DOA_m \times \frac{L_m}{L_M}$

Where *CDOA* is collective degree of accessibility for the entire group of sidewalks, $DOA_m$ is degree of accessibility of sidewalk *m*, *M* is total number of sidewalks in the group, $L_m$ is total length of sidewalk *m*, and $L_M$ is total length of all sidewalks.

## 5 Sidewalk Upgrade Types

Every non-compliant sidewalk must be upgraded to achieve full compliance with accessibility laws and regulations. However, this upgrade process can be either *full upgrade* or *partial upgrade*. The full upgrade process requires the demolition and reconstruction of non-compliant sidewalks in order to achieve compliance, while the partial upgrade required the alteration or addition of parts of the sidewalk to achieve full compliance. The type of upgrade required for each non-compliant sidewalk depends on the accessibility requirements that are not met in this specific sidewalk. Some sidewalk accessibility requirements such as surface discontinuities and protruding objects can be met by performing a partial upgrade of the non-compliant sidewalk, while others such as minimum width and cross slope require a full upgrade, as shown in Figure 3.

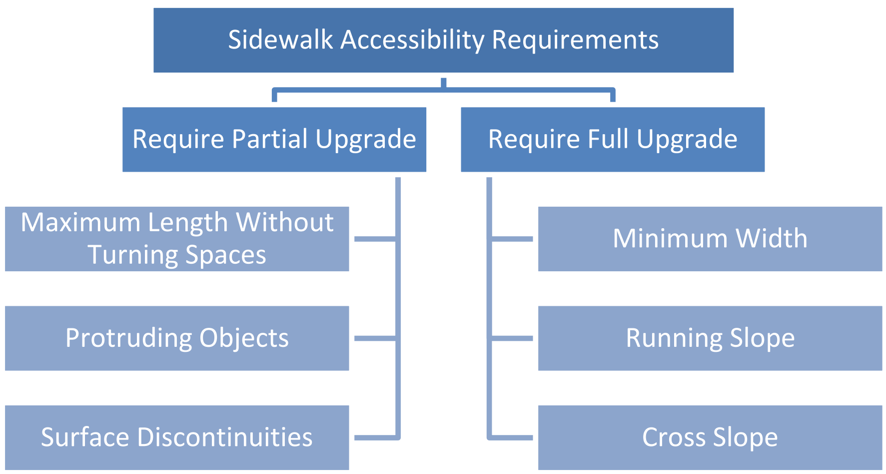


Figure 3: Sidewalk accessibility requirements classified by upgrade type

For example, in case of a protruding object that is hanging over a sidewalk, rendering it inaccessible for people with disabilities. To achieve full compliance, an upgrade process will only require the removal or relocation of this protruding object to clear the sidewalk. This is considered a partial upgrade since it required a minor alteration of the protruding object and did not affect the sidewalk itself. On the other hand, if a sidewalk width is less than the minimum sidewalk width accessibility requirements, this non-compliant sidewalk must be demolished and reconstructed with the required width. This is considered a full upgrade. The present model is capable of classifying non-compliant sidewalks based on the type of upgrade required to achieve full compliance with sidewalk accessibility requirements. This enables decision makers to gain more understanding of the overall conditions of the sidewalk network.

## 6 Case Study

To illustrate the use of the model and demonstrate its capabilities, a case study of a small town that includes 864 sidewalks is analyzed. The case study requires assessing the degree of accessibility of all sidewalks in the town in order to comply with the federal self-evaluation requirements and prioritize future upgrade projects for non-complaint sidewalks. For this case study, the required input data by the model include (1) existing dimensions, geometry, and conditions of all sidewalks in the case study, and (2) a list of sidewalks in each group for which the model is required to calculate CDOA. The model utilizes this input data to determine (1) the degree of accessibility DOA of each sidewalk in the case study, (2) the collective degree of accessibility CDOA for each group of sidewalks set by the decision makers, and (3) the type of upgrade required for each sidewalk in order to achieve full compliance with sidewalk accessibility requirements.

The capability of the present model to efficiently quantify the degree of accessibility of sidewalks can be illustrated by its ability to (1) calculate DOA for all sidewalks in the case study, and (2) complete the assessment of all the 864 aforementioned sidewalks in less than 2.0 seconds, with an average computational time of 0.0023 seconds per sidewalk. The model is also capable of calculating the collective degree of accessibility for a group of sidewalks to enable decision makers to prioritize upgrade projects of different groups of sidewalks based on their collective degree of accessibility. For example, the case study results illustrate that group number 21 has the highest CDOA (87.8%), while group number 2 has the lowest CDOA (60.9), as shown in Figure 4. This means that upgrading sidewalks in group 2 is more urgent than those in group 21.

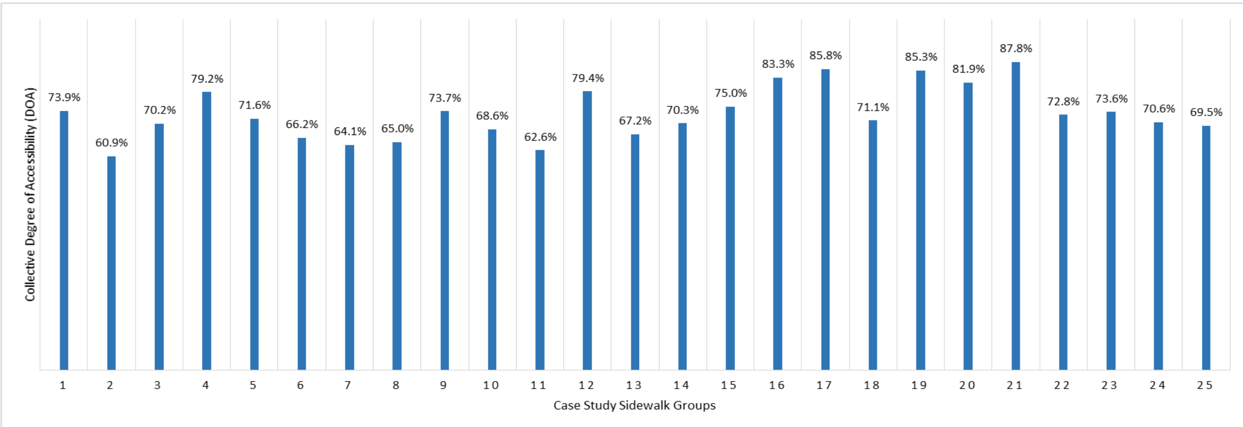


Figure 4: Collective DOA for all groups of sidewalks in the case study

The model also provides the capability of classifying sidewalks based on the type of upgrade required to achieve full compliance with sidewalk accessibility requirements. For example, the case study results illustrate that only 4 sidewalks (less than 1%) are fully accessible for people with disabilities in the entire case study, while 766 sidewalks (89%) are partially accessible and require partial upgrade, and 94 sidewalks (11%) are completely inaccessible and require full upgrade, as shown in Figure 5.

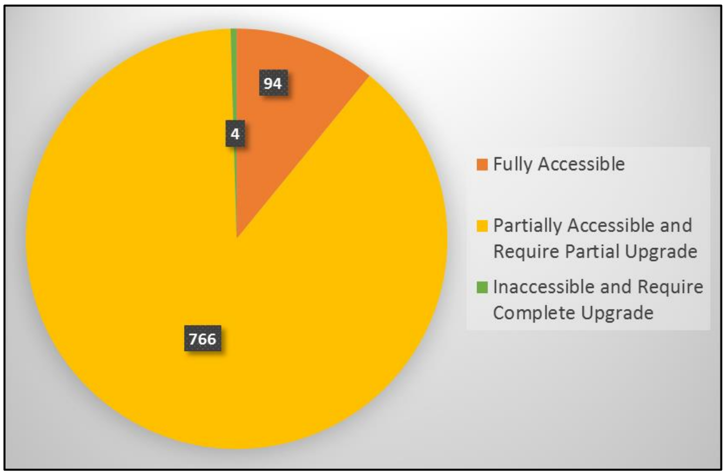


Figure 5: Sidewalk upgrade types

## 7 Model Validation Plan

To validate and verify the model results, another data set will be analyzed and compared with human-based assessment of the ground truth of the same set of sidewalks. A set of manually collected and evaluated data for the sidewalks of a city with a population of approximately 83,000 was obtained from its Regional Planning Committee. This dataset will be used to validate and verify the results of the developed model.

## 8 Acknowledgements

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