OPTIMIZING THE COMPLIANCE OF PEDESTRIAN FACILITIES CONSTRUCTION AND ALTERATION WITH ACCESSIBILITY REQUIREMENTS

BY

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DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Civil Engineering
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2018

Urbana, Illinois

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ABSTRACT

State and local governments are required by federal and state laws and regulations to provide and maintain accessibility on their sidewalks and pedestrian facilities. Failure of public agencies to comply with these requirements resulted in injuries and subjected several state and local governments to costly non-compliance penalties and legal settlements. To provide better service to people with disabilities and avoid accessibility related penalties, state and local government need to achieve full compliance with accessibility laws and regulations by conducting self-evaluations and developing transition plans. Self-evaluations must be created and frequently updated by state and local governments to assess the compliance of their pedestrian network with accessibility requirements. Transition plans must include a detailed schedule of all upgrade projects that are required to achieve full compliance with accessibility requirements. These self-evaluation and transition plan requirements proved to be a challenging task for state and local governments due to (1) the large size of their pedestrian networks, (2) the limited availability of resources, and (3) lack of specific guidance in accessibility regulations and standards on how to execute these tasks efficiently. Accordingly, decision makers in state and local governments need to improve the efficiency of self-evaluation and optimize the development of transition plans to maximize their compliance with accessibility requirements within their limited budgets and resources.

The main goal of this research study is to develop novel models, methodologies, and frameworks for maximizing the compliance of sidewalks and pedestrian facilities with accessibility requirements. To accomplish this goal, the research objectives of this study are to develop: (1) a comprehensive literature review of the latest laws, regulations, standards, guidelines, best practices, court cases, and legal settlements; (2) an effective and concise accessibility field guide; (3) a novel and practical framework for automating the extraction and modeling of sidewalk conditions, dimensions, and geometry from image; (4) a new methodology for assessing the degree of non-compliance of

pedestrian facilities with accessibility requirements; and (5) an innovative multi-objective model to optimize the development and execution of transition plan.

The performance of the developed models, methodologies, and frameworks was analyzed using real-life case studies. The results of analyzing these case studies illustrated the novel, unique, and practical capabilities of the research outcomes in enabling decision makers to improve the efficiency and effectiveness of their self-evaluations and optimize the development and execution of their transition plans. These capabilities will result in increasing the accessibility of sidewalks and pedestrian facilities for people with disabilities, which will improve their participation in public activities and assist state and local governments in achieving full compliance with accessibility requirements.

To My Wife, Hadil Helaly
“The Best Joy of this World is a Righteous Wife”

To My Children Malak, Khaled, and Fareeda
“You are the light of my life, to you I dedicate this work”

ACKNOWLEDGEMENTS

First, I want to thank God for blessing me with the strength, patience, and knowledge to finish this challenge. This dissertation would never be complete without giving credit to many people who have graciously guided and supported me through the six years I spent working on my PhD studies.

I want to express my sincere appreciation and gratitude to my mentor and academic advisor, Professor Khaled El-Rayes. His advice, guidance, and relentless support during my doctoral program was invaluable to my successful completion. His leadership will forever be cherished and I look forward to his continued support beyond my time at Illinois. I also want to extend my deepest appreciation to Professor Liang Liu, Professor Mani Golparvar-Fard, Professor Nora El-Gohary, and Professor Kathryn Anthony for their dedicated service on my thesis supervisory committee and all their guidance and constructive feedback.

I also want to sincerely thank my dear friends and colleagues Moatassem Abdallah, Hatem Ibrahim, Ahmed Abdelmohsen, Ernest-John Ignacio, and Ahmed Adel for their support during my doctoral study. I would like to thank Ms. Joan Christian, Ms. Maxine Peyton, and the rest of the frontline staff of the Civil and Environmental Engineering Department for their patience, kindness, and diligence in helping me and all my colleagues in the department.

Words cannot express how grateful I am to my beloved wife, Hadil Helaly. I owe her everything I achieved in my life. This dissertation would never have been completed without her love, patience, and support. I dedicate this thesis to her as a token of appreciation for our 11 years of marriage. I also want to thank my three wonderful children: Malak, Khaled, and Fareeda. Their smiles are the fuel for all my hard work. Additionally, I want to thank my parents, Mohammed Halabya and Fatma Elsayad and my mother in law, Azza Abouwarda. I would be nothing without their support. Finally, I want to thank my brother, Ahmed Halabya for being my compass. His wisdom shaped my path in life.

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CHAPTER 1 - INTRODUCTION

1.1. Overview and Problem Statement

State and local governments are required by Federal laws and regulations to provide and maintain accessibility on their sidewalks and pedestrian facilities (U.S. Congress 1990). In order to provide and maintain accessibility, laws and regulations require State and local governments to perform self-evaluations to assess existing accessibility conditions on their sidewalks and pedestrian facilities, and develop a transition plan that states in detail the actions and measures needed to bring these sidewalks and pedestrian facilities to full compliance with accessibility requirements. State and local governments must keep their self-evaluations and transition plans up to date to comply with Federal regulations (U.S. Department of Justice 2010a).

Failure of public agencies to provide and maintain accessibility on their sidewalks and pedestrian facilities has resulted in costly settlements. Examples of these settlements include: (1) City of Los Angeles, which agreed in 2015 to spend $1.4 billion on upgrading the city's sidewalks over 30 years starting in 2015, the settlement was given preliminary approval by the United States District Court, C.D. California in February 2016 ("Willits v. City of L.A." 2016); (2) California Department of Transportation (Caltrans), which agreed in a settlement in 2010 to spend $1.1 billion of highway funds over the period of 30 years to upgrade neglected accessibility elements (*CDR v. Caltrans* 2010); (3) City of Chicago, which agreed in 2007 to spend $50 million of new money over the period of five years to upgrade the city's sidewalks to comply with accessibility standards, in addition to $18 million each year installing curb ramps and sidewalks as a part of the City's annual resurfacing work ("Council for Disability Rights v. City Of Chicago" 2007); (4) City of Atlanta, which agreed in 2008 to pay $3 million to a person with a disability who suffered injuries due to inaccessible conditions; and (5) City of Sacramento, which agreed in 2002 to allocate 20% of its annual transportation fund for the following 30 years to ensure compliance of its pedestrian facilities with accessibility standards ("Barden v.

Sacramento" 2002). To avoid and minimize these costly settlements, State and local governments need to develop and frequently update self-evaluations and transition plans to comply with accessibility requirements on their sidewalks and pedestrian facilities.

1.1.1. Self-Evaluations

In order to maintain accessibility on their sidewalks and pedestrian facilities, State and local governments need to evaluate the compliance of their sidewalks with accessibility requirements regularly. For example, if a tree root grows under a sidewalk causing the sidewalk pavement to crack resulting in a change in slope, texture, or creating a gap of more than 0.5 inch, this sidewalk shall be considered non-complying with accessibility requirements. Accordingly, this segment of the sidewalk shall be documented in a self-evaluation as non-complying as soon as possible. State and local governments need to perform self-evaluation after severe weather events or disasters that might result in reducing accessibility on sidewalks and pedestrian facilities such as hurricanes, tornadoes, and storms.

To perform the required self-evaluations, State and local government often need to use significant resources (e.g. personnel, equipment, and funds) to measure and document the existing conditions of all their sidewalks and pedestrian facilities. Currently, most State and local governments use traditional evaluation methodologies (e.g. manual measurements, paper drawings, and human inspection) to perform self-evaluations of their sidewalks and pedestrian facilities. Availability of resources and personnel form a great challenge for most State and local governments, and often result in delays or inability to perform the required self-evaluation. Millions of dollars are spent annually on settlements and alterations due to the inability of State and local governments to allocate the resources needed to keep their self-evaluations up to date. These challenges create an urgent need for improving the efficiency and effectiveness of conducting the required self-evaluations.

1.1.2. Transition Plans

Federal laws and regulations require State and local governments to develop a transition plan that clearly states, in detail, all the actions and measures needed to bring their sidewalks and pedestrian facilities to full compliance with accessibility requirements. This transition plan depends on the outcomes of the aforementioned self-evaluation.

Transition plans require the collaboration of designers, engineers, and construction inspectors to select and design the most efficient actions and measures needed to bring sidewalks and pedestrian facilities to full compliance with accessibility requirements. Transition plans are also required to indicate the priority of altering each of the non-complying segments of sidewalks and pedestrian facilities that are documented in a self-evaluation. State and local governments are required to keep their transition plans up to date according to their latest self-evaluations. Whenever a segment of a roadway or pedestrian facility under the jurisdiction of a State or local government is identified and documented in a self-evaluation as non-compliant with accessibility requirements, it should immediately be included in their transition plan.

The development and execution of these transition plans need to be optimized to ensure that the State and local governments can use their limited budgets in the most cost-effective manner to achieve maximum compliance for their sidewalks and pedestrian facilities with accessibility requirements. Achieving maximum compliance with limited budgets also enables State and local governments to avoid costly litigation and settlements that may result from the non-compliance of their facilities with accessibility requirements. The aforementioned challenges create a pressing need for optimizing the development and execution of transition plans to maximize compliance while considering budget and time constraints.

Despite the significant contributions of the aforementioned research studies and analytical methods, they are incapable of: (1) improving the understanding and communication of accessibility requirements for sidewalks and pedestrian facilities, (2) automatically extracting and modeling sidewalk conditions, dimensions and geometry, (3) automatically assessing the degree of non-compliance with accessibility requirements, and (4) optimizing the development and execution of transition plans, as shown in Figure 1.

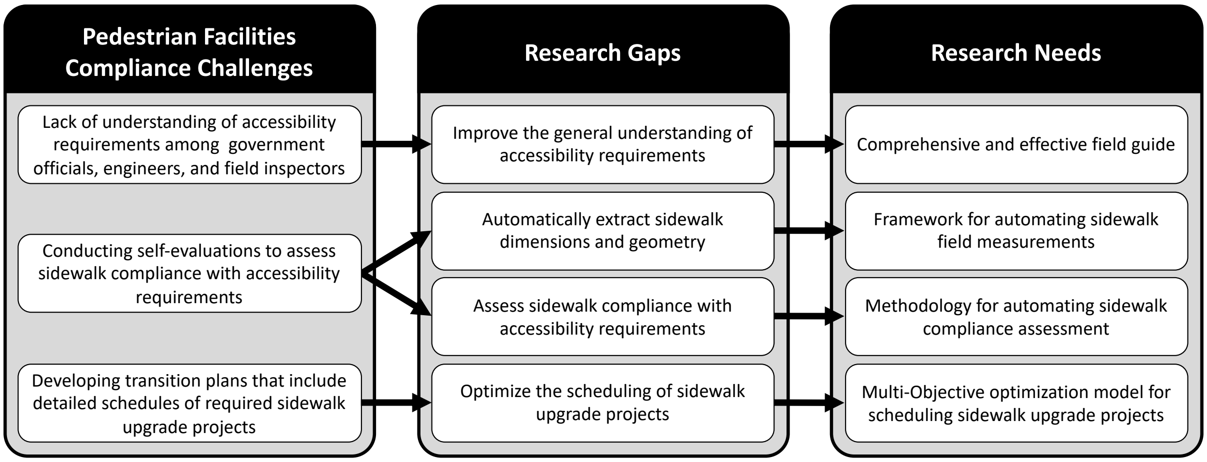


Figure 1: Research needs in pedestrian facilities compliance with accessibility requirements

1.2. Research Objectives

The primary goal of this research study is to develop a robust methodology for improving the efficiency and effectiveness of performing self-evaluations and optimizing transition plans that are required by accessibility laws and regulations. To accomplish this goal, the objectives of this research study along with its research questions are as follows:

<u>Objective One:</u>

Conduct a comprehensive literature review on the latest requirements, practices, and research on (a) accessibility laws, regulations, standards, and guidelines; (b) best practices of state and local governments in achieving compliance with accessibility laws and regulations, (c) requirements of self-evaluations and transition plans; (d) best practices for achieving compliance with accessibility requirements; and (e) related legal court cases and settlements.

Research Questions:

(i) What are the effective accessibility laws, regulations, standards? (ii) Are there any available federal or state guidelines for achieving full compliance with accessibility requirements? (iii) What are the best practices for achieving compliance with accessibility requirements for sidewalks and pedestrian facilities? (iv) What are the requirements for self-evaluations and transition plans? And (v) What is the impact of any related court cases or legal settlements on compliance with accessibility requirements?

Objective Two:

Develop a comprehensive and effective field guide to improve the understanding and communication of accessibility requirements for sidewalks and pedestrian facilities.

Research Questions:

(i) How to design the field guide to maximize its practicality, clarity, and usability? (ii) How to develop a comprehensive field guide content that addresses all the latest accessibility requirements for sidewalks and pedestrian facilities? and (iii) What is the optimum form factor and publishing medium for maximizing the adaptation of the field guide?

Objective Three:

Develop a novel and practical framework for automating the extraction and modeling of sidewalk conditions, dimensions and geometry from images.

Research Questions:

(i) What is the best methodology for isolating sidewalk-related visual data in captured sidewalk images? (ii) How to model the existing conditions, dimensions, and geometry of sidewalks from images? (iii) How to extract sidewalk dimensions and geometry from a reconstructed 3D model? And (iv)How to validate and verify the performance of the developed framework?

Objective Four:

Develop a novel methodology for automating the assessment of the degree of non-compliance of pedestrian facilities with accessibility requirements.

Research Questions

(i) How to create a comprehensive list of all accessibility requirements? (ii) How to quantify compliance of sidewalks and pedestrian facilities with accessibility requirements? (iii) What are the metrics and sub-metrics that can be used to measure the compliance of sidewalks and pedestrian facilities with accessibility requirements? (iv) How to measure the collective degree of compliance of a sidewalk network? And (v) How to evaluate the performance of the developed methodology?

Objective Five:

Develop a novel multi-objective optimization model for scheduling pedestrian facilities upgrade projects that is capable of generating optimal trade-offs among the three main objectives of (1) minimizing the total number of interrupted/canceled pedestrian trips due to non-compliance with accessibility requirements, (2) minimizing total upgrade duration, and (3) minimizing annual upgrade budgets.

Research Questions

(i) How to quantify the impact of upgrading non-compliant pedestrian facilities? (ii) What are the decision variables and constraints that best represent the alteration of sidewalks and pedestrian facilities? (iii) How to formulate the optimization functions to minimize interrupted pedestrian trips, annual upgrade cost, and total upgrade duration? (iv) What is the most efficient way to implement the model? And (v) How to verify the results of the model and evaluate its performance?

1.3. Research Methodology

To accomplish the aforementioned objectives of this study, a research methodology is proposed, as shown in Figure 2. The proposed methodology consists of five research tasks: (1) conduct a comprehensive literature review on the latest requirements, practices, and research studies on accessibility of sidewalks and pedestrian facilities, computer vision, and optimization techniques; (2) develop a comprehensive and effective field guide to improve the understanding and communication of accessibility requirements for sidewalks and pedestrian facilities; (3) develop a novel and practical framework for automating the extraction and modeling of sidewalk conditions, dimensions and geometry from images; (4) develop a novel methodology for automating the assessment of the degree of non-compliance of pedestrian facilities with accessibility requirements; and (5) Develop a novel multi-objective optimization model for scheduling pedestrian facilities upgrade projects to minimize interrupted pedestrian trips, annual upgrade cost, and total upgrade duration.

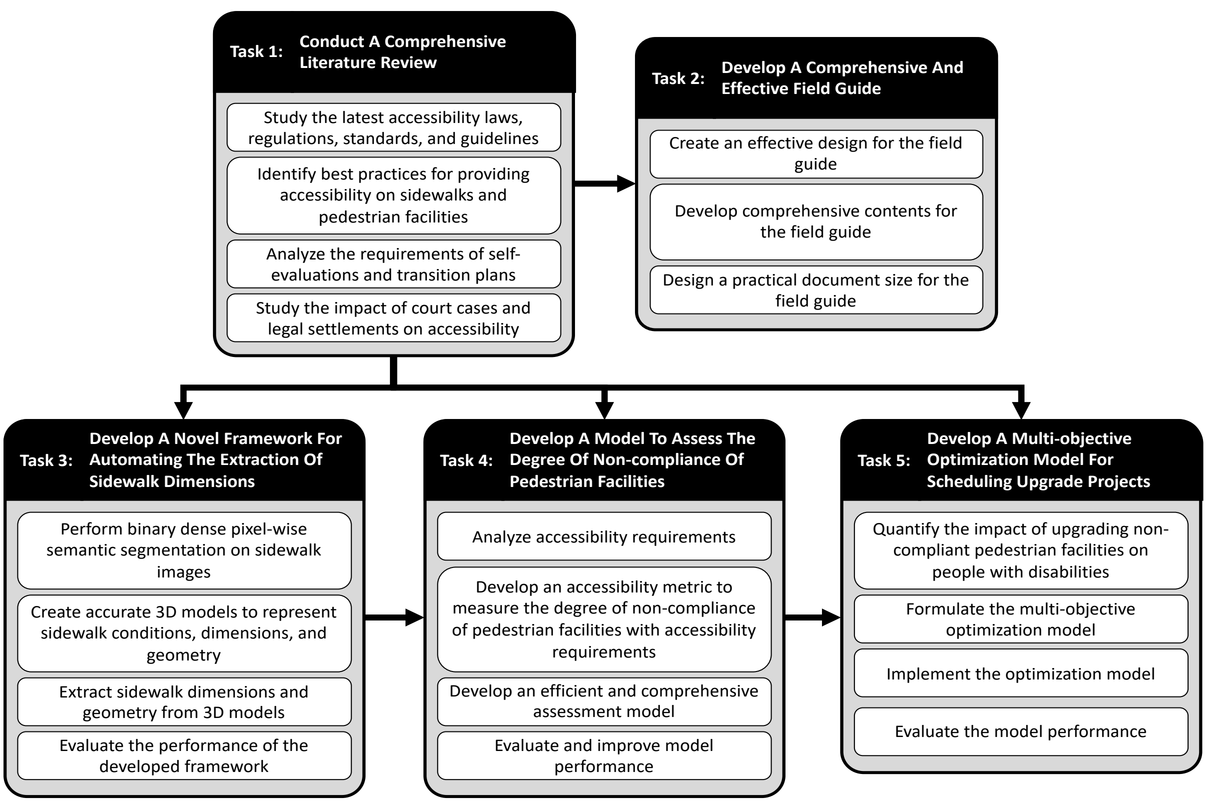


Figure 2: Research Tasks

1.3.1. Task 1 - Conduct a Comprehensive Literature Review

1.3.1.1. Study the latest accessibility laws, regulations, standards, and guidelines

The objective of this research task is to investigate and study the latest enforceable accessibility laws, regulations, and standards at the Federal and State levels. This task also covers accessibility guidelines that are soon to be adopted as standards.

1.3.1.2. Identify best practices for providing accessibility on sidewalks and pedestrian facilities.

This task focuses on investigating existing non-enforceable guidelines, design manuals, and field guides that provide guidance on achieving compliance of sidewalks and pedestrian facilities with accessibility requirements.

1.3.1.3. Analyze the requirements of self-evaluations and transition plans

This task analyzes the requirements of self-evaluations and transition plans in Federal, State, and local laws and codes. The output of this task provides a clear understanding and explanation of the requirements of self-evaluations and transition plans.

1.3.1.4. Study the impact of court cases and legal settlements on accessibility

This task identifies relevant court cases and legal settlements to understand their impact on achieving compliance with accessibility requirements.

1.3.2. Task 2 - Develop a Comprehensive and Effective Field Guide

1.3.2.1. Create an effective design for the field guide

The focus of this task is to create multiple prototypes of the field guide. An experienced multidisciplinary team of engineers, designers, legal experts, and DOT administrators will evaluate the performance of the designs. Their feedback will be used to refine and select the most effective design for on-site inspection.

1.3.2.2. *Develop comprehensive contents for the field guide*

This task focuses on identifying the latest accessibility requirements from all available Federal regulations, standards, and guidelines. These requirements will be combined in a comprehensive list to facilitate their use for on-site inspection without the need for further references. Descriptive illustrations and pictures will be created to improve clarity of the field guide by adding visual explanations to the text of the requirements.

1.3.2.3. *Design a practical document size for the field guide*

In this task, multiple document sizes will be proposed for the field guide. Feedback from the aforementioned multidisciplinary team will be used to select the most effective size for the field guide to facilitate its use for on-site inspection.

1.3.3. Task 3 - Develop a Novel and Practical Framework for Automating the Extraction and Modeling of Sidewalk Conditions, Dimensions and Geometry from Images

1.3.3.1. *Perform binary dense pixel-wise semantic segmentation on sidewalk images*

The scope of this task includes the development of a novel and practical Fully Convolutional Network that is capable of identifying all sidewalk pixels in input images and isolating them by discarding all non-related pixels.

1.3.3.2. *Create accurate 3D models to represent sidewalk conditions, dimensions, and geometry*

The purpose of this subtask is to generate a dense 3D point cloud that represents the conditions, dimensions, and geometry of existing sidewalks using the masked images generated in the previous semantic segmentation task.

1.3.3.3. *Extract sidewalk dimensions and geometry from 3D models*

The main focus of this subtask is to automate the extraction of sidewalk dimensions and geometry from the dense point clouds that was generated in the previous subtask.

1.3.3.4. Evaluate the performance of the developed framework

This subtask focuses on analyzing a real-life case study to verify the results of the developed framework and evaluate its accuracy and performance.

1.3.4. Task 4 - Develop a Novel Methodology to Assess The Degree of Non-Compliance of Pedestrian Facilities with Accessibility Requirements

1.3.4.1. Analyze accessibility requirements

This task will focus on identifying accessibility requirements and techniques used to verify pedestrian facilities compliance with these requirements.

1.3.4.2. Develop an accessibility metric to measure the degree of non-compliance of pedestrian facilities with accessibility requirements

The purpose of this task is to quantify the degree of non-compliance of sidewalks and pedestrian facilities with accessibility requirements. In this task, a novel index will be developed to represent the degree of non-compliance of sidewalks or pedestrian facilities with accessibility requirements based on the outcomes of the previous subtask.

1.3.4.3. Develop an efficient and comprehensive assessment model

The objective of this task is to formulate evaluation criteria and target performance in order to assess the compliance of sidewalks and pedestrian facilities with accessibility requirements. This task will utilize the accessibility compliance metric developed in the previous subtask to determine the collective degree of non-compliance of groups of pedestrian facilities based on their location and/or type.

1.3.4.4. Evaluate and improve model performance

In this task, application examples will be analyzed to evaluate and improve the performance of the developed assessment model.

1.3.5. Task 5 - Develop an Innovative Multi-Objective Optimization Model for Scheduling Sidewalk Upgrade Projects

1.3.5.1. Quantify the impact of upgrading non-compliant pedestrian facilities on people with disabilities

This subtask focuses on developing novel metrics to measure the impact of upgrading each non-compliant pedestrian facility on people with disabilities. This metric is essential in driving upgrade project scheduling and prioritization decisions.

1.3.5.2. Formulate the multi-objective optimization model

This task focuses on identifying the most relevant decision variables, formulating objective functions, and deciding on the most relevant constraints for the multi-objective optimization model in order to minimize interrupted pedestrian trips, total upgrade duration, and annual upgrade cost.

1.3.5.3. Implement the optimization model

In this task, the formulated optimization model will be implemented using a robust optimization technique. Several optimization techniques will be investigated, such as linear programming, dynamic programming, and genetic algorithms. The choice among these optimization tools will be based on (1) effectiveness in generating high-quality optimal solutions, and (2) efficiency in reaching those optimal solutions with a reasonable computational time.

1.3.5.4. Evaluate the model performance

This subtask focuses on analyzing a real-life case study to illustrate the use of the model and demonstrate its novel and unique capabilities.

1.4. Research Significance

The proposed study is expected to lead to significant research contributions in a number of areas, including: (1) developing a comprehensive and effective field guide that improves communication and understanding of accessibility requirements for sidewalks and pedestrian facilities, (2) identifying new metrics for quantifying sidewalks and pedestrian facilities compliance with accessibility requirements, (3) establishing a novel and practical framework for automating the extraction and modeling of sidewalk conditions, dimensions and geometry from images, (4) developing novel model to analyze, assess, and document compliance of sidewalks and pedestrian facilities with accessibility requirements, and (5) creating an innovative model for optimizing the development and execution of transition plans to minimize interrupted pedestrian trips, total upgrade duration, and annual upgrade budget.

Furthermore, the implementation of the proposed methodologies can lead to broad and profound impacts on roadway and pedestrian facilities construction. These impacts include: (1) improving understanding of accessibility requirements and improving the accuracy of their inspection in the field, (2) maximizing the efficiency and effectiveness of performing self-evaluations, (3) generating an accurate documentation of the existing conditions of sidewalks and pedestrian facilities in a reliable digital format, and (4) streamlining and optimizing the development and execution of transition plans to ensure achieving maximum compliance with accessibility requirements while considering all budget and time constraints.

1.5. Report Organization

The organization of this report along with its relation to main research tasks is discussed as follows:

1.5.1. Chapter 2 – Literature Review

Chapter 2 presents a detailed literature review that establishes baseline knowledge of the latest practices and research on (a) accessibility laws, regulations, standards, and guidelines; (b) best practices for providing accessibility on sidewalks and pedestrian facilities; (c) requirements of self-evaluations and transition plans; and (d) the impact of court cases and legal settlements on accessibility.

1.5.2. Chapter 3 –Field Guide Development

Chapter 3 describes the process of developing a comprehensive field guide that explains the latest accessibility requirements for sidewalks and pedestrian facilities in an efficient and effective manner to ensure that it communicates all accessibility requirements concisely and clearly. The field guide is also structured and organized to simplify the explanation of complex accessibility requirements using concise description and illustrative figures.

1.5.3. Chapter 4 – Automated Extraction and Modeling of Sidewalk Dimensions and Geometry from Images

Chapter 4 presents the development of a novel and practical framework for automating the extraction and modeling of sidewalk conditions, dimensions and geometry from images. The framework provides decision makers in state and local governments with an automated methodology that overcomes the aforementioned limitations of existing self-evaluation techniques by (1) providing a practical and cost-effective procedure for conducting self-evaluations, (2) creating 3D models of existing sidewalks, and (3) identifying sidewalk dimensions and geometry from sidewalk images. The present framework is developed in three modules: (a) semantic segmentation module that uses Fully Convolutional Networks (FCNs) to recognize and mask sidewalks in input images, (b) 3D reconstruction module that builds a 3D point cloud of the recognized sidewalks, and (c) sidewalk dimensions module that fits a 3D surface to the reconstructed point cloud and extracts sidewalk dimensions and geometry from the 3D surface

1.5.4. Chapter 5 – Automated Assessment of the Degree of Non-Compliance of Pedestrian Facilities with Accessibility Requirements

Chapter 4 describes the development of a novel model for automating the assessment of the degree of non-compliance of pedestrian facilities with accessibility requirements. The model is developed in four main phases: (1) accessibility requirements analysis phase that identifies pedestrian facility types and their related accessibility requirements, (2) non-compliance assessment phase that quantifies the degree of non-compliance of each pedestrian facility with accessibility requirements; (3)

collective non-compliance phase that aggregates the individual non-compliance indices of a group of pedestrian facilities based on their type and/or geographical region; and (4) performance evaluation phase that analyzes a case study to illustrate the use of the developed model and demonstrate its novel capabilities.

1.5.5. Chapter 6 –Optimizing the Scheduling of Sidewalk Upgrade Projects

Chapter 6 presents the development of a novel multi-objective optimization model for scheduling pedestrian facilities upgrade projects that is capable of generating optimal trade-offs among the three main objectives of (1) minimizing the total number of interrupted/canceled pedestrian trips due to non-compliance with accessibility requirements, (2) minimizing total upgrade duration, and (3) minimizing annual upgrade budgets. The model is also designed to support decision makers in (a) quantifying the impact of upgrading non-compliant pedestrian facilities on people with disabilities, (b) generating detailed optimal schedules for upgrading non-compliant pedestrian facilities to satisfy ADA transition plan requirements, and (c) generating visualizations, illustrations, and maps to facilitate the analysis and use of the optimization results.

1.5.6. Chapter 7 – Summary and Conclusions

Chapter 7 presents the conclusions, research contributions, and recommended future research of the present study.

CHAPTER 2 - LITERATURE REVIEW

2.1. Federal Accessibility Laws, Regulations and Standards

2.1.1. Laws

The U.S. Congress has enacted a number of laws to prohibit discrimination against persons with disabilities. These laws include (1) the Architectural Barriers Act (ABA) enacted in 1968 (U.S. Congress 1968); (2) the Rehabilitation Act enacted in 1973 (U.S. Congress 1973); and (3) the Americans with Disabilities Act (ADA) enacted in 1990 (U.S. Congress 1990). The following sections provide a concise review of these three Federal laws.

2.1.1.1. Architectural Barriers Act (ABA)

The Architectural Barriers Act (ABA) was enacted by the U.S. Congress in 1968 to recognize the rights of persons with disabilities in the United States (42 U.S.C. §§4151 et seq.). The ABA requires that facilities designed, built, altered, or leased with funds supplied by the United States Federal Government be accessible to the public. The ABA appointed four Federal agencies (General Services Administration, Department of Housing and Urban Development, Department of Defense, and United States Postal Service) to be responsible for implementing the act and developing regulations related to accessibility.

2.1.1.2. Rehabilitation Act

The Rehabilitation Act was enacted by the U.S. Congress in 1973 to prohibit discrimination on the basis of disability in programs or activities receiving Federal financial assistance (29 U.S.C. § 701 et seq.). Section 504 of the Rehabilitation Act (29 U.S.C. § 794) states (in part):

> *"No otherwise qualified individual with a disability in the United States, as defined in section 705(20) of this title, shall, solely by reason of her or his disability, be excluded from the participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance or under any program or activity conducted by any Executive agency or by the United States Postal Service."*

The Rehabilitation Act guaranteed certain rights to people with disabilities, and it defined "disability" as "a physical or mental impairment, which substantially limits one or more major life activities." To be eligible for protection under Section 504 of the Rehabilitation Act, an individual must have a physical or mental impairment, a record of an impairment, or be regarded as having an impairment.

2.1.1.3. <u>Americans with Disabilities Act (ADA)</u>

The Americans with Disabilities Act (ADA) was enacted by the U.S. Congress in 1990 to prohibit discrimination based on disability (42 U.S.C. § 12101 et seq.). The ADA adopted the same definition of "disability" and the same eligibility criteria as those used under Section 504 of the Rehabilitation Act. The ADA extended the protection already given to persons with disabilities under Section 504 of the Rehabilitation Act to include all programs, services and activities provided by state and local governments regardless of Federal financial assistance. The ADA defines a "public entity" as "(a) *any State or local government; (b) any department, agency, special purpose district, or other instrumentality of a State or States or local government; and (c) the National Railroad Passenger Corporation, and any commuter authority (as defined in section 24102(4) of title 49)*" (42 U.S.C. §§ 12131(1))".

In 2008, the ADA was amended by the U.S. Congress and it was signed into law by the president and took effect in 2009. The ADA Amendment Act (ADAAA) focused on clarifying the definition of disability and was initiated when the Congress viewed that the Supreme Court narrowed the definition of disability in the ADA in a way that deprived many eligible persons with disabilities from their right to be protected by the ADA (U.S. Congress 2008). ADAAA retains the ADA's basic definition of "disability" as an impairment that substantially limits one or more major life activities, a record of such an impairment, or being regarded as having such an impairment. In addition, it clarifies and expands the definition of disability and it states that it "shall be construed in favor of broad coverage of individuals under this Act, to the maximum extent permitted by the terms of this Act." It clarifies that the Congress intended the terms to impose less demanding standards than those stated by the Supreme Court in the Toyota case (Toyota Motor Manufacturing, Kentucky, Inc. v. Williams) .

The ADA includes five titles: Title I-Employment, Title II-Public Services, Title III-Public Accommodations and Services Operated by Private Entities, Title IV-Wire or Radio Communication, and Title V-Miscellaneous Provisions. Title II of the ADA focuses on public services provided by state and local governments. It consists of two parts (Part A) "Prohibition Against Discrimination and Other Generally Applicable Provisions" which provides general rules for non-discrimination in public services, and (Part B) "Actions Applicable to Public Transportation Provided by Public Entities Considered Discriminatory" which provides rules for non-discrimination in transportation provided by public entities. Title II also defines a qualified individual with disability as:

> *"The term "qualified individual with a disability" means an individual who, with or without reasonable modifications to rules, policies, or practices, the removal of architectural, communication, or transportation barriers, or the provision of auxiliary aids and services, meets the essential eligibility requirements for the receipt of services or the participation in programs or activities provided by a public entity" (42 U.S.C. §§ 12131(2)).*

It should be noted that Title II of the ADA applies to all programs, activities, and services provided or operated by state and local governments, while Section 504 of the Rehabilitation Act applies only to programs or activities receiving Federal financial assistance. Accordingly, many state and local government operations that do not receive Federal funds are not covered by Section 504; however, they must comply with Title II of the ADA.

2.1.2. Regulations

Each of the aforementioned Federal accessibility laws assigns one or more Federal agencies the responsibility to develop regulations for implementing the law and enforcing the regulation. Federal agencies, boards, or commissions issue regulations to explain how they intend to execute the law. Federal regulations are created through a process known as rulemaking.

Federal agencies must consult the public when creating, modifying, or deleting rules in the Code of Federal Regulations (CFR). CFR is an annual publication that lists the official and complete text of Federal agency regulations. Once an agency decides that a regulation needs to be added, changed, or deleted, it typically publishes a proposed rule in the Federal Register to ask the public for comments. After the agency considers public feedback and makes changes where appropriate, it then publishes a final rule in the Federal Register with a specific date for when the rule will become effective and enforceable. When the agency issues a final rule for comment, it must describe and respond to the public comments it received.

The following sections provide a summary of the Federal regulations that were developed to enforce the implementation of the aforementioned three Federal accessibility laws

2.1.2.1. ABA Regulations

The Architectural Barriers Act of 1968 appointed four Federal agencies as standard-setting agencies: General Services Administration, Department of Housing and Urban Development, Department of Defense, and United States Postal Service. These agencies were required to enforce and implement the application of ABA in buildings and facilities under their jurisdiction. These Federal agencies implemented ABA by integrating ABA-related sections in their existing regulations; however, they did not develop specific and dedicated ABA regulations.

2.1.2.2. *<u>Section 504 of the Rehabilitation Act Regulations</u>*

Section 504 of the Rehabilitation Act applies to all programs and activities provided by entities receiving Federal financial assistance. Each Federal agency has its own set of Section 504 regulations that apply to its own programs and activities. The requirements in these regulations include reasonable accommodation for employees with disabilities, program accessibility, effective communication with people who have hearing or vision disabilities, and accessible new construction and alterations.

Each agency is responsible for enforcing its own Section 504 regulations. The following are examples of Section 504 regulations made by the U.S. Department of Education, U.S. Department of Justice, and U.S. Department of Housing and Urban Development.

In 1980, the U.S. Department of Education published its version of Section 504 regulations titled "Nondiscrimination on the Basis of Handicap in Programs or Activities Receiving Federal Financial Assistance" in the Federal register under code (34 C.F.R. § 104). These regulations include seven subparts discussing nondiscrimination in education practices. Subpart C is titled "Accessibility" and it defines prohibited discrimination as follows:

> *"No qualified handicapped person shall, because a recipient's facilities are inaccessible to or unusable by handicapped persons, be denied the benefits of, be excluded from participation in, or otherwise be subjected to discrimination under any program or activity to which this part applies" (34 C.F.R. § 104.21).*

Subpart C of the regulations discusses both existing facilities and new construction requirements to achieve compliance with Section 504. These regulations were amended in 2000 (34 C.F.R. § 104.21-104.23).

In 1982, the U.S. Department of Justice (DOJ) published another version of Section 504 regulations titled "Nondiscrimination on The Basis of Handicap in Programs and Activities Receiving Federal Financial Assistance" in the Federal register under code (7 C.F.R. §§ 15b.1 - 15b.42). These regulations were similar to those made by the U.S. Department of Education. They contain seven subparts including subpart C that covers requirements for both existing facilities and new constructions to comply with Section 504. These regulations were updated in 2003.

In 1988, the U.S. Department of Housing and Urban Development (HUD) published its own Section 504 regulations titled "Nondiscrimination Based on Handicap in Federally Assisted Programs and Activities of the Department of Housing and Urban Development" in the Federal register under code (24 C.F.R. § 8). These regulations include four subparts, where subpart C explains requirements that must be followed by all programs and activities receiving Federal financial assistance from HUD. The 1988 HUD Section 504 regulations are more detailed than the other two mentioned above. The 1988 HUD Section 504 regulations classify different types of construction separately (e.g. non-housing facilities, housing new construction, housing alteration, and historic buildings). Since 1988, HUD incorporated accessibility standards into these regulations by stating:

> *"Effective as of July 11, 1988, design, construction, or alteration of buildings in conformance with sections 3-8 of the Uniform Federal Accessibility Standards (UFAS) shall be deemed to comply with the requirements of §§8.21, 8.22, 8.23, and 8.25 with respect to those buildings" (24 C.F.R. § 8.32a).*

This statement requires all programs and activities that receive Federal financial assistance from HUD to comply with the Uniform Federal Accessibility Standards (UFAS) as part of their compliance with Section 504.

2.1.2.3. <u>ADA Regulations</u>

The ADA assigned the responsibility of developing and enforcing regulations related to Title II and Title III of the ADA to the U.S. Department of Justice (DOJ) and the U.S. Department of Transportation (DOT). These regulations require achieving access to all programs, services and activities offered by any public entity at the State and local level (e.g., school district, municipality, city, and county) as well as public accommodations and commercial facilities. The aforementioned public entities must comply with Title II regulations issued by the U.S. Department of Justice to provide access for persons with disabilities to all their programs, services and activities. This access includes physical access described in the ADA standards for accessible design and programmatic access that might be obstructed by discriminatory policies or procedures of the entity (U.S. Department of Justice 2010a).

2.1.2.3.1. *1991 ADA Regulations*

In 1991, the U.S. Department of Justice (DOJ) published ADA regulations in the Federal Register, which included two main parts. The first part was titled "Nondiscrimination on the Basis of Disability in State and Local Government Services", and it was published under code (28 C.F.R. § 35). This part was developed to regulate the application of Title II of the ADA, which focuses on the programs, services and activities offered by state and local governments. The second part was titled "Nondiscrimination on The Basis Of Disability by Public Accommodations and in Commercial Facilities", and it was published under code (28 C.F.R. § 36). The second part was developed to regulate the application of Title III of the ADA, which focuses on public accommodations and commercial facilities. It also integrated the 1991 accessibility standards into the regulations and was published in the Federal register as appendix A of the title III regulation in the Code of Federal Regulations in July 1994 (28 C.F.R. § 36 – appendix D).

The 1991 ADA Title II regulations included the six subparts: (Subpart A) General, which includes four titles explaining the purpose, applications, relationship with other laws, and definitions of Title II; (Subpart B) General Requirements, which includes 13 titles, and sets forth the general principles of nondiscrimination applicable to all entities subject to Title II; (Subpart C) Specific Requirements, which includes 10 titles that provide guidance on the application of the statute to specific situations; (Subpart D) New Construction and Alterations, which includes seven titles including guidance on the application of Title II to both new construction and alterations; (Subpart E)

Enforcement, which includes 8 titles that cover enforcement procedures and authorities related to Title II; and (Subpart F) Certification of State Laws or Local Building Codes. In addition, the 1991 ADA Title II regulations included two appendices: (Appendix A) Standards for Accessible Design, which includes a copy of the "ADA Accessibility Guidelines for Buildings and Facilities" that was published by the Access Board in 1991; and (Appendix B) Preamble to Regulation on Nondiscrimination on the Basis of Disability by Public Accommodations and in Commercial Facilities.

2.1.2.3.2. <u>2010 ADA Title II Regulations</u>

In 2010, the U.S. Department of Justice (DOJ) finalized and published the latest and current set of Title II ADA regulations, as shown in Figure 3. These regulations took effect on March 15, 2011, and were published in the 2011 edition of the Code of Federal Regulations (CFR) under the same code of the 1991 regulations (28 C.F.R. § 35) for Title II regulations and under code (28 C.F.R. § 36) for Title III regulations. The 2010 version of the regulations also maintained the same titles as the 1991 version.

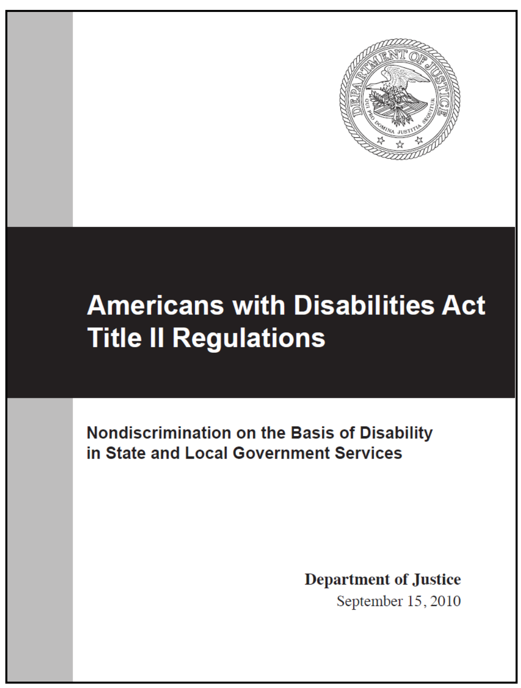


Figure 3: Cover page of the Americans with Disabilities Act Title II regulations (U.S. Department of Justice 2010a)

The 2010 ADA Title II regulations (28 C.F.R. § 35) includes seven subparts: (Subpart A) General, which includes eight titles explaining the purpose, applications, relationship with other laws, self-evaluation, and definitions of Title II; (Subpart B) General Requirements, which includes ten titles and it sets forth the general principles of nondiscrimination applicable to all entities subject to Title II; (Subpart C) Employment, which includes two titles that cover discrimination in employment; (Subpart D) Program Accessibility, which includes five titles that provide guidance on the application of Title II in new construction, alterations, and detention facilities; (Subpart E) Communications, which includes 6 titles that cover providing equal opportunity of communications for persons with disabilities; (Subpart F) Compliance Procedures, which includes ten titles that cover the enforcement and grievance procedures for Title II; and (Subpart G) Designated Agencies, which cover the responsibilities of Federal agencies appointed by law to enforce Title II. Additionally, the 2010 ADA Title II regulations includes two appendices: (Appendix A) 2010 Guidance and Section-by-Section Analysis, which provides guidance on the 2010 regulations; and (Appendix B) 1991 Preamble and Section-by-Section Analysis, which provides guidance on the provisions of the 1991 regulations. The 2010 Title II regulations included the following new definitions for its adopted standards and guidelines:

- The term “1991 Standards” refers to the ADA standards for Accessible Design, originally published in 1991, and republished as Appendix D to part 36.

- The term “2004 ADAAG” refers to ADA Chapter 1, ADA Chapter 2, and Chapters 3 through 10 of the Americans with Disabilities Act and Architectural Barriers Act Accessibility Guidelines, which were issued by the Access Board in 2004, and published into the Code of Federal Regulations in 2009 (36 CFR § 1191, app. B and D).

- The term “2010 Standards” refers to the 2010 ADA Standards for Accessible Design, which consists of the 2004 ADAAG and the requirements contained in § 35.151.

Furthermore, the 2010 Title II regulations included several sections that address sidewalks and pedestrian facilities and highlight the responsibility of State and local governments to provide curb ramps or sloped areas in any newly constructed or altered streets, roads and highways. For example, Subpart D of this regulation states (in part) that:

> *"(1) Newly constructed or altered streets, roads, and highways must contain curb ramps or other sloped areas at any intersection having curbs or other barriers to entry from a street level pedestrian walkway.*
>
> *(2) Newly constructed or altered street level pedestrian walkways must contain curb ramps or other sloped areas at intersections to streets, roads, or highways." (28 C.F.R. § 35.151(i)(1), 28 C.F.R. § 35.151(i)(2)).*

The 2010 Title II regulations require compliance with the 2010 ADA standards. These standards are published as two Appendices in Title III regulations: (1) Appendix B that includes analysis and commentary on the 2010 ADA Standards for Accessible Design; and (2) Appendix D that includes the original accessibility standards that were published in Appendix A in the 1991 Title III regulations (28 C.F.R. § 36 Appendix (B) and (D)).

2.1.2.3.3. *Guidance on the Definition of Road Alteration in ADA Regulations*

In 2013, the U.S. Department of Justice and the U.S. Department of Transportation collaborated in developing a technical assistance to help clarify the scope and definition of alteration in Title II of the ADA. This joint technical assistance was initiated as a response to a court case that was decided in 1993 in the third circuit (9 F 3d 1067) to provide further guidance on the scope of the alterations requirement with respect to the provision of curb ramps when streets, roads or highways are being resurfaced, and to clarify whether particular road surface treatments fall within the ADA definition of alterations or maintenance which would not trigger the obligation to provide curb ramps.

In this joined technical assistance, the Department of Justice and the Federal Highway Administration (FHWA) defined the conditions in which a resurfacing project would be considered alteration that would trigger the ADA requirements for providing curb ramps and sloped areas as:

> *"Resurfacing is an alteration that triggers the requirement to add curb ramps if it involves work on a street or roadway spanning from one intersection to another, and includes overlays of additional material to the road surface, with or without milling"* (DOJ/DOT 2013)

2.1.3. Standards

Accessibility standards establish design requirements for the construction and alteration of facilities to ensure access for persons with disabilities. These enforceable standards apply to any facility that falls under the jurisdiction of accessibility laws including places of public accommodation, commercial facilities, and state and local government facilities.

Laws appoint certain Federal agencies as standard-setting agencies and give them the authority to develop regulations and adopt standards that are essential for enforcing the law. To cover the technical side of regulations, the standard-setting Federal agencies either develop technical design standards or request other governmental entities to develop them. Standards are developed through a detailed rulemaking process that can be divided into two main phases: (a) guidelines development, and (b) standards adoption. The first phase focuses on developing design guidelines in order to provide guidance to architects, engineers and contractors to help them understand the requirements of the law and its impact on their design and construction. These guidelines are typically developed using a detailed process that involves conducting research, experiments, review of practices, and analysis of comments and suggestions from the public. The second phase focuses on transforming the developed guidelines to enforceable standards. This is typically performed by one of the standard-setting Federal agencies (e.g. Department of Justice) that adopts the developed guidelines after any required modifications as Federal standards. These Federal standards are then integrated or referenced in the Federal accessibility regulations as Appendices such as the aforementioned 2004 ADAAG (36 CFR §

1190 and 1191). Once adopted as part of the Federal regulations, these standards act as enforceable minimum design requirements. The following sections provide a concise review of the main Federal accessibility standards.

2.1.3.1. ABA Standards

In 1968, The Architectural Barriers Act (ABA) appointed four Federal agencies to be responsible for developing regulations and standards related to accessibility and enforcing these regulations. Following the approval of ABA by the U.S. Congress, efforts were made by the four standard-setting Federal agencies (General Services Administration, Departments of Housing and Urban Development, Department of Defense, and United States Postal Service) to develop regulations and standards for the ABA. These efforts were separate, and each agency developed its own standards.

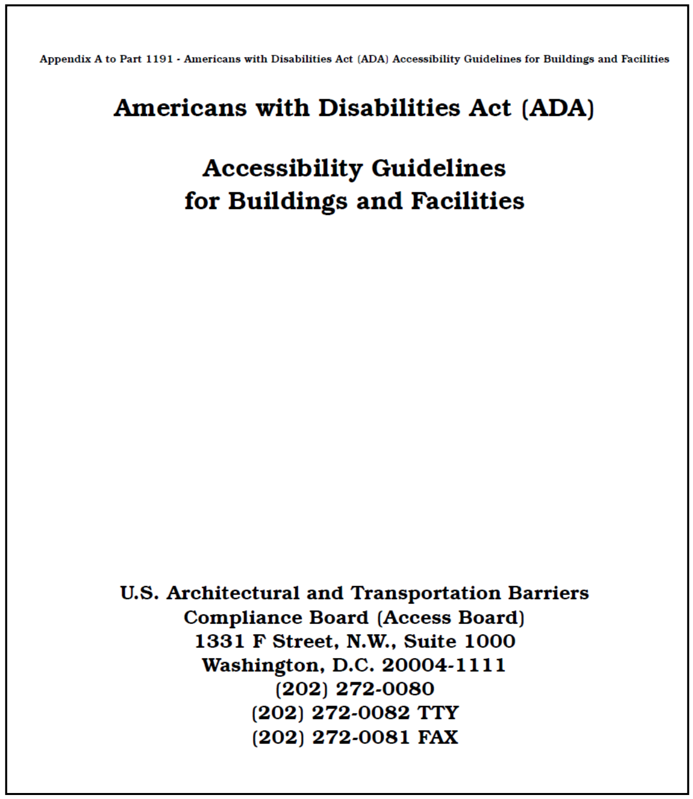
The original standards (A117.1) developed by the American National Standards Institute (ANSI) in 1961, acted as the technical base for accessibility standards adopted by the Federal government and most states. ANSI is a private non-profit organization that oversees the development of voluntary consensus standards for products, services, processes, systems, and personnel in the United States (ANSI, 2014). ANSI also coordinates U.S. standards with international standards so that American products can be used worldwide. (A117.1) standards were modified in 1986 and in 2003. The current version of the standards was published in 2009 under the title “Accessible and Usable Buildings and Facilities” (ANSI 2009).

2.1.3.2. Uniform Federal Accessibility Standards (UFAS)

In 1984, the Uniform Federal Accessibility Standards (UFAS) were published in the Federal Register. The UFAS are the result of a joined effort by the four standard-setting Federal agencies appointed by the ABA to develop a master standards that would avoid any contradiction between the different standards prepared by each agency separately. The UFAS focused on minimizing the differences between the standards previously used by these four agencies. The UFAS was first published in the Federal Register on August 7, 1984 under code (49 FR 31528). Later, each of the four standard-setting agencies took actions in accordance with its own procedures to incorporate the UFAS in its own standards, regulations, or other directives, as the UFAS by itself were not enforceable standards. For example, the GSA adopted the UFAS in its regulations (41 C.F.R. § 101-19.6), effective August 7, 1984; and HUD adopted the UFAS in its regulations (24 C.F.R. § 40), effective October 4, 1984. The UFAS is still in effect to date in many agencies under the ABA and other laws.

2.1.3.3. 1991 ADA Accessibility Standards

The 1991 ADA Accessibility Standards were published in the Federal Register under the code (36 C.F.R. § 1191 Appendix A) with the title of "Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities (ADAAG)", as shown in Figure 4. These standards were adopted based the accessibility guidelines that were developed by the U.S. Access Board that was established by Section 502 of the Rehabilitation Act (29 U.S.C. § 792) in 1973. The Access Board consists of 13 members appointed by the President from the public, a majority of which is individuals with disabilities, and the heads of 12 federal agencies or their designees. The federal agencies are: The Departments of Commerce, Defense, Education, Health and Human Services, Housing and Urban Development, Interior, Justice, Labor, Transportation, and Veterans Affairs; General Services Administration; and United States Postal Service (76 FR 75844).



Appendix A to Part 1191 - Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities

Americans with Disabilities Act (ADA)

Accessibility Guidelines
for Buildings and Facilities

U.S. Architectural and Transportation Barriers
Compliance Board (Access Board)
1331 F Street, N.W., Suite 1000
Washington, D.C. 20004-1111
(202) 272-0080
(202) 272-0082 TTY
(202) 272-0081 FAX

Figure 4: Cover page of 1991 Accessibility Guidelines that were adopted as standards in 1994 (USAB 1991)

The Access Board is responsible for developing and updating accessibility guidelines for the design, construction, and alteration of facilities to ensure that they are readily accessible to and usable by individuals with disabilities. These guidelines are used by the Department of Justice (DOJ) and the Department of Transportation (DOT) in setting enforceable standards that the public must follow. The Access Board's guidelines play an important role in the implementation of three laws that require newly constructed and altered facilities to be accessible to individuals with disabilities: the Americans with Disabilities Act, Section 504 of the Rehabilitation Act, and the Architectural Barriers Act. These laws require other Federal agencies to issue regulations, which include accessibility standards for the design, construction, and alteration of facilities. The regulations issued by other Federal agencies to implement these laws typically adopt the U.S. Access Board's guidelines as accessibility standards. When the Access Board's guidelines are adopted, with or without additions and modifications, as accessibility standards in regulations issued by other Federal agencies implementing these laws, compliance with the accessibility standards is mandatory (76 FR 75844).

It should be noted that the 1991 ADA Accessibility Standards (36 C.F.R. § 1191 Appendix A) did not provide specific requirements for the sidewalks and pedestrian facilities. Instead, the design requirements for sidewalks and pedestrian facilities were addressed in different chapters of the standards. For example, passenger-loading zones, curb ramps, and detectable warning surfaces were mentioned in chapter 4 as items number 4.6, 4.7, and 4.29 respectively. Chapter 15 was titled recreational facilities, and it included guidance on items related to public rights-of-way. Chapter 14 was titled public rights-of-way but it was removed from these standards. The 1991 ADA Accessibility Standards were effective until March 14, 2012 until they were replaced by the 2010 ADA standards.

2.1.3.4. *2010 ADA Standards*

The Department of Justice published the 2010 ADA Standards for Accessible Design on September 15 2010 (see Figure 5) as part of its 2010 ADA regulations. The 2010 ADA Standards were adopted by the Department of Justice based on the "Americans with Disabilities Act Accessibility Guidelines (ADAAG) for Buildings and Facilities" that were developed six years earlier by the U.S. Access Board in 2004. The 2010 ADA standards for Accessible Design consist of two parts. The first part is titled "New Construction and Alterations" and was published as part of the 2010 ADA regulations under code (28 C.F.R. § 35.151); and the second part is the 2004 ADAAG and was published under code (36 C.F.R. § 1191 Appendices B and D).

The first part of the 2010 ADA Standards for "new construction and alterations" included eleven sections: (a) design and construction that requires all facilities built by or on behalf of any entity covered by the ADA to be accessible except in cases when its impractical to achieve accessibility, (b) alterations that covers alterations to historic properties, path of travel, and primary function, (c) accessibility standards and compliance date, (d) scope of coverage, (e) social service center establishments, (f) housing at a place of education, (g) assembly areas, (h) medical care facilities, (i) curb ramps, (j) facilities with residential dwelling units for sale to individual owners, and (k) detention and correctional facilities.

The second part of the 2010 ADA Standards is the 2004 Americans with Disabilities Act Accessibility Guidelines (ADAAG) that were developed by the U.S. Access Board in 2004. The 2004 ADAAG is commonly known as the ADA Accessibility Guidelines (ADAAG 2004). The 2004 ADAAG consists of ten chapters that are titled: (1) application and administration, (2) scoping requirements, (3) building blocks, (4) accessible routes, (5) general site and building elements, (6) plumbing elements and facilities, (7) communication elements, (8) special rooms, spaces, and elements, (9) built-in elements, and (10) recreational facilities. The accessibility requirements for sidewalks and pedestrian facilities in the 2004 ADAAG were distributed over several chapters including chapters 4, 5, and 10. These 2004 ADA accessibility guidelines (ADAAG) are still the latest and most current accessibility guidelines to date.

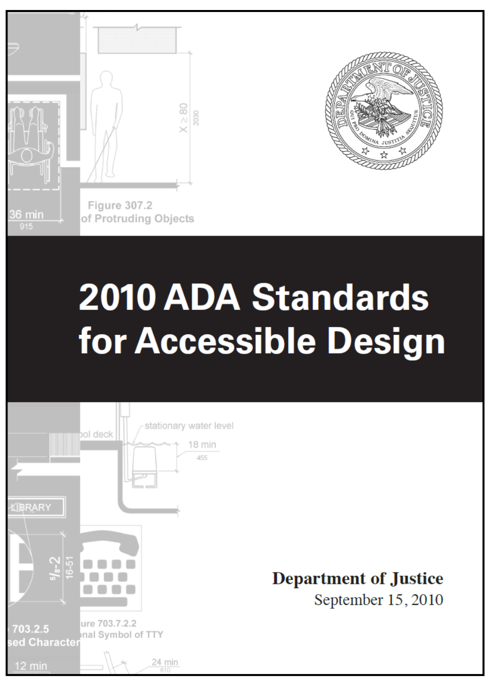


Figure 5: Cover page of the 2010 ADA Standards for Accessible Design (U.S. Department of Justice 2010b)

The current ADA standards that are adopted and enforced by the Departments of Justice and Transportation are based on the aforementioned 2004 ADAAG. Although these two current standards of the Departments of Justice and Transportation are very similar, each of them contains additional requirements that address the specific facilities covered by the two departments. These additional requirements define the types of facilities covered, set effective dates, and provide additional scoping or technical requirements for those facilities.

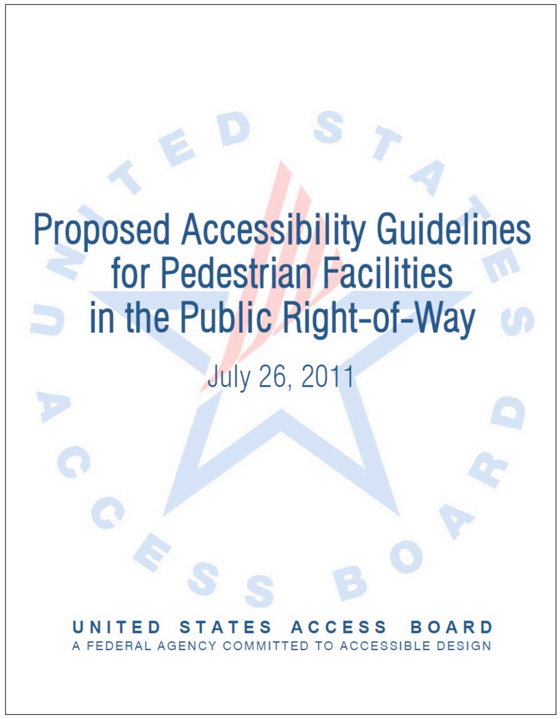
The Department of Justice stated in its 2010 ADA regulations that all state and local government facilities projects of new construction or alteration starting on or after March 15, 2012 must comply with the 2010 Standards. For projects starting before that date, they need to comply with (a) the aforementioned 1991 Standards or the UFAS; or (b) the 2010 Standards if the project start date is after September 15, 2010, as shown in Table 1.

Table 1: ADA Standards Validity Periods Under Title II of the ADA (28 C.F.R. § 35).

Project Start Date	July 26, 1991 to September 14, 2010	September 15, 2010 to March 14, 2012	On or after March 15, 2012
UFAS	Effective	Effective	Not effective
1991 Standards	Effective	Effective	Not effective
2010 Standards	-	Effective	Effective

2.1.4. Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG)

As stated earlier, the process of developing accessibility standards usually starts with the U.S. Access Board developing Guidelines that are later adopted by one of the standard-setting Federal agencies to become enforceable standards. For example, the aforementioned 2004 ADAAG later became part of the 2010 ADA Standards after it was adopted by the U.S. DOJ in its 2010 update of Title II and Title III regulations. Similarly, the U.S. Access Board developed in 2011 "Proposed Accessibility Guidelines for Pedestrian Facilities in The Public Right-of-Way" (see Figure 6). To improve clarity, these 2011 proposed guidelines will be referred to as "PROWAG" in this report. The 2011 proposed guidelines (PROWAG) are currently undergoing the final stages of their rulemaking process before they can be published as design guidelines.


Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way

July 26, 2011

UNITED STATES ACCESS BOARD

A FEDERAL AGENCY COMMITTED TO ACCESSIBLE DESIGN

Figure 6: Cover page of Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG) (USAB 2011)

As soon as these proposed accessibility guidelines (PROWAG) are finalized and published, they will address various sidewalks and pedestrian facilities accessibility requirements, including access for blind pedestrians at street crossings, wheelchair access to on-street parking, and various constraints posed by space limitations, roadway design practices, slope, and terrain. These new guidelines will cover pedestrian access to sidewalks and streets, including crosswalks, curb ramps, street furnishings, pedestrian signals, parking, and other components of sidewalks and pedestrian facilities. The aim of these guidelines is to ensure that access for persons with disabilities is provided wherever a pedestrian way is newly built or altered, and that the same degree of convenience, connection, and safety available to the public generally is available to pedestrians with disabilities.

Once these guidelines are adopted by the Department of Justice, they will become enforceable standards under Title II of the ADA.

These proposed guidelines address access to both newly constructed and altered public streets and sidewalks covered by the American with Disabilities Act (ADA) and the Architectural Barriers Act (ABA) or the Rehabilitation Act, in the case of federally funded projects. In case of alteration projects, these requirements apply only to public right-of way elements (e.g. curb ramps and sidewalks) that are included in the original project scope (76 FR 44664). The Access Board's ADA and ABA Accessibility Guidelines (ADAAG) address access to buildings and facilities located on sites. Standards based on the ADAAG apply within the boundary of covered sites as defined by public right-of-way and property lines. The new proposed guidelines mainly pick up where the ADAAG leaves off, to cover accessibility requirements in the context of sidewalks and pedestrian facilities outdoor environment (76 FR 44664).

To ensure consistency and to avoid redundancy, the 2011 proposed guidelines refer to other requirements in (a) the ADA/ABA guidelines for specific elements such as escalators and toilet facilities, and (b) the FHWA Manual on Uniform Traffic Control Devices (MUTCD 2009) for streets and highways. The 2011 proposed guidelines cover new or altered sidewalks and pedestrian facilities, including sidewalks and other pedestrian ways, street crossings, medians and traffic islands, overpasses, underpasses and bridges. They also cover on-street parking, transit stops, toilet facilities, signs, and street furniture. The guidelines apply to permanent as well as temporary facilities, such as temporary routes around work zones and portable toilets. The proposed guidelines consist of four chapters entitled: (1) application and administration, (2) scoping requirements, (3) technical requirements, and (4) supplementary technical requirements. A brief description of each of these four chapters is presented in Table 2 through Table 5.

Table 2: The First Chapter of PROWAG (76 FR 44664 - R1)

Chapter 1: Application and Administration	
Section	Description
Section-1: *Purpose*	Explains the goal of the document to ensure that facilities for pedestrian circulation and use located in the public right-of-way are readily accessible to and usable by pedestrians with disabilities, and also states that these guidelines do not address existing facilities unless the facilities are included within the scope of an alteration undertaken by an entity covered by title II of the ADA
Section-2: *Equivalent Facilitation*	Permits the use of alternative measures and technologies if they will result in equivalent or greater accessibility than the requirements of the guidelines
Section-3: *Convention*	Explains the use of different conventions, tolerances and units of measurement throughout the guidelines
Section-4: *Referenced Standards*	Defines all referenced standards that were used throughout the guidelines
Section-5: *Definitions*	Defines all legal and technical terms used in these guidelines

Table 3: The Second Chapter of PROWAG (76 FR 44664 – R2)

Chapter 2: Scoping Requirements	
Section-1: *Application*	States that all newly constructed facilities, altered portions of existing facilities, and elements added to existing facilities as well as temporary and permanent facilities for pedestrian circulation and use located in the public right-of-way shall comply with the requirements in the guidelines
Section-2: *Alterations and Elements Added to Existing Facilities*	Covers addition and alteration of elements and prohibits any alterations or additions that could result in reduction of accessibility
Section-3: *Machinery Spaces*	Excludes machinery spaces from the accessibility requirements mentioned in these guidelines, only if the spaces are solely for the purpose of machinery and maintenance
Section-4: *Pedestrian Access Routes*	Covers pedestrian access routes and their elements such as sidewalks, street crossings, overpasses and underpasses
Section-5: *Alternate Pedestrian Access Routes*	Expands the requirements of pedestrian access routes to any temporary paths, stating that all temporary pedestrian routes should be accessible
Section-6: *Pedestrian Street Crossings*	Requires pedestrian street crossings to comply with requirements in the third chapter
Section-7: *Curb Ramps*	Requires curb ramps and blended transitions to comply with requirements in the third chapter
Section-8: *Detectable Warning Surfaces*	Requires that detectable warning surfaces be provided at all intersections between pedestrian path and any street or rail
Section-9: *Accessible Pedestrian Signals and Pushbuttons*	Refers to the requirements in the MUTCD, and also requires that all existing signals and pushbuttons comply with these guidelines whenever altered or modified
Section-10: *Protruding Objects*	Requires that any elements or objects along or overhanging any portion of the pedestrian path shall not reduce its width
Section-11: *Signs*	Covers pedestrian signs, transit signs, and accessible parking space and passenger loading zone signs

Table 3 cont.

Chapter 2: Scoping Requirements	
Section-12: *Street Furniture*	Provides scoping requirements for drinking fountains, public toilets, tables, counters, and benches
Section-13: *Transit Stops and Shelters*	requires transit stops and transit shelters to comply with requirements in the third chapter
Section-14: *On-Street Parking Spaces*	Covers the number of accessible parking spaces required in any public parking lot, as shown in Figure 7
Section-15: *Passenger Loading Zones*	Requires that at least one accessible passenger loading zone be provided each 100ft whenever needed
Section-16: *Stairways and Escalators*	Requires that stairways and escalators comply with these requirements if they are on an accessible path, and also prohibits including them as part of the accessible route
Section-17: *Handrails*	Requires handrails to comply with requirements in the third chapter
Section-18: *Doors, Doorways, and Gates*	Requires compliance with requirements for doors, doorways, and gates in the third chapter

Public Rights-of-Way Accessibility Guidelines

R214 On-Street Parking Spaces. Where on-street parking is provided on the block perimeter and the parking is marked or metered, accessible parking spaces complying with R309 shall be provided in accordance with Table R214. Where parking pay stations are provided and the parking is not marked, each 6.1 m (20.0 ft) of block perimeter where parking is permitted shall be counted as one parking space.

Table R214 On-Street Parking Spaces

Total Number of Marked or Metered Parking Spaces on the Block Perimeter	Minimum Required Number of Accessible Parking Spaces
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4
101 to 150	5
151 to 200	6
201 and over	4 percent of total

Advisory R214 On-Street Parking Spaces. The MUTCD contains provisions for marking on-street parking spaces (see section 3B.19). Metered parking includes parking metered by parking pay stations. Where parking on part of the block perimeter is altered, the minimum number of accessible parking spaces required is based on the total number of marked or metered parking spaces on the block perimeter.

Figure 7: Sample requirements for on-street parking spaces (USAB 2011)

Table 4: The Third Chapter of PROWAG (76 FR 44664 – R3)

Chapter 3: Technical Requirements	
Section-1: *General*	states that the technical requirements in this chapter shall apply where required by chapter 2
Section-2: *Pedestrian Access Routes*	Covers technical accessibility requirements for the pedestrian access routes such as continuous width, passing space, grade, cross-slope, and surface, as shown in Figure 8
Section-3: *Alternate Pedestrian Access Routes*	Expands the requirements of pedestrian access routes to any temporary paths, stating that all temporary pedestrian routes should be accessible
Section-4: *Curb Ramps and Blended Transitions*	Provides technical accessibility requirements for perpendicular curb ramps, parallel curb ramps, and blended transitions including turning spaces, running slope, cross slope, flared sides, width, and grade break
Section-5: *Detectable Warning Surfaces*	Provides technical requirements about dome size, dome spacing, color contrast, size, and placement
Section-6: *Pedestrian Street Crossings*	Includes requirements for pedestrian signal phase timing, roundabouts, channelized turn lanes at roundabouts, and channelized turn lanes at other intersections
Section-7: *Accessible Pedestrian Signals*	Refers to section 9 in the second chapter
Section-8: *Transit Stops and Transit Shelters*	Includes requirements for boarding and alighting areas, boarding platforms, surfaces, connections, slope, cross slope, and coordination between platform and vehicle floor
Section-9: *On-Street Parking Spaces*	Includes requirements for parallel parking spaces, perpendicular parking spaces, angled parking spaces, sidewalk width, curb ramps, and parking meters, as shown in Figure 9
Section-10: *Passenger Loading Zones*	Includes requirements for vehicle pull-up space and access aisle dimensions

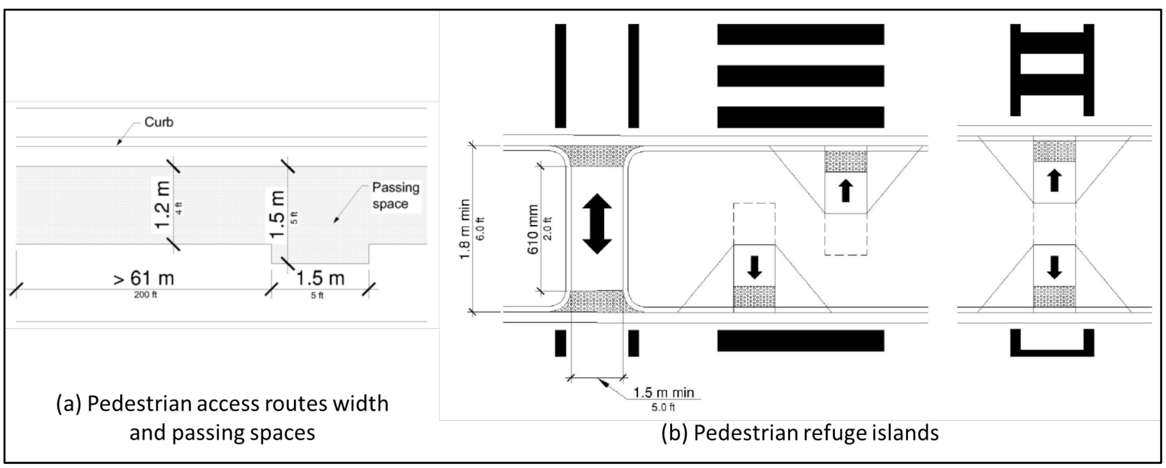


Figure 8: Example accessibility guidelines for pedestrian access routes (USAB 2011).

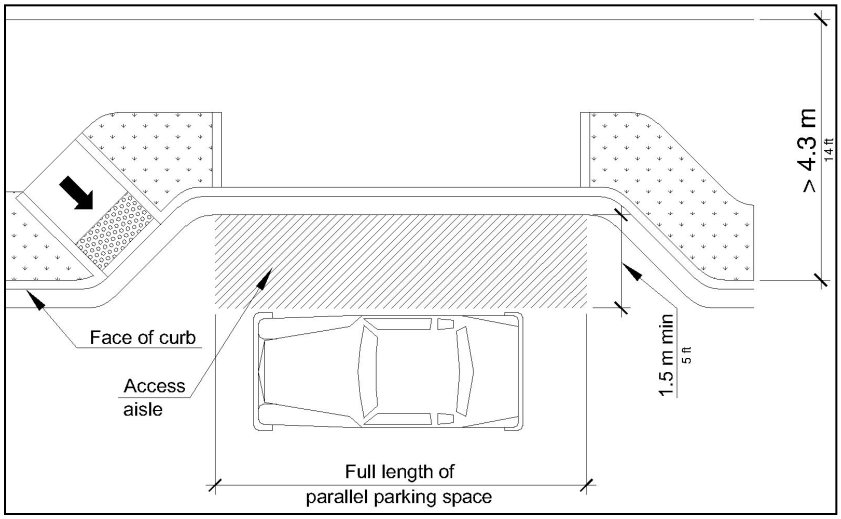


Figure 9: On-street parking space dimensions (USAB 2011).

Table 5: The Fourth Chapter of PROWAG (76 FR 44664 – R4)

Chapter 4: Supplementary Technical Requirements	
Section-1: *General*	States that the technical requirements in this chapter shall apply where required by chapter 2
Section-2: *Protruding Objects*	Includes requirements on protrusion limits, post-mounted objects, and vertical clearances
Section-3: *Operable Parts*	Includes requirements for clear space, height, and operations
Section-4: *Clear Spaces*	Includes requirements for surface, size, knee and toe clearance, position, approach, and maneuvering space
Section-5: *Knee and Toe Clearance*	Covers the required clearances and dimensions to accommodate persons on wheel chairs
Section-6: *Reach Ranges*	Includes dimensions and illustrations of reachable space around persons with mobility devices
Section-7: *Ramps*	Lists the requirements of accessible ramps such as running slope, cross slope, landings, width, rise, change in direction, surfaces, handrails, and edge protection, as shown in Figure 10
Section-8: *Stairways*	Covers requirements for treads and risers, open risers, tread surface, nosing, and handrails
Section-9: *Handrails*	Includes requirements for continuity, height, gripping surface, clearance, and cross section
Section-10: *Visual Characters on Signs*	Includes requirements for finishing contrast, case, style, character proportions, character height, character spacing, and line spacing
Section-11: *International Symbol of Accessibility*	Includes a figure of the international symbol of accessibility

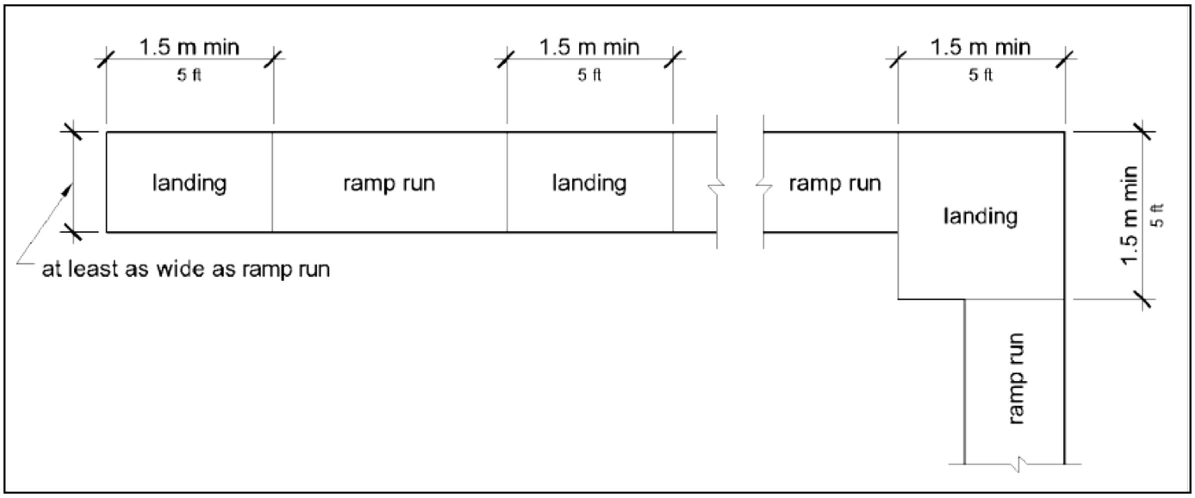


Figure 10: Example requirements for ramp and landing dimensions (USAB 2011).

Although the aforementioned 2011 proposed accessibility guidelines for pedestrian facilities in the public right-of-way (PROWAG) have not become enforceable standards by law, they are expected to be finalized as guidelines and then adopted as enforceable standards in the near future.

2.2. Illinois Accessibility Laws and Codes

States have their own set of laws and codes that are applicable within the jurisdiction of the state. These state laws and codes along with the federal laws and regulations are enforceable within each state. State and local government facilities in the state of Illinois must comply with federal accessibility laws and regulations in addition to any effective Illinois laws and codes. The following section provides a concise review of accessibility laws and codes in the State of Illinois.

2.2.1. Illinois Environmental Barriers Act (EBA)

In 1985, the state of Illinois enacted its own accessibility rights law titled "Illinois Environmental Barriers Act (EBA)", and it was published under the code (410 ILCS 25/1 et seq.). Illinois EBA is the statute that governs physical access for people with disabilities in new construction, additions and alterations to public facilities within the state of Illinois. The Illinois Accessibility Code (see Figure 11) contains the design standards required by the Illinois EBA such as the required width of a door and the number of accessible parking spaces that must be provided.

Within the state of Illinois, state and local governments must comply with all accessibility laws and regulations including (1) the aforementioned Federal laws of the ADA, the Rehabilitation Act and the ABA; and (2) State of Illinois laws such as the Illinois EBA. The ADA states that all entities subjected to Title II and Title III shall comply with ADA regulations and standards only if these regulations and standards provide equal or greater accessibility than state and local laws and regulations. Accordingly, any newly constructed or altered public facility in the state of Illinois must comply with the strictest available Federal and state laws and regulations (28 C.F.R. § 35.103).

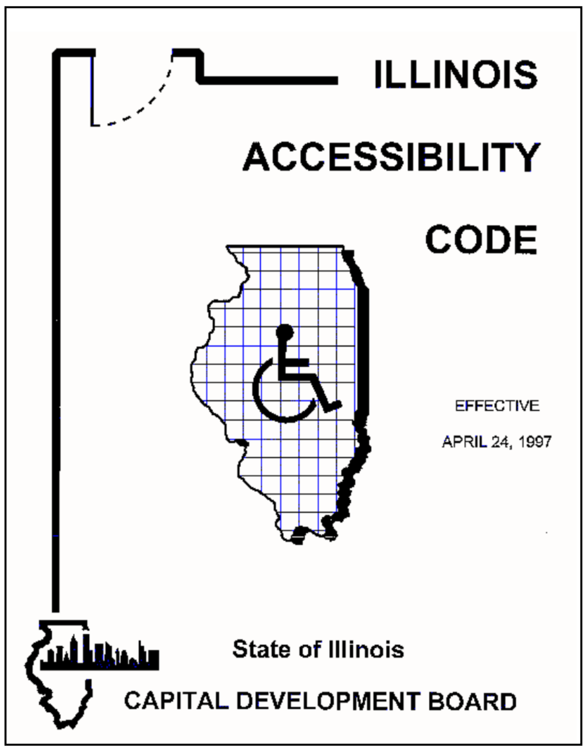


Figure 11: Cover Page of the Illinois Accessibility Code (CDB 1997)

2.2.2. Illinois Accessibility Code (IAC)

The Illinois Accessibility Code (IAC) was developed and published by the State of Illinois Capital Development Board in 1997, as shown in Figure 11. It includes a set of rules that were adopted by the Capital Development Board to implement the Illinois Environmental Barriers Act (EBA). The Code includes design requirements for buildings, including all spaces and elements within the buildings. The purpose of the Code is to ensure that these buildings are designed, constructed, and/or altered to be readily accessible and usable by persons with disabilities. The IAC has the force of a building code and is law in the State of Illinois. The IAC constitutes minimum requirements for all governmental units in Illinois. It also allows governmental units to adopt stricter requirements to increase access for persons with disabilities (CDB 1997).

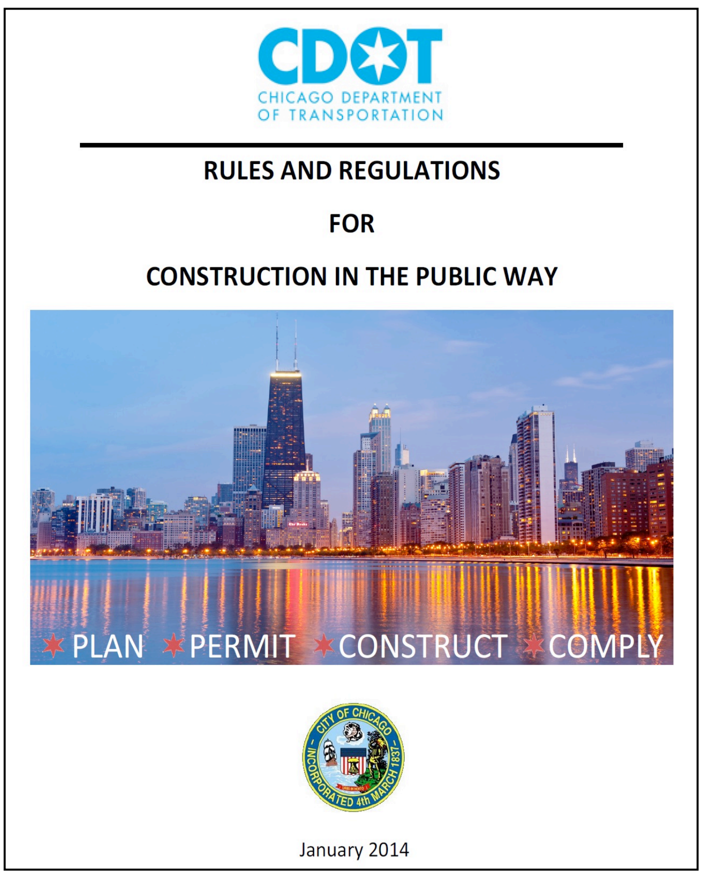
The Illinois Accessibility Code (IAC) focused on resolving areas of difference between the aforementioned ADAAG 2004 and the former Illinois accessibility standards, applicable to buildings and facilities in the State of Illinois covered by the Illinois EBA. The IAC adopted the stricter of the former State and Federal accessible design standards (CDB 1997). Any building covered by the Illinois EBA must satisfy the IAC requirements, even if the building is also financed by Federal funds or covered by the ADA. The Illinois EBA requires a Statement of Compliance by the architect/engineer unless the cost of construction or alteration is less than $50,000. The Statement must certify that the plans and specifications for the building comply with the Illinois EBA.

The IAC includes sections that cover accessibility requirements for new construction, addition and alteration of public facilities in Illinois, and multistory housing and historic preservation. Although the focus of IAC is on buildings and facilities, it includes sections that contain sidewalks and pedestrian facilities accessibility requirements for (1) accessible routes, (2) curb ramps, (3) detectable warnings, (4) parking and passenger loading zones, (5) protruding objects, and (6) temporary buildings and facilities. Compliance with both these IAC sections and the aforementioned 2010 ADA regulations is mandatory for any sidewalks and pedestrian facilities work in the state of Illinois (CBD 1997).

2.2.3. Rules and Regulations for the City of Chicago

In 2014, The City of Chicago published its own set of rules and regulations for construction in the public way, as shown in Figure 12. The main purpose of these regulations were to *"provide utility companies (both public and private), contractors, and developers with a tool that will assist in* *minimizing conflicts that occur between construction in the Public Way and the vital uses the Public Way provides"* (CDOT 2014).

The Chicago rules and regulations cover construction in the public way within the jurisdiction of the City of Chicago. They include four chapters that cover requirements for the coordination, permitting, executing, and compliance of work in the public way. The rules and regulations also include Appendix B that provide ADA standards for openings, construction and repair in the public way. The Appendix includes four sections that provide (1) twenty-one plan sheets, as shown in the sample sheet in Figure 13; (2) five alley and driveway sheets; (3) five notes sheets; and (4) three details sheets (CDOT 2014).


CDOT
CHICAGO DEPARTMENT
OF TRANSPORTATION

RULES AND REGULATIONS

FOR

CONSTRUCTION IN THE PUBLIC WAY

PLAN PERMIT CONSTRUCT COMPLY

CITY OF CHICAGO
INCORPORATED 4th MARCH 1837

January 2014

Figure 12: Rules and Regulations for Construction in the Public Way (CDOT 2014)

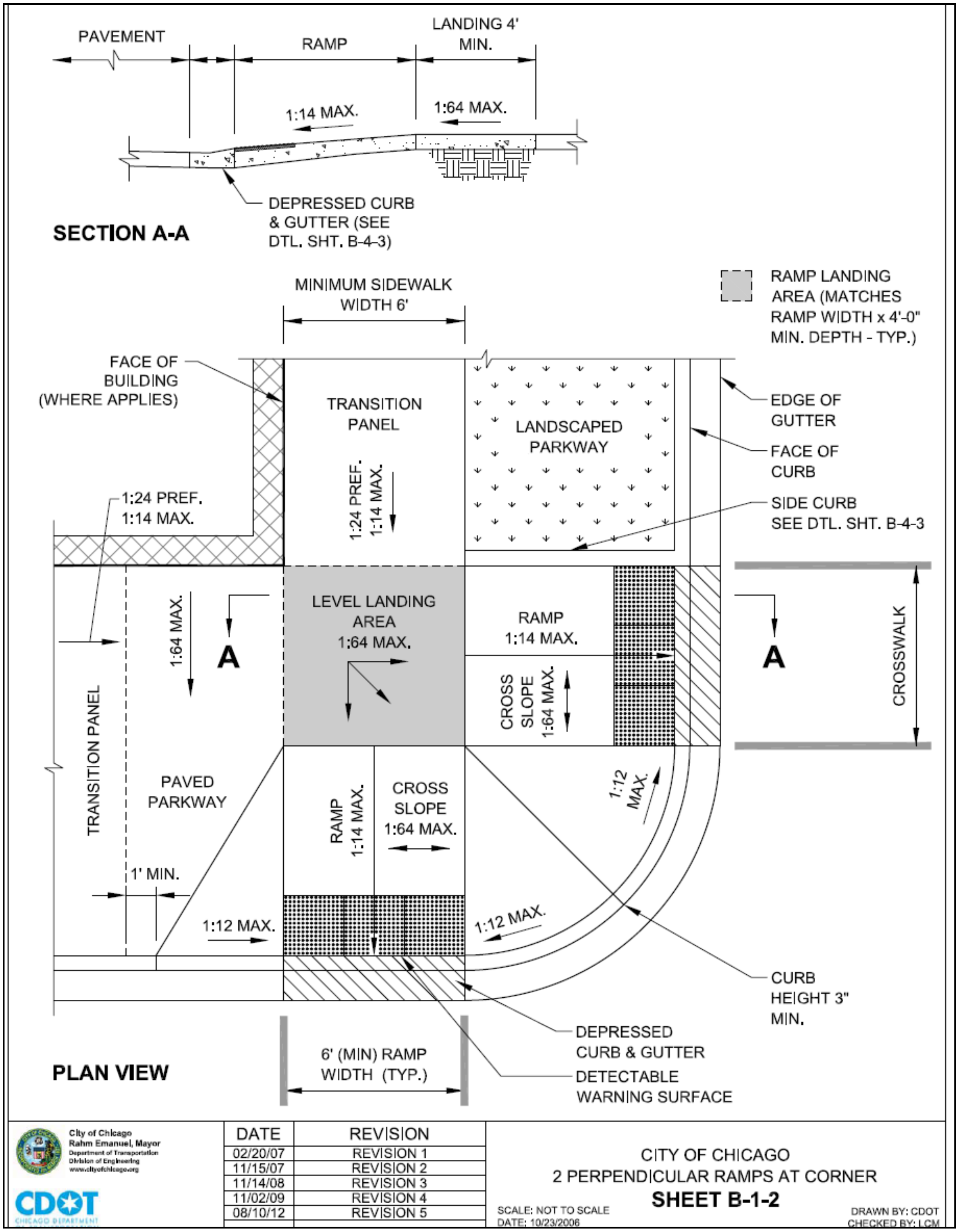


Figure 13: Sample plan sheet (CDOT 2014)

2.3. Best Practices

Many Federal and State government agencies developed best practices to provide guidance for officials in public entities to ensure their compliance with the aforementioned accessibility laws and regulations. These Federal and State best practices include manuals and design guides that are summarized in the following two sections.

2.3.1. Federal Manuals and Design Guides

Many federal agencies developed manuals and design guides to provide best practices that can be used to comply with accessibility laws and regulations. These Federal best practices include (1) planning and designing for alterations in the public rights-of way; (2) best practices design guide for designing sidewalks and trails for access; (3) ADA best practices tool kit for state and local governments; (4) guide to best practices for accessible pedestrian signals; (5) ADA Title II technical assistance manual; (6) several guides provided by the Department of Justice; (7) review of existing guidelines and practices for designing sidewalks and trails for access; and (8) review of practices for ADA compliance at transportation agencies.

2.3.1.1. Accessible Public Rights-of-Way: Planning and Designing for Alterations

In 2007, the public rights-of-way access advisory committee (PROWAAC) published a report titled "Accessible Public Rights-of-Way: Planning and Designing for Alterations", as shown in Figure 14. This design guide provides guidance and recommendations to achieve accessibility in alteration projects within the public rights-of-way. The guide was based on the recommendations of a subcommittee of PROWAAC that developed a model for sidewalks and pedestrian facilities design alternatives, design processes for making alterations, design solutions to specific problems, and case studies demonstrating examples of accessible design practices from across the United States. The goal of this design guide is to improve projects in the public rights-of-way that are classified as alterations under the ADA (PROWAAC 2007). The design guide includes six chapters: (1) introduction, (2) alterations, (3) design process, (4) design solutions, (5) model sidewalks, and (6) curb ramp examples.

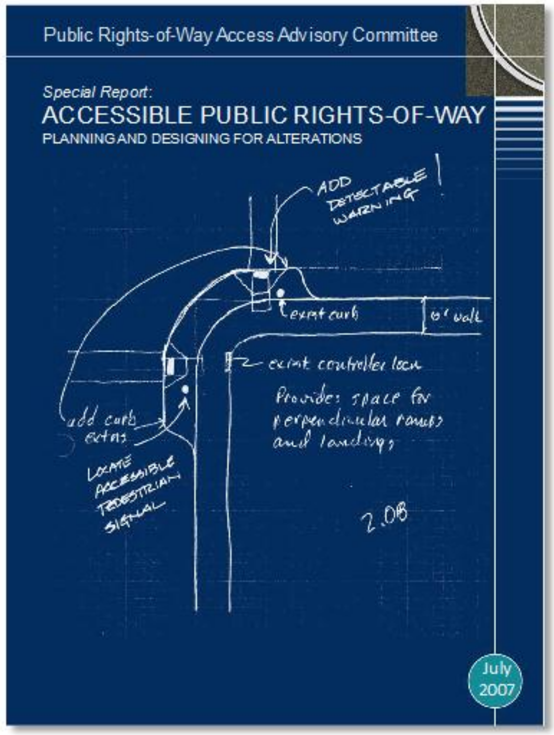
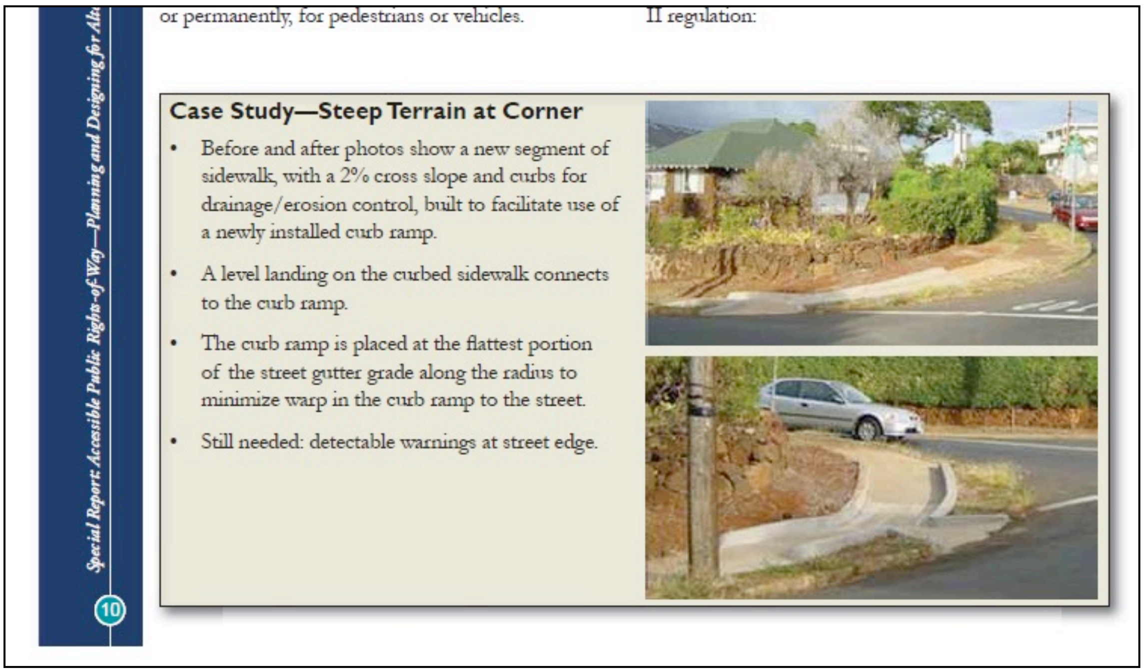


Figure 14: The cover page of the PROWAAC 2007 (PROWAAC 2007)

The first chapter is entitled "Introduction" provides a general background in four sections: (1) The Public Right-of-Way, (2) Accessibility Regulations, (3) Alterations, and (4) Existing Facilities.

The second chapter "Alterations" focuses on explaining both the nature of alteration projects and the principles of accessibility in seven sections: (1) *Terminology*, which explains ADA requirements in case of alteration in the context of sidewalks and pedestrian facilities; (2) *Project Physical Constraints*, which focuses on the physical, financial, and architectural constraints that limit the flexibility of alteration projects; (3) *Analyzing Accessibility Alternatives*, which explains the possible ways of achieving accessibility and the selection criteria for choosing the correct alternative; (4) *Project Scope*, which focuses on the scoping of alteration projects; (5) *How do you know when you've maximized accessibility?*, which explains the measures, metrics and techniques for achieving maximum possible accessibility within an alteration project; (6) *Project Approach*, which focuses on promoting the accessibility design requirements in the architectural, engineering and construction industry; and (7) *Frequently-Asked Questions*, which provides answers for frequently asked questions on alterations. This chapter also includes several case studies that illustrate common design challenges, as shown in the example in Figure 15 (PROWAAC 2007).


or permanently, for pedestrians or vehicles. II regulation:

Case Study—Steep Terrain at Corner

- Before and after photos show a new segment of sidewalk, with a 2% cross slope and curbs for drainage/erosion control, built to facilitate use of a newly installed curb ramp.
- A level landing on the curbed sidewalk connects to the curb ramp.
- The curb ramp is placed at the flattest portion of the street gutter grade along the radius to minimize warp in the curb ramp to the street.
- Still needed: detectable warnings at street edge.

Special Report: Accessible Public Rights-of-Way—Planning and Designing for Alt

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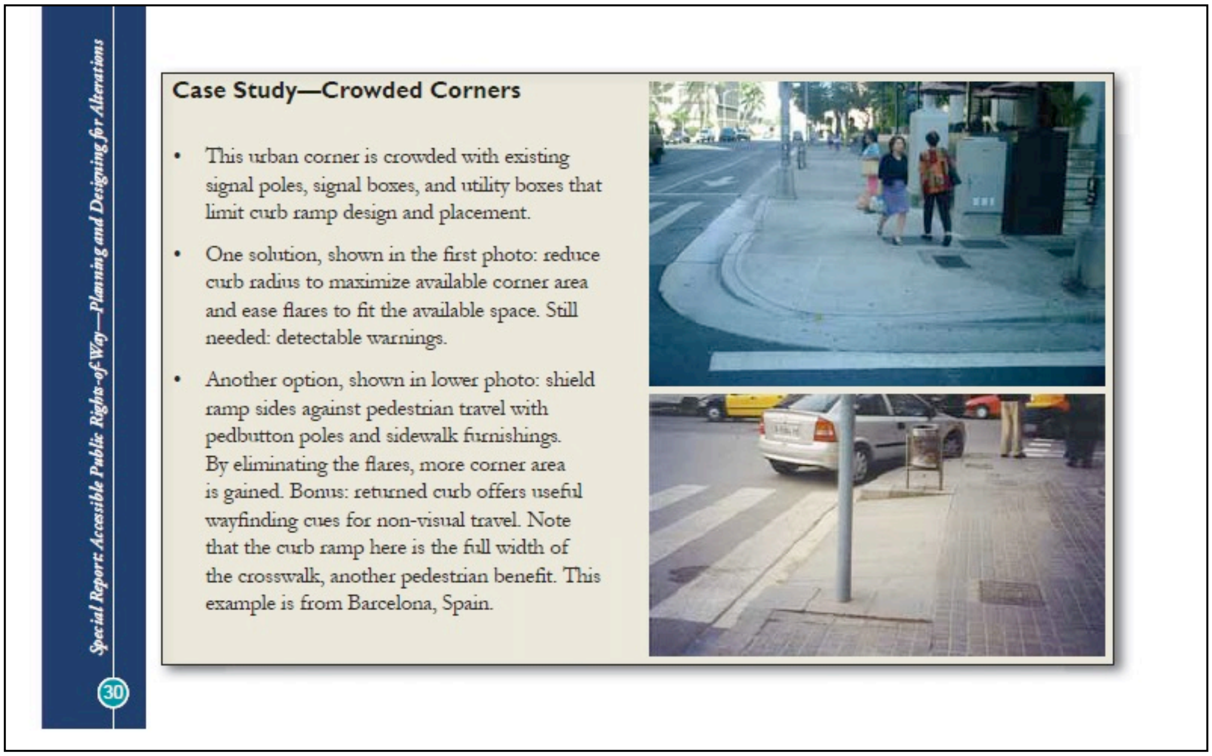
Figure 15: Example of an alteration case study (PROWAAC 2007)

The third chapter "Design Process" provides guidance on the design process in five sections: (1) *Gathering Information*, which emphasizes the importance of gathering information about the applicable accessibility laws and regulations in order to assist with the scoping of the design; (2) *Planning the Scope of Work*, which focuses on determining the actual extent of work to be covered by the project and deciding the required accessibility modifications according to the scope of the project; (3) *Identification of Constraints and Opportunities*, which focuses on the means and methods to identify any barriers or constraints in the project site that can cause further expansions in the scope of work in order to achieve compliance with ADA requirements; (4) *Development of Alternatives*, which discusses the importance of developing more than one design solution to overcome the constraints and limitations that are typically encountered during alteration projects; (5) *Project Documentation*, which focuses on documenting the analysis of every design problem including description of alternatives developed and decision made. This chapter also includes several case studies to illustrate common design challenges, as shown in the example in Figure 16 (PROWAAC 2007).



Special Report: Accessible Public Rights-of-Way—Planning and Designing for Alterations

Case Study—Crowded Corners

- This urban corner is crowded with existing signal poles, signal boxes, and utility boxes that limit curb ramp design and placement.
- One solution, shown in the first photo: reduce curb radius to maximize available corner area and ease flares to fit the available space. Still needed: detectable warnings.
- Another option, shown in lower photo: shield ramp sides against pedestrian travel with pedbutton poles and sidewalk furnishings. By eliminating the flares, more corner area is gained. Bonus: returned curb offers useful wayfinding cues for non-visual travel. Note that the curb ramp here is the full width of the crosswalk, another pedestrian benefit. This example is from Barcelona, Spain.

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Figure 16: Example of design challenges in alteration projects (PROWAAC 2007)

The fourth chapter "Design Solutions" provides guidance and examples to solve and overcome most common design problems in five sections: (1) *Accessible Design is a Safety Best Practice*, which highlights the relation between accessibility and safety; (2) *Information in this Chapter*, which describes the methodology for selecting and analyzing the case studies in this chapter; (3) *Design Problems*, which defines five common design problems in alteration projects that are discussed along with their solutions in the following five sections; (4) *Limited Right-of-Way*, which provides guidance on methods to overcome the lack of sufficient right-of-way space to accommodate all accessibility requirements; (5) *Above Ground Obstructions*, which provides guidance on methods to overcome existing obstructions that reduce the width or accessibility of pedestrian access route; (6) *Push Buttons are not Accessible*, which provides guidance on methods to overcome the inaccessibility of existing pedestrian signals and pushbuttons, as shown in the example in Figure 17; (7) *Excessive Roadway Slope*, which provides guidance on managing the difference between the existing roadway slope and accessible route slope requirements; (8) *Underground Obstructions*, which provides guidance on managing the impact of existing underground structures (e.g. drainage structures and utility vaults) on achieving the requirements for running and cross slope in accessible routes; (9) *Accessible Parking Spaces General Discussion*, which discusses accessible parking spaces. This chapter also includes case studies that illustrate possible solution for several design problems, as shown in the example in Figure 18 (PROWAAC 2007).

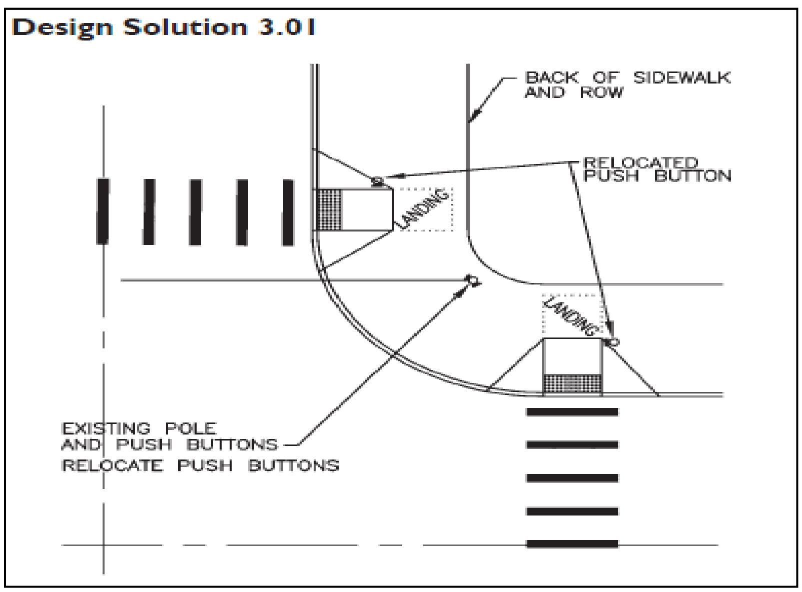
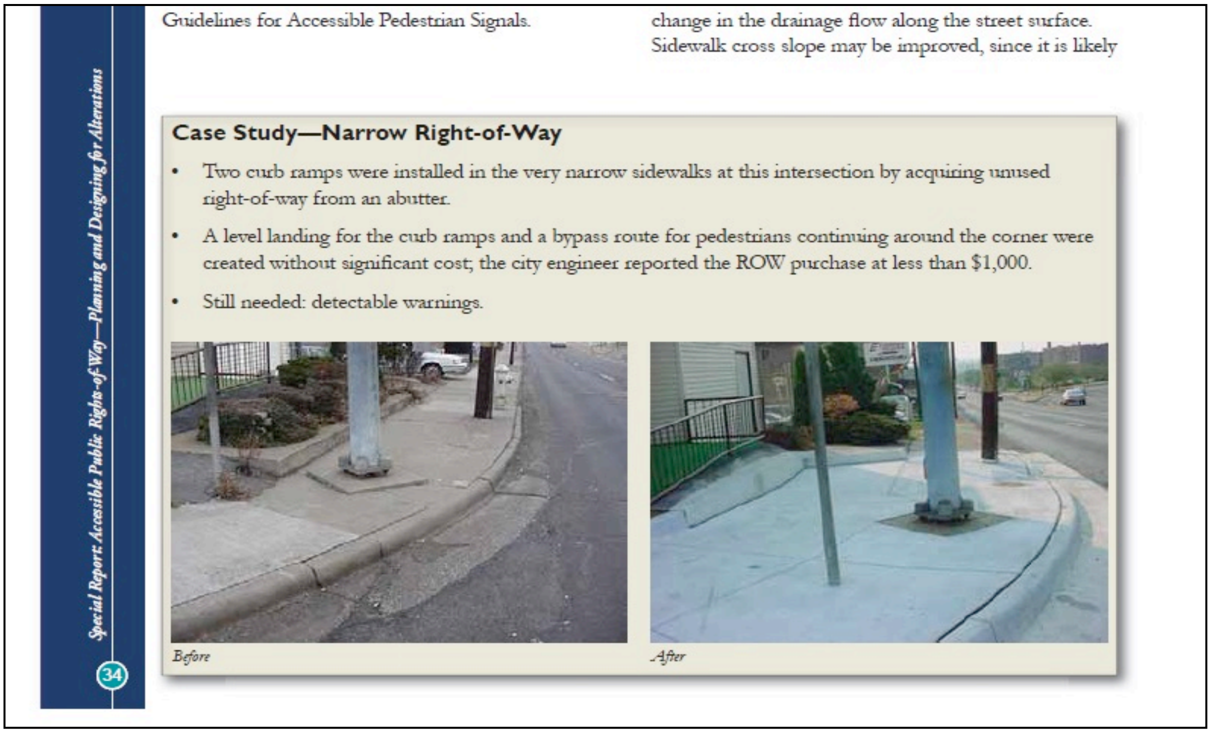


Figure 17: Example for improving accessibility to existing push button (PROWAAC 2007)



Special Report: Accessible Public Rights-of-Way—Planning and Designing for Alterations

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Guidelines for Accessible Pedestrian Signals.

change in the drainage flow along the street surface. Sidewalk cross slope may be improved, since it is likely

Case Study—Narrow Right-of-Way

- Two curb ramps were installed in the very narrow sidewalks at this intersection by acquiring unused right-of-way from an abutter.
- A level landing for the curb ramps and a bypass route for pedestrians continuing around the corner were created without significant cost; the city engineer reported the ROW purchase at less than $1,000.
- Still needed: detectable warnings.

Before

After

Figure 18: Example solution for narrow right-of-way (PROWAAC 2007)

The fifth chapter "Model Sidewalks" provides examples of model sidewalks for varying dimensions of sidewalks and pedestrian facilities in five sections: (1) *Model Sidewalks*, (2) *15- to 20-Foot Curb to Right-of-Way Line*, as shown in Figure 19 (A), (3) *12-Foot Curb to Right-of-Way Line*, as shown in Figure 19 (B), (4) *8- to 9-Foot Curb to Right-of-Way Line*, as shown in Figure 19 (C), and (5) *4- to 5-Foot Curb to Right-of-Way Line.* This chapter also includes one case study that illustrates parallel curb ramps (PROWAAC 2007).

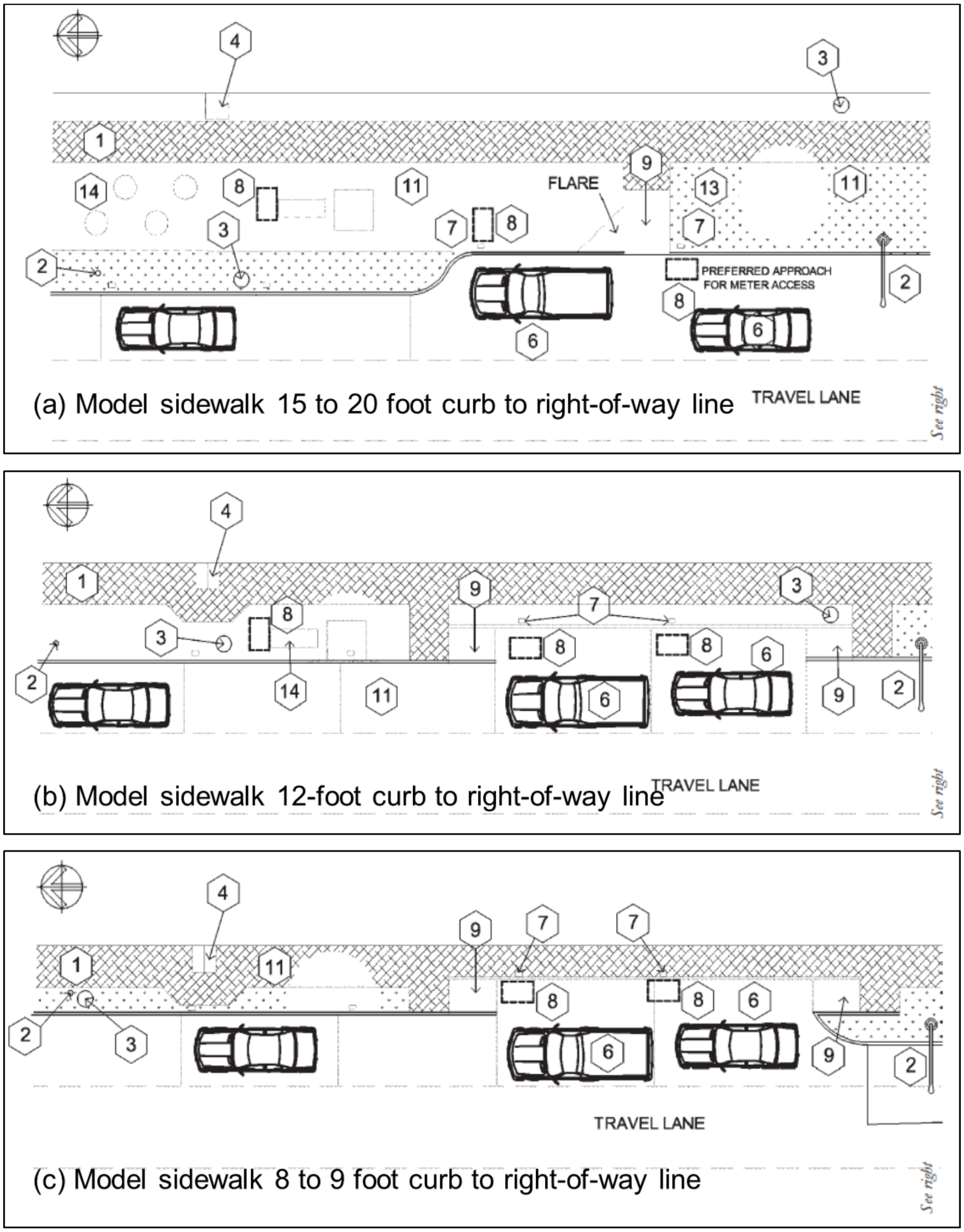
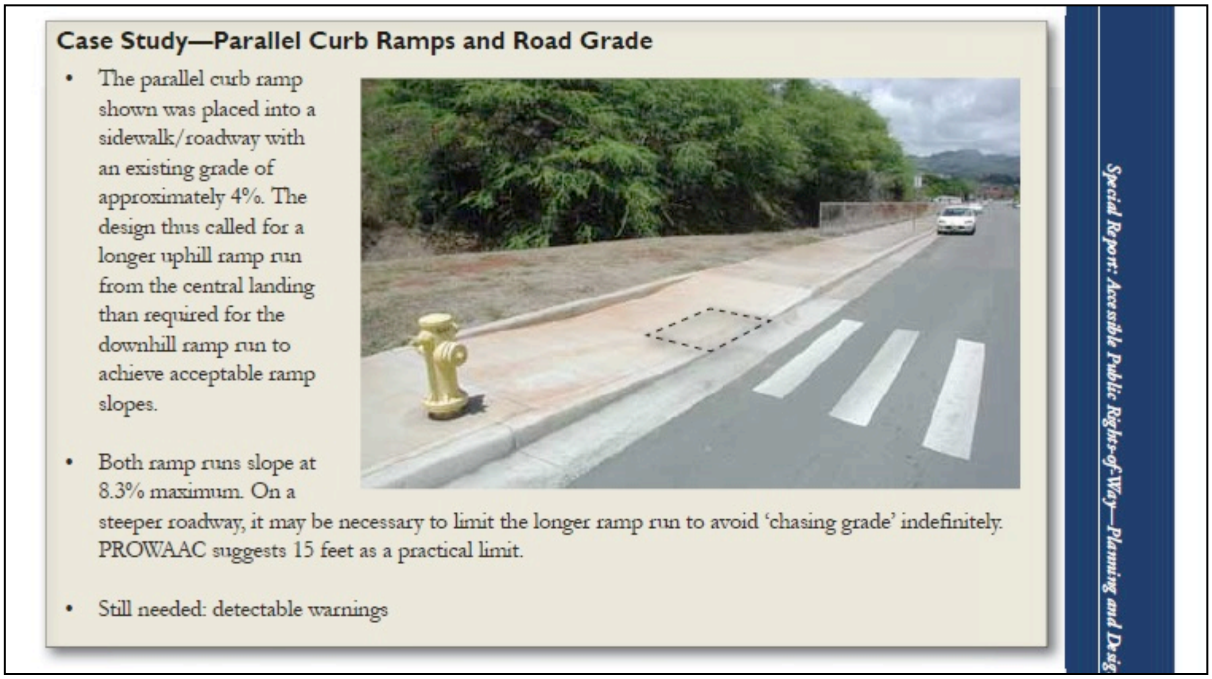


Figure 19: Examples of model sidewalks (PROWAAC 2007)

The sixth chapter "Curb Ramp Examples" provides examples of different types of curb ramps and turning spaces, as shown in Figure 20. This chapter includes three sections: (1) *Curb Ramp Examples*, (2) *10-Foot Radius Curb Returns*, and (3) *30-Foot Radius Curb Returns*. (PROWAAC 2007)



Case Study—Parallel Curb Ramps and Road Grade

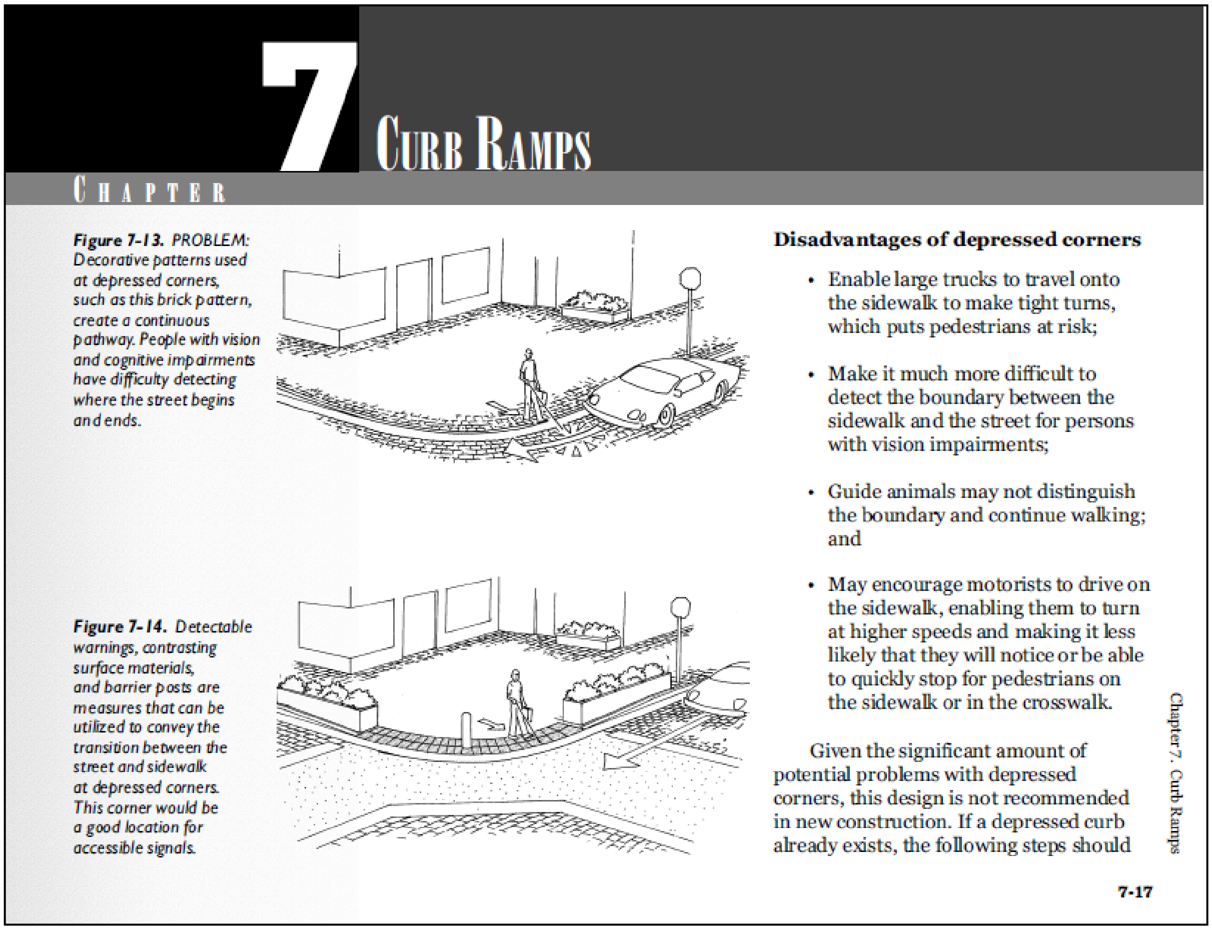
- The parallel curb ramp shown was placed into a sidewalk/roadway with an existing grade of approximately 4%. The design thus called for a longer uphill ramp run from the central landing than required for the downhill ramp run to achieve acceptable ramp slopes.
- Both ramp runs slope at 8.3% maximum. On a steeper roadway, it may be necessary to limit the longer ramp run to avoid 'chasing grade' indefinitely. PROWAAC suggests 15 feet as a practical limit.
- Still needed: detectable warnings

Special Report: Accessible Public Rights-of-Way—Planning and Desig

Figure 20: Case study of parallel curb ramps (PROWAAC 2007)

2.3.1.2. Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide

In 2001, the Federal High Way Administration (FHWA) published a report titled "Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide". This design guide was based on the findings of an earlier FHWA study (Axelson et al. 1999) that will be described later in section 2.3.1.7. This best-practices design guide provides guidelines for designing sidewalks and trails to ensure their compliance with accessibility requirements. The design guidelines for sidewalks are described in chapters 2 to 11 in this guide including: (1) understanding sidewalk and trail users, (2) integrating pedestrians into the project planning process, (3) sidewalk corridors, (4) driveway crossings, (5) providing information to pedestrians, (6) curb ramps, (7) pedestrian crossings, (8) traffic calming, (9) sidewalk maintenance and construction site safety, and (10) sidewalk assessment. Each of these chapters provides guidance and best practices, as shown in the curb ramp example in Figure 21. The design guide also includes in its appendices several forms and checklists for assessment of sidewalk accessibility, as shown in the example in Figure 22 (FHWA 2001).



7 CHAPTER

CURB RAMPS

Figure 7-13. PROBLEM: Decorative patterns used at depressed corners, such as this brick pattern, create a continuous pathway. People with vision and cognitive impairments have difficulty detecting where the street begins and ends.

Figure 7-14. Detectable warnings, contrasting surface materials, and barrier posts are measures that can be utilized to convey the transition between the street and sidewalk at depressed corners. This corner would be a good location for accessible signals.

Disadvantages of depressed corners

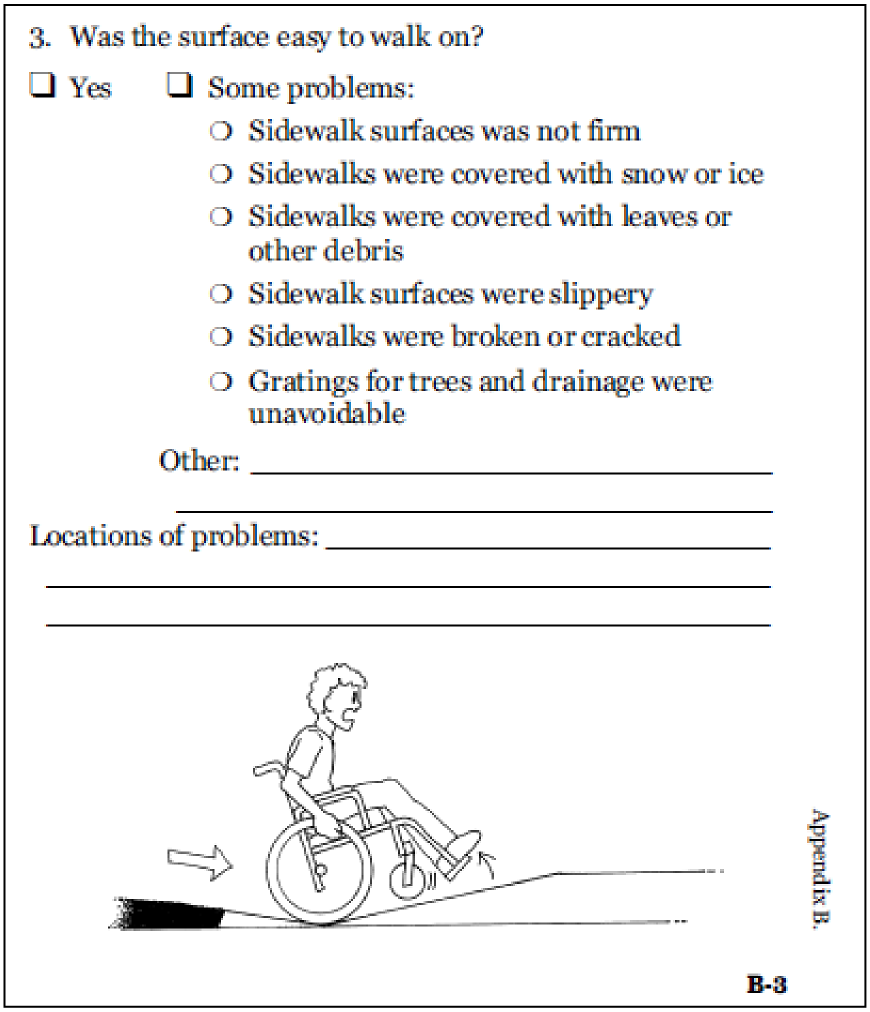
- Enable large trucks to travel onto the sidewalk to make tight turns, which puts pedestrians at risk;
- Make it much more difficult to detect the boundary between the sidewalk and the street for persons with vision impairments;
- Guide animals may not distinguish the boundary and continue walking; and
- May encourage motorists to drive on the sidewalk, enabling them to turn at higher speeds and making it less likely that they will notice or be able to quickly stop for pedestrians on the sidewalk or in the crosswalk.

Given the significant amount of potential problems with depressed corners, this design is not recommended in new construction. If a depressed curb already exists, the following steps should

Chapter 7. Curb Ramps

7-17

Figure 21: Example best practices for curb ramps (FHWA 2001)



3. Was the surface easy to walk on?

❑ Yes ❑ Some problems:

- ❍ Sidewalk surfaces was not firm
- ❍ Sidewalks were covered with snow or ice
- ❍ Sidewalks were covered with leaves or other debris
- ❍ Sidewalk surfaces were slippery
- ❍ Sidewalks were broken or cracked
- ❍ Gratings for trees and drainage were unavoidable

Other: ______________________________

Locations of problems: ______________________________

Appendix B.

B-3

Figure 22: Example checklist for sidewalk accessibility assessment (FHWA 2001)

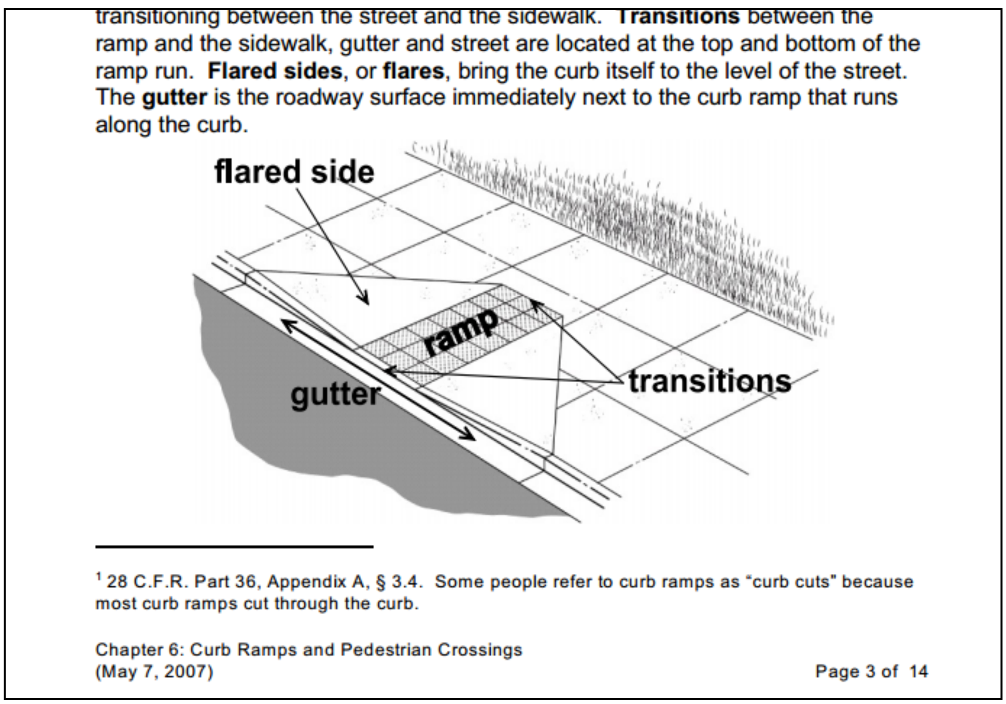
2.3.1.3. The ADA Best Practices Tool Kit for State and Local Governments

In 2006, the Civil Rights Department of the U.S. DOJ issued its first installment of a technical assistance publication to aid state and local officials in applying the requirements of Title II of the ADA to their programs, services, activities and facilities. The technical assistance document was released in seven installments between December 5, 2006 and July 26, 2007, and it was titled "The ADA Best Practices Tool Kit for State and Local Governments." The preamble of this toolkit states (in part):

> *"The Tool Kit is designed to teach state and local government officials how to identify and fix problems that prevent people with disabilities from gaining equal access to state and local government programs, services, and activities. It will also teach state and local officials how*

to conduct accessibility surveys of their buildings and facilities to identify and remove architectural barriers to access."

The tool kit includes seven chapters:(1) ADA basics, statutes and regulations, (2) ADA coordinator notice and grievance procedure, (3) general effective communication requirements under Title II of the ADA, (4) 9-1-1 and emergency communications services, (5) website accessibility under Title II of the ADA, (6) curb ramps and pedestrian crossings (see Figure 23), (7) emergency management under Title II of the ADA. The toolkit also includes two appendices titled: (a) survey instructions for curb ramps, and (b) survey forms for curb ramps. The toolkit included extensive checklists for the ADA Title II requirements. The DOJ highly recommends implementing the best practices that are listed in this toolkit (U.S. Department of Justice 2007).



transitioning between the street and the sidewalk. **Transitions** between the ramp and the sidewalk, gutter and street are located at the top and bottom of the ramp run. **Flared sides**, or **flares**, bring the curb itself to the level of the street. The **gutter** is the roadway surface immediately next to the curb ramp that runs along the curb.

[1] 28 C.F.R. Part 36, Appendix A, § 3.4. Some people refer to curb ramps as "curb cuts" because most curb ramps cut through the curb.

Chapter 6: Curb Ramps and Pedestrian Crossings
(May 7, 2007) Page 3 of 14

Figure 23: Example best practices for curb ramps (U.S. Department of Justice 2007)

2.3.1.4. <u>Accessible Pedestrian Signals: A Guide to Best Practices</u>

In 2010, The American Association of State Highway and Transportation Officials (AASHTO) sponsored a research study in cooperation with the Federal Highway Administration to develop best practices for accessible pedestrian signals. The findings of this study were published in a report titled "Accessible Pedestrian Signals: A Guide to Best Practices" (NCHRP 2009).

The objective of this research study was to develop guidelines and training materials for implementation of accessible pedestrian signals (APS). The guidelines explained how APS could provide optimal information through media such as tones and tactile or verbal indicators, and under what circumstances their installation would be recommended. The training materials aimed to facilitate the application of the guidelines and the installation and operation of APS.

The study included ten chapters that cover (1) Introduction to APS, (2) Travel by Pedestrians Who Are Blind or Who Have Low Vision, (3) Understanding Traffic Signals and Modern Intersection Design, (4) Features of APS (see Figure 24) , (5) When to Install APS, (6) Designing APS Installations, (7) Installation, Operation, and Maintenance, (8) Public Education about APS, (9) U.S. Case Studies, and (10) International Practice. It also included five appendices titled (a) Current Guidelines, (b) Product Information, (c) Research on APS, (d) APS Prioritization Tool Instructions and Forms, and (e) Glossary (NCHRP 2009).

ADDITIONAL INFORMATION

It is important that the arrow points in the direction of travel on the crosswalk, as it indicates which crosswalk is controlled by that pushbutton. Tactile arrows provide general alignment information for all pedestrians. However, it is important to note that tactile arrows do not seem to enable the extremely accurate alignment required for blind and visually impaired pedestrians. To align the arrow properly, the installer needs to understand that pedestrians are expecting the arrow to be aligned toward the destination across the street. The purpose is not to point toward the beginning of the crosswalk, or the curb ramp location. Misalignment of the arrow may direct a blind pedestrian into the center of the intersection.

For arrows on the face of the device, the alignment is determined by the installation of the pushbutton on the pole. Arrows on the top of the pushbutton housing are typically glued into place after the pushbutton is installed and their alignment can be adjusted separately from the pushbutton.

Figure 4-2. This APS has a high-contrast, raised tactile arrow on the pushbutton and a high-contrast, recessed tactile arrow on the sign above the button

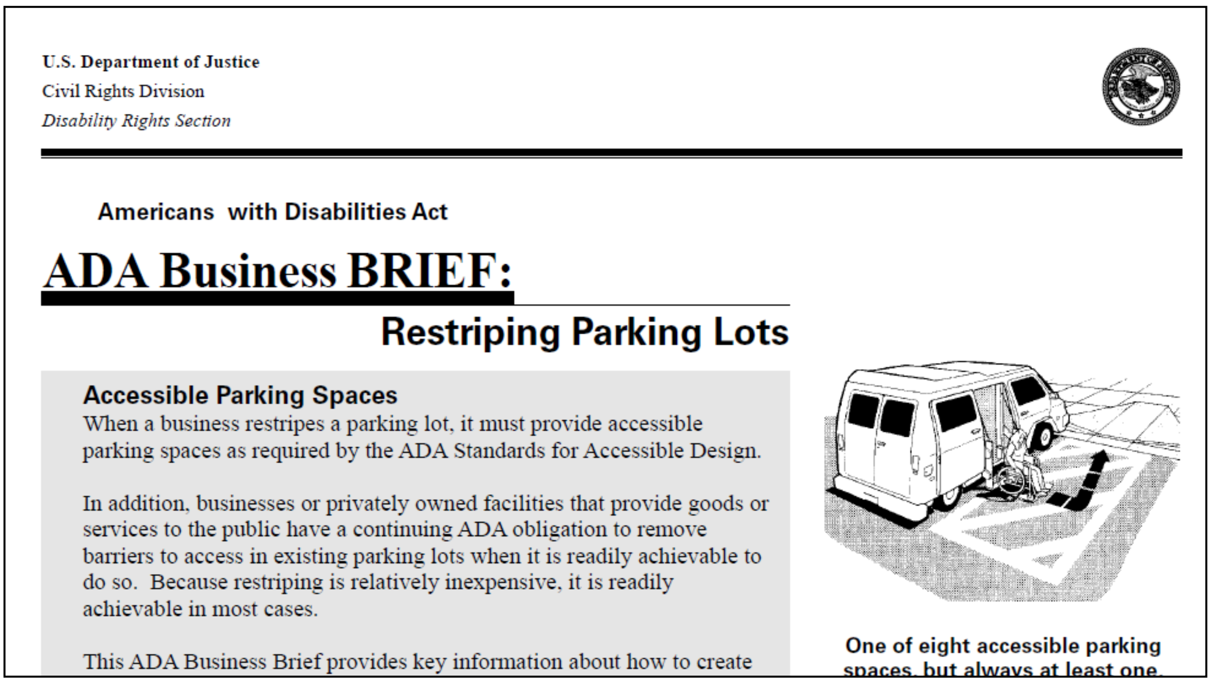
Figure 24: Example of tactile arrows on pushbuttons (NCHRP 2009)

2.3.1.5. <u>The Americans with Disabilities Act Title II Technical Assistance Manual</u>

The ADA Title II technical assistance manual was developed in 1993 to promote voluntary compliance with Title II requirements. The manual states that its purpose "is to present the ADA's requirements for State and local governments in a format that will be useful to the widest possible audience" (U.S. Department of Justice 1994). The manual provides answers to frequently asked accessibility questions and illustrations to explain ADA Title II requirements. The manual includes nine chapters that are titled: (1) coverage, (2) qualified individuals with disabilities, (3) general requirements, (4) employment, (5) program accessibility, (6) new construction and alterations, (7) communications, (8) administrative requirements, and (9) investigation of complaints and enforcement (U.S. Department of Justice 1994).

2.3.1.6. <u>Department of Justice Guides</u>

Since the approval of the ADA, the Civil Rights Division of the U.S. DOJ published many concise manuals and field guides. Each of these provides guidance on the applications and requirements of the ADA in a specific context. These manuals include (1) “ADA Business Brief: Restriping Parking Lots” that explains to small businesses how to organize their parking lots to comply with ADA, as shown in Figure 25 (DOJ 2001); (2) “Common ADA Errors and Omissions in New Construction and Alterations” that focuses on the most common errors and omissions related to accessibility in buildings and outdoors, as shown in Figure 26 (DOJ 2002); (3) “ADA Guide for Small Towns” that summarizes ADA requirements for small local governments such as towns, townships, and rural counties, as shown in Figure 27 (DOJ 2007).



U.S. Department of Justice
Civil Rights Division
Disability Rights Section

Americans with Disabilities Act

ADA Business BRIEF:

Restriping Parking Lots

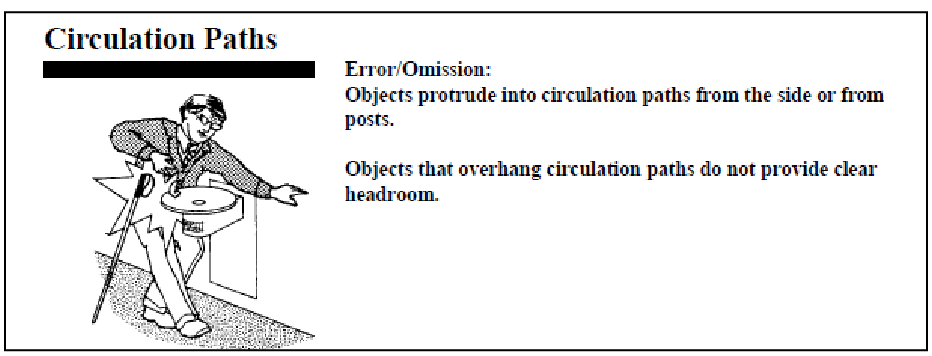
Accessible Parking Spaces
When a business restripes a parking lot, it must provide accessible parking spaces as required by the ADA Standards for Accessible Design.

In addition, businesses or privately owned facilities that provide goods or services to the public have a continuing ADA obligation to remove barriers to access in existing parking lots when it is readily achievable to do so. Because restriping is relatively inexpensive, it is readily achievable in most cases.

This ADA Business Brief provides key information about how to create

One of eight accessible parking spaces, but always at least one.

Figure 25: Sample page of restriping parking lots (DOJ 2001)

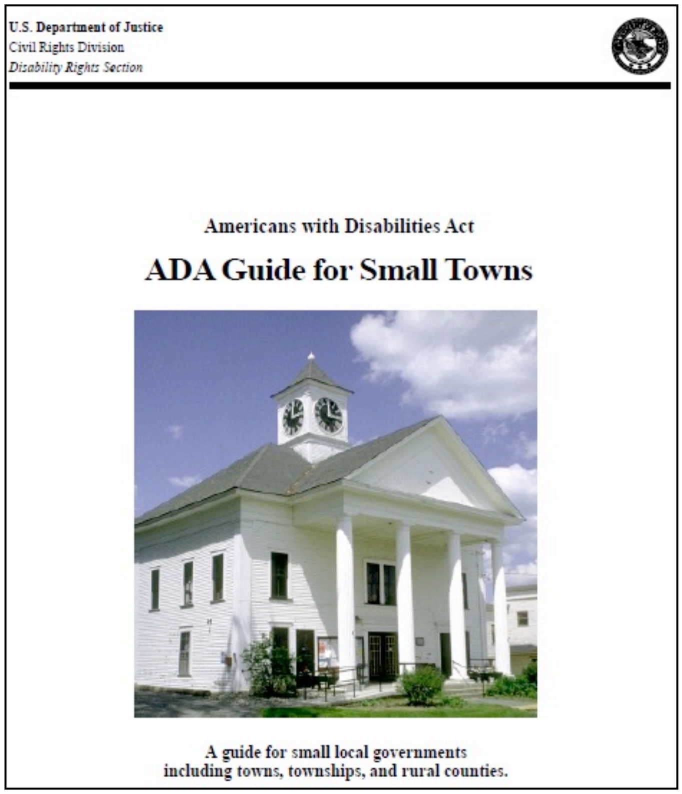


Circulation Paths

Error/Omission:
Objects protrude into circulation paths from the side or from posts.

Objects that overhang circulation paths do not provide clear headroom.

Figure 26: Example of common ADA errors and omissions (DOJ 2001)


U.S. Department of Justice
Civil Rights Division
Disability Rights Section

Americans with Disabilities Act

ADA Guide for Small Towns

A guide for small local governments
including towns, townships, and rural counties.

Figure 27: Cover page of ADA Guide for Small Towns (DOJ 2007)

2.3.1.7. <u>Designing Sidewalks and Trails for Access, Part I of II: Review of Existing Guidelines and Practices</u>

In 1999, the Federal High Way Administration (FHWA) published a report titled "Designing Sidewalks and Trails for Access, Part I of II: Review of Existing Guidelines and Practices". This report presented the findings of a research study on sidewalks and trails accessibility that was sponsored by the U.S. DOT to provide planners, designers, and transportation engineers with a better understanding of how sidewalks and trails should be developed to promote pedestrian access for all users, including people with disabilities.

This study conducted an extensive literature review, and analyzed existing guidelines and recommendations for developing sidewalks and trails. In addition, site visits were conducted to several towns and cities across the United States that (a) provide excellent accommodations for people with disabilities, and (b) lack adequate accessible facilities. Quantitative measurements of sidewalk and trail characteristics that affect accessibility were taken at the sites. Experts also were interviewed to obtain the most current information on sidewalk and trail access as it relates to people with disabilities (Axelson et al. 1999).

The study includes five chapters that cover (1) Disability Rights Legislation and Accessibility Guidelines and Standards in the United States, (2) Characteristics of Pedestrians, (3) Summary of the Planning Process, (4) Sidewalk Design Guidelines and Existing Practices, (see Figure 28), and (5) Trail Design for Access. It also includes three appendices titled (a) Abbreviations and Acronyms, (b) Glossary, and (c) Bibliography.

The outcomes of this study showed that (a) sidewalks should be designed as a whole, not a set of separate elements, (b) accessibility of sidewalks increase when it is integrated into the early stages of the design process, and (c) community involvement is vital to the process of designing sidewalks (Axelson et al. 1999).

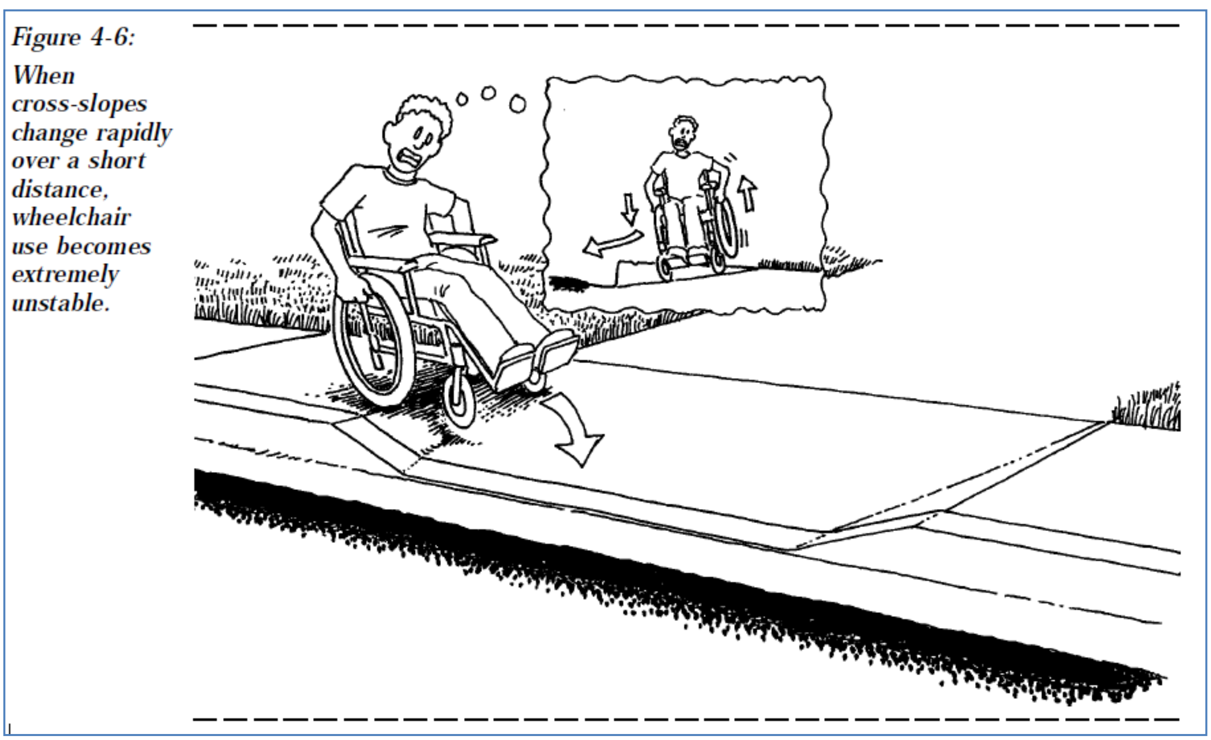


Figure 28: Example of changes in cross slope over a short distance (Axelson et al. 1999)

2.3.1.8. <u>ADA Compliance at Transportation Agencies: a Review of Practices</u>

In 2007, the American Association of State Highway and Transportation Officials (AASHTO) sponsored a research study on ADA compliance in transportation agencies. The study was titled "ADA Compliance at Transportation Agencies: a Review of Practices". The purpose of the study was to gather information and develop a synthesis of practices, including best practices, on the various approaches transportation agencies use to address ADA compliance issues. The focus of the project was on pedestrian infrastructure on sidewalks and pedestrian facilities, including sidewalks, curb ramps, pedestrian crossings, and obstructions. The analysis did not include buildings, facilities, or transit infrastructure. The study conducted a comprehensive literature review, a survey, and several interviews. The published report of this study includes five chapters titled: (1) introduction, (2) literature review of standards, guidelines, and current practices, (3) online survey procedure and results, (4) interviews and other information gathered from stakeholders, and (5) summary of practices (Quiroga and Turner 2008).

2.3.2. State Guidelines

Many state agencies developed manuals and design guides to provide best practices that can be used to comply with accessibility laws and regulations. Accessibility-related guidelines developed by other states were gathered, analyzed and categorized according to their relevance and level of detail. The analysis revealed that a number of these gathered guidelines were too brief, outdated, or irrelevant. This section presents examples of the most relevant, detailed, and current state guidelines, including (1) Accessible sidewalk requirements by Iowa Department of Transportation; (2) Field guide for accessible public rights of way by the Washington State Department of Transportation; (3) ADA project design guide by Minnesota Department of Transportation;(4) temporary pedestrian facilities handbook by California Department of Transportation; (5) accessibility policy and guidelines for pedestrian facilities along state highways by the Maryland Department of Transportation; and (6)

PROWAG/ADAAG standards - guidance for temporary pedestrian access route facilities and devices by Minnesota Department of Transportation.

2.3.2.1. WSDOT Field Guide for Accessible Public Rights of Way

In 2012, the Washington State Department of Transportation published a field guide titled "Field Guide for Accessible Public Rights of Way 2012 Edition" to provide assistance to its officials and local engineers on achieving compliance with accessibility laws and regulations. The field guide is intended to serve as a pocket guide in the actual worksites to facilitate the process of construction and inspection of pedestrian facilities in sidewalks and pedestrian facilities. The field guide covers (1) Accessibility Criteria Checklists; (2) Pedestrian Circulation Path (PCP); (3) Protruding Objects/Obstructions; (4) Pedestrian Access Route (PAR); (5) Access Route Surface Elements; (6) Curb Ramps, which includes sections that cover: perpendicular type curb ramp, parallel type curb ramp, combination type curb ramp, single-direction parallel type curb ramp, and diagonally-oriented parallel type curb ramp; (7) Curb Ramp Transitions; (8) Detectable Warning Surfaces (DWS); (9) Pedestrian Push Buttons and Accessible Pedestrian Signals (APS); (10) Crosswalks; (11) Driveways; (12) Bus Stops, and (13) Alternate Pedestrian Circulation Paths and Pedestrian Detours. The field guide includes figures and illustrations that provide clear explanation of accessibility regulations and standards (see Figure 29) (Washington DOT 2012).

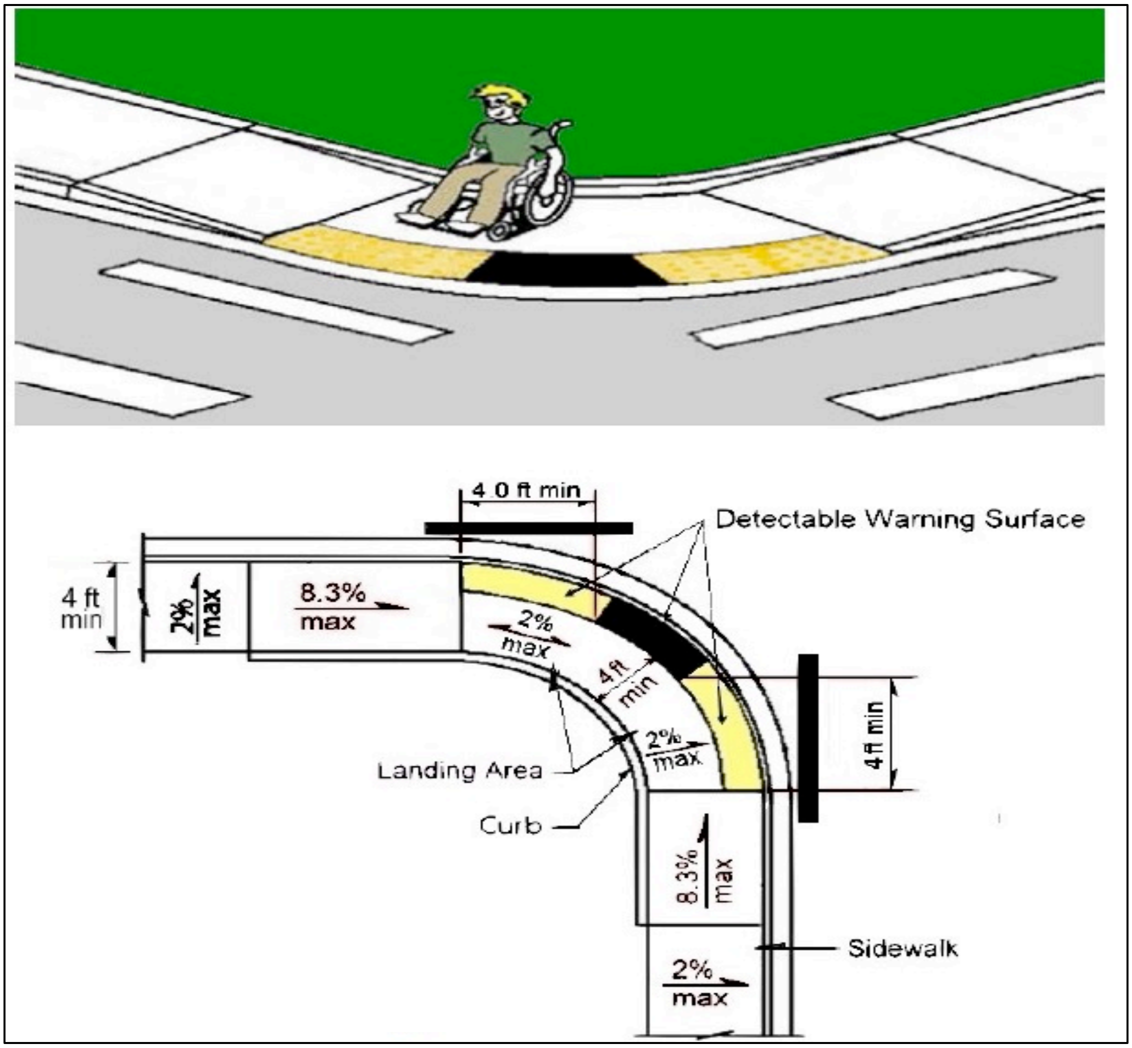


Figure 29: Diagonally oriented parallel type curb ramp (Washington DOT 2012)

2.3.2.2. IowaDOT Accessible Sidewalk Requirements

In 2012, the Iowa Department of Transportation updated its design manual to include a new chapter titled "Chapter 12: Accessible Sidewalk Requirements" that provides guidance on the application of accessibility regulations and standards on sidewalks and pedestrian facilities. This chapter is based on the 2011 Proposed Accessibility Guidelines (PROWAG). The chapter was updated three times with the most recent update on August 16 2013. The chapter covers (A) Introduction, (B) Transition Plan, (C) Definitions, (D) Applicability, (E) Standards for Accessibility, (F) Bus Stop, and (G) Accessible Pedestrian Signals. The chapter also includes several illustrations and figures to clarify accessibility requirements (see Figure 30) (Iowa DOT 2013)

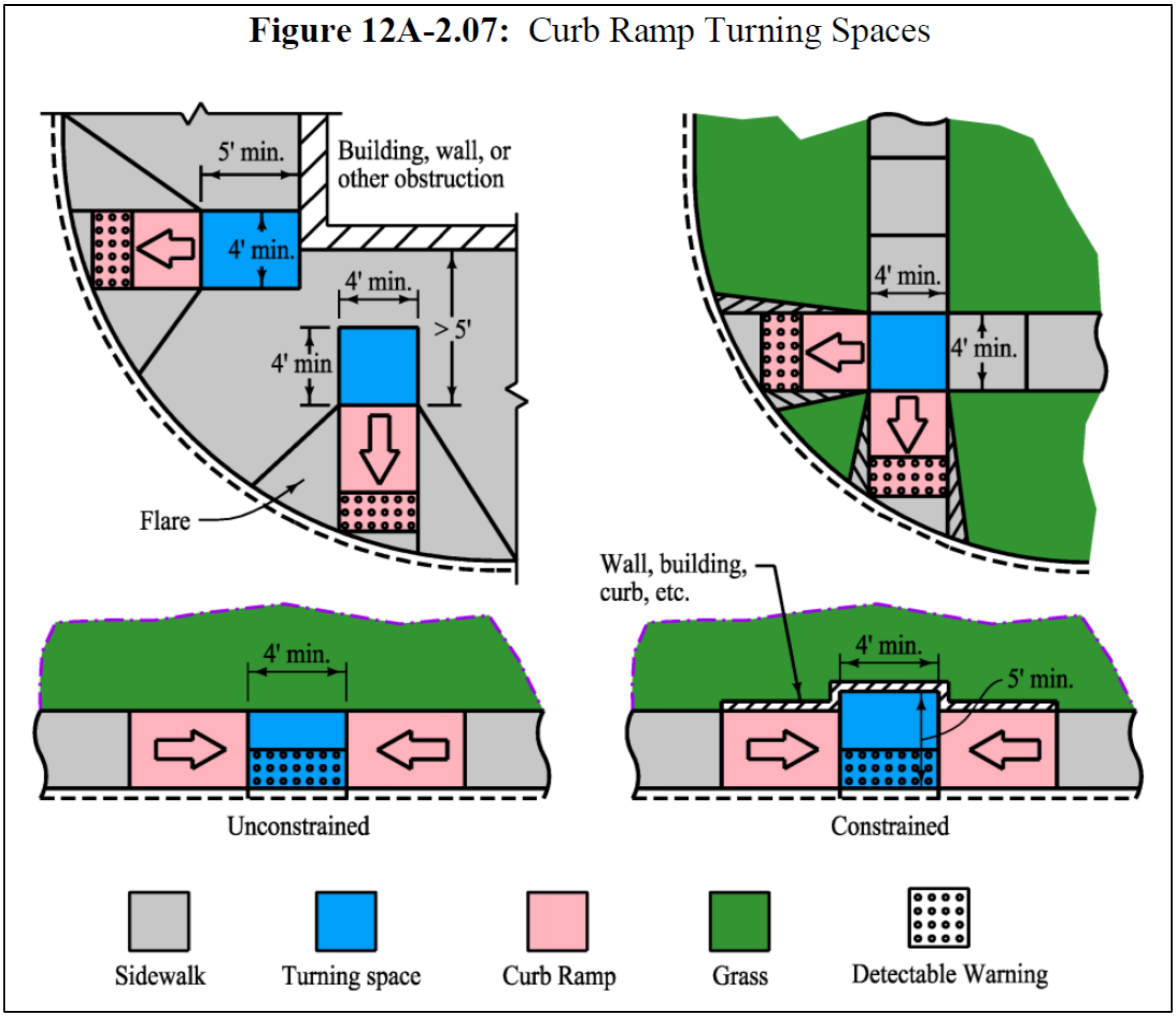


Figure 30: Curb ramp turning spaces (Iowa DOT 2013)

2.3.2.3. MNDOT ADA Project Design Guide

In 2012, the Minnesota Department of Transportation (MNDOT) published a design guide that was titled "ADA Project Design Guide". This guide covers (A) introduction, (B) scoping, (C) pre-design-determining the level of plan detail & survey needs, (D) design considerations, (E) signals, (F) surveys, (G) drainage, (H) materials, (I) utilities, (J) right of way, (K) traffic control/temporary pedestrian access routes, (L) signing/striping, (M) pork chop islands, (N) medians, (O) construction, (P) trails/pedestrian facilities, and (Q) pay item guidance. The MNDOT guide is comprehensive; however, it did not include illustrations or figures (MNDOT 2012).

2.3.2.4. <u>Caltrans Temporary Pedestrian Facilities Handbook</u>

In 2011, the California Department of Transportation (Caltrans) published a handbook that focused on the requirements of temporary pedestrian facilities on sidewalks. This handbook covers (A) introduction, (B) related Caltrans standards, (C) California MUTCD requirements, (D) permanent facilities, and (E) an ADA checklist (Caltrans 2011). The handbook included several illustrations and figures (see Figure 31)

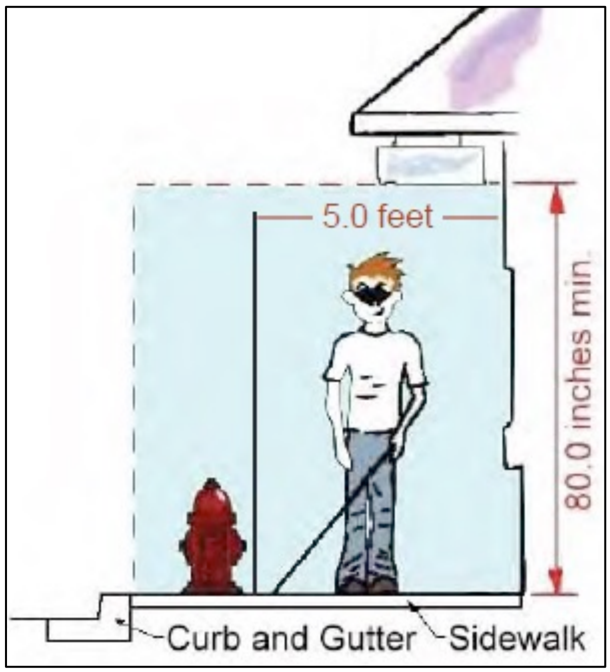


Figure 31: Pedestrian path width (Caltrans 2011)

2.3.2.5. <u>MDOT Accessibility Policy and Guidelines for Pedestrian Facilities along State Highways</u>

In 2010, the Maryland Department of Transportation (MDOT) published a report titled "Accessibility Policy and Guidelines for Pedestrian Facilities along State High Way". The report focused on conveying the importance of compliance with ADA requirements and explained ADA requirements in an easy to understand way. The report also included checklists and detailed illustrations to assist local architects, engineers and contractors in achieving compliance with ADA requirements (MSHA 2010).

2.3.2.6. MNDOT PROWAG/ADAAG Standards Guidance for Temporary Pedestrian Access Route (TPAR) Facilities and Device

In 2010, the Minnesota Department of Transportation issued a draft publication to assist its officials, architects and engineers to assess the degree of compliance of any route to determine whether it is considered up to "Pedestrian Access Route" (PAR) Standards. The report is titled "PROWAG/ADAAG Standards Guidance for Temporary Pedestrian Access Route (TPAR) Facilities and Devices" and it focused on compiling accessibility standards that are related to ADA and Section 504 (Minnesota DOT 2010).

Despite the availability of these field guides, their limitations include: (1) none of them is comprehensive, (2) none of them include a summary of all accessibility related requirements, and (3) they do not display the requirements in a concise, clear, and effective manner.

2.4. Self-Evaluations and Transition Plans

Title II of the ADA and Section 504 of the Rehabilitation Act require public entities covered by these laws to (1) perform a self-evaluation process in order to identify barriers in their physical facilities, policies and practices that could limit compliance with Title II requirements; and (2) if the public entity employs 50 or more persons, to prepare a transition plan that explains how these entities plan to achieve compliance with accessibility regulations.

2.4.1. Self-Evaluations

The ADA Title II regulations that were developed by the Department of Justice require all public entities to complete self-evaluations in order to evaluate (1) their current services, policies, and practices, and their compliance with the requirements of Title II of the ADA; and (2) the extent of modification of any such services, policies, and practices that are required for compliance with the ADA Title II requirements (28 C.F.R. § 35.105 (a)).

2.4.1.1. *Definition and Scope*

The U.S. Department of Justice defines self-evaluation In the ADA Title II Technical Assistance Manual as:

> *"A public entity's assessment of its current policies and practices. The self-evaluation identifies and corrects those policies and practices that are inconsistent with Title II's requirements. As part of the self-evaluation, a public entity should:*
>
> *1) Identify all of the public entity's programs, activities, and services; and*
>
> *2) Review all the policies and practices that govern the administration of the public entity's programs, activities, and services."* (U.S. Department of Justice 1994).

The U.S Department of Justice in its ADA Title II Technical Assistance Manual states that a public entity's policies and practices are typically reflected in its laws, ordinances, regulations, administrative manuals or guides, policy directives, and memoranda. Other practices, which may not be recorded, may be based on local custom. Once a public entity has identified its policies and practices, it should analyze whether these policies and practices adversely affect the full participation of individuals with disabilities in its programs, activities, and services. The DOJ also states that areas that need to be reviewed in these self-evaluations include (U.S. Department of Justice 1994):

- A public entity must examine each program to determine whether any physical barriers to access exist. It should identify steps that need to be taken to enable these programs to be made accessible when viewed in their entirety. If structural changes are necessary, they should be included in the transition plan.
- A public entity must review its policies and practices to determine whether any exclude or limit the participation of individuals with disabilities in its programs, activities, or services. Such policies or practices must be modified, unless they are necessary for the operation or provision of the program, service, or activity. The self- evaluation should identify policy modifications

to be implemented and include complete justifications for any exclusionary or limiting policies or practices that will not be modified.

- A public entity should review its policies to ensure that it communicates with applicants, participants, and members of the public with disabilities in a manner that is as effective as its communications with others.
- A public entity should review its policies to ensure that they include provisions for readers for individuals with visual impairments; interpreters or other alternative communication measures, as appropriate, for individuals with hearing impairments; and amanuenses for individuals with manual impairments.
- A review should be made of the procedures to evacuate individuals with disabilities during an emergency. This may require the installation of visual and audible warning signals and special procedures for assisting individuals with disabilities from a facility during an emergency.
- A review should be conducted of a public entity's written and audio-visual materials to ensure that individuals with disabilities are not portrayed in an offensive or demeaning manner.
- If a public entity operates historic preservation programs, it should review its policies to ensure that it gives priority to methods that provide physical access to individuals with disabilities.
- A public entity should review its policies to ensure that its decisions concerning a fundamental alteration in the nature of a program, activity, or service; or a decision will not cause an undue financial and administrative burden.
- A public entity should review its policies and procedures to ensure that individuals with mobility impairments are provided access to public meetings.

- A public entity should review its employment practices to ensure that they comply with other applicable nondiscrimination requirements, including Section 504 of the Rehabilitation Act and the ADA regulation issued by the Equal Employment Opportunity Commission.
- A public entity should review its building and construction policies to ensure that the construction of each new facility or part of a facility, or the alteration of existing facilities after January 26, 1992, conforms to the Standards designated under the title II regulation.
- A review should be made to ascertain whether measures have been taken to ensure that employees of a public entity are familiar with the policies and practices for the full participation of individuals with disabilities. If appropriate, training should be provided to employees.
- If a public entity limits or denies participation in its programs, activities, or services based on drug usage, it should make sure that such policies do not discriminate against former drug users, as opposed to individuals who are currently engaged in illegal use of drugs.

Once a public entity identified, in its self-evaluation, policies and practices that deny or limit the participation of individuals with disabilities in its programs, activities, and services, it should take immediate actions to eliminate the impediments to full and equivalent participation. Structural modifications that are required for program accessibility should be made as soon as possible (DOJ 1994).

2.4.1.2. *Public Feedback Requirement*

The ADA Title II regulations require all public entities to provide an opportunity to interested persons, including individuals with disabilities or organizations representing individuals with disabilities, to participate in the self-evaluation process by submitting comments (28 C.F.R. § 35.105 (b)).

Public entities are required to accept comments from the public on the self-evaluation and are strongly encouraged by the U.S. Department of Justice to consult with individuals with disabilities and organizations that represent them to assist in the self-evaluation process. Many individuals with disabilities have unique perspectives on a public entity's programs, activities, and services. For example, individuals with mobility impairments can readily identify barriers preventing their full enjoyment of the public entity's programs, activities, and services. Similarly, individuals with hearing impairments can identify the communication barriers that hamper participation in a public entity's programs, activities, and services.

2.4.1.3. *Covered Public Entities*

The ADA Title II regulations require each public entity that employs 50 or more persons, for at least three years following completion of the self-evaluation, to maintain on file and make available for public inspection: (1) a list of the interested persons consulted; (2) a description of areas examined and any problems identified; and (3) a description of any modifications made (28 C.F.R. § 35.105 (c)).

2.4.1.4. *Required Updating of Self-Evaluations*

The U.S. Department of Justice in its ADA Title II Technical Assistance Manual strongly recommends public entities to periodically review and update their self-evaluations, especially if they were completed earlier under Section 504 of the Rehabilitation Act. Because most Section 504 self-evaluations were done many years ago, the U.S. Department of Justice states in its Title II Technical Assistance Manual that it expects that many public entities will re-examine all their policies and practices. Programs and functions may have changed significantly since the Section 504 self-evaluation was completed. Actions that were taken to comply with Section 504 may not have been implemented fully or may no longer be effective. In addition, Section 504's coverage has been changed by statutory amendment, particularly the Civil Rights Restoration Act of 1987, which expanded the definition of a covered "program or activity." Therefore, public entities should ensure that all programs, activities, and services are examined fully, except where there is evidence that all policies were previously scrutinized under Section 504 (DOJ 1994).

2.4.1.5. *<u>Self-Evaluation Guides</u>*

In 2004, the Division of Community Services of the North Dakota Department of Commerce published an extensive guide for preparing self-evaluations and transition plans. The guide was titled "Section 504/ADA Technical Assistance Handbook". The handbook is divided into three sections. The first section is a checklist to help public entities determine if they need a self-evaluation and if they need to keep it for three years. The second section discusses self-evaluations and how to achieve them in the most effective way. The third part explains transition plans and their requirements including a checklist (NDDOC 2004).

In 2010, the Massachusetts Department of Housing and Community Development (MDHCD) developed a guide to assist its officials in preparing self-evaluations and transition plans. The guide focused on self-evaluations and transition plans for housing developments; however, its guidelines can be applied to sidewalks and pedestrian facilities. The report was prepared by Kessler McGuinness and Associates, and was titled "ADA/504 Self Evaluation and Transition Plan Guide" (MDHCD 2010).

Another tool for self-evaluations was developed by the Texas Governor's Committee on People with Disabilities and the Office for Civil Rights. The tool is titled "Americans with Disabilities Act Self Evaluation Tool". The tool consists of four parts: (i) part I that deals with issues affecting Title II employers and includes a brief introduction and a summary of key definitions; (ii) part II that deals with the Title II requirements for self-evaluation; (iii) part III that provides a "Quick Look" Checklist for accessibility; and (iv) part IV is a partial list of agencies, organizations and disability groups that can provide information and assistance (CPD 2014).

2.4.2. Transition Plans

The ADA Title II regulations that were developed by the Department of Justice require all public entities to develop a transition plan when: (1) the public entity has completed a self-evaluation that requires structural changes to facilities to achieve program accessibility, and (2) the public entity employs 50 or more employees. The transition plan should state the steps necessary to complete the required structural changes (28 C.F.R § 35.150 (d)).

2.4.2.1. Definition and Scope

The ADA Title II regulations specify the minimum requirements of a transition plan as follows:

"The plan shall, at a minimum

(i) Identify physical obstacles in the public entity's facilities that limit the accessibility of its programs or activities to individuals with disabilities;

(ii) Describe in detail the methods that will be used to make the facilities accessible;

(iii) Specify the schedule for taking the steps necessary to achieve compliance with this section and, if the time period of the transition plan is longer than one year, identify steps that will be taken during each year of the transition period; and

(iv) Indicate the official responsible for implementation of the plan" (28 C.F.R § 35.150 (d) (3)).

The ADA Title II regulations state that if a public entity has responsibility or authority over streets, roads, or walkways, its transition plan shall include a schedule for providing curb ramps or other sloped areas where pedestrian walks cross curbs, giving priority to walkways serving entities covered by the Act, including State and local government offices and facilities, transportation, places of public accommodation, and employers, followed by walkways serving other areas (28 C.F.R. § 35.150 (d) (2)).

If a public entity has already complied with the transition plan requirement of a Federal agency regulation implementing Section 504 of the Rehabilitation Act of 1973, then these requirements shall apply only to those policies and practices that were not included in the previous transition plan (28 C.F.R. § 35.150 (d) (4)).

The ADA Title II Regulations did not provide a specific time frame or interval for updating transition plans. However, the Department of Justice strongly recommends updating all transition plans on a regular basis to achieve compliance with the latest changes in regulations and standards and to avoid costly penalties in case of non-compliance (DOJ 1994).

2.4.2.2. Public Feedback Requirement

The ADA Title II regulations state that a public entity shall provide an opportunity to interested persons, including individuals with disabilities or organizations representing individuals with disabilities, to participate in the development of the transition plan by submitting comments. A copy of the transition plan shall be made available for public inspection (28 C.F.R. § 35.150 (d) (1)).

2.4.2.3. Transition Plan Guides

In 2012, the Chicago Metropolitan Agency for Planning (CMAP) developed a brochure to explain and promote the process of making and updating self- evaluations and transition plans for the local communities in the Chicago region, as shown in Figure 32. The brochure included sections that cover the definition of a transition plan, who should prepare it, when should it be prepared, which facilities fall under the requirements of a transition plan, and how does a local government develop a transition plan (CMAP 2012).

The Chicago Metropolitan Agency for Planning mentioned in its brochure that updates to transition plans should be completed to reflect new guidelines and standards. These recent guidelines and standards include the aforementioned (1) 2010 ADA Accessibility Standards that became effective in 2012 (28 C.F.R. § 35); and (2) 2011 proposed accessibility guidelines for pedestrian facilities in the public right-of-way (PROWAG) (USAB 2011). CMAP also recommended that most communities should update their transition plans, if their plans have not recently been updated to reflect the latest guidelines and standards (CMAP 2012). A sample of the City of Urbana transition plan is shown in Appendix B (COU 2012).

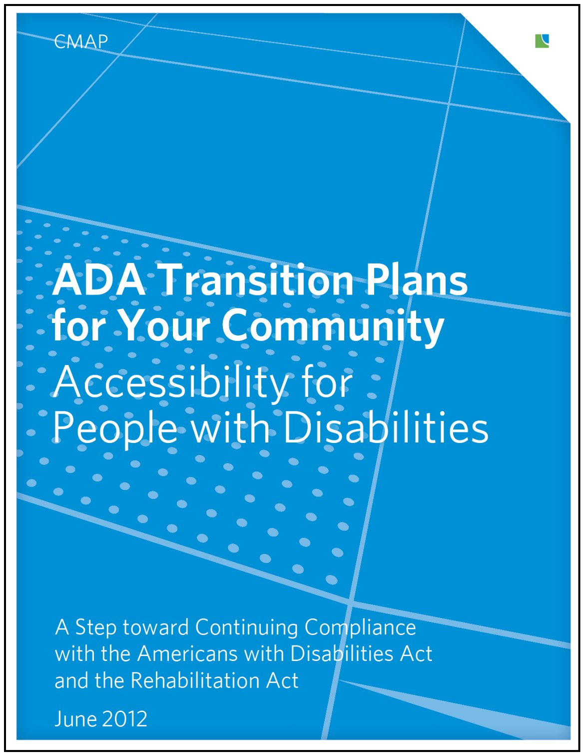


Figure 32: Cover page of ADA Transition Plan (CMAP 2012)

2.5. Legal Cases

This section provides a review of court cases and legal settlements that are related to accessibility of sidewalks and pedestrian facilities.

2.5.1. Decided Court Cases

In *Kinney v. Yerusalim* (1993), *Kinney et al.* pursued complaints against the Secretary of the Pennsylvania Department of Transportation (Yerusalim) and the Philadelphia Streets Department. Among other findings, the Court of Appeals for the Third Circuit established that the resurfacing of a city street constituted an "alteration" in the language of ADA. Therefore, the Court ordered the City to install curb ramps on those portions of streets where resurfacing would take place (including retroactive requirements for those streets that had been resurfaced since January 26, 1992, the effective date of ADA). In addition, the Court agreed that the "undue burden" language in ADA applies only to existing facilities and does not apply once alterations take place. Therefore, the cost of providing accessible ramps was of no issue once the resurfacing was established as an alteration (9 F.3d 1067, 1993).

In this case, resurfacing was considered an alteration and was "defined as laying at least 1½ inches of new asphalt, sealing joints and cracks, and patching depressions of more than 1 inches, spanning the length and width of a city block" (Quiroga and Turner 2008). This was significant, as the court decision and its definition of resurfacing require providing curb ramps at intersections in compliance with the ADA standards. The related sections of the final court decision stated (in part):

> *"Whether resurfacing a street constitutes an "alteration" is thus dependent on whether resurfacing affects the usability of the street. We think that it does. As stated above, the DOJ has indicated that the concept of usability should be read broadly. The ADA is a remedial statute, designed to eliminate discrimination against the disabled in all facets of society. As a remedial statute it must be broadly construed to effectuate its purposes. Unlike merely painting a wall or polishing a floor, resurfacing affects the street in ways integral to its purpose. Resurfacing makes driving on and crossing streets easier and safer. It also helps to prevent damage to vehicles and injury to people, and generally promotes commerce and travel. The surface of a street is the part of the street that is "used" by both pedestrian and vehicular traffic. When that surface is improved, the street becomes more usable in a fundamental way.*
>
> *Furthermore, the process of resurfacing entails more than minor repair work or maintenance. According to the parties, city streets generally consist of three layers, a sub-base consisting of stone, a base consisting of concrete, and a top layer of asphalt. While sometimes new asphalt may simply be overlaid on top of the old surface, more often the old asphalt is removed by a process known as "milling." Milling consists of removing and then replacing the top layer of asphalt with the use of heavy machinery. This process may require either that the entire surface from curb to curb be removed, or that seven or eight feet from either curb may be removed, depending on the nature of the street. During this process any necessary reconstruction will be*

performed, for example, any cracks in the concrete base of the road will be repaired and manholes may be raised or lowered to be flush with the street when the resurfacing is complete. We conclude that resurfacing a street is an alteration within the meaning of the regulations and triggers the obligation to install curb ramps or slopes." (9 F.3d 1067).

"Whatever the extent of work performed under a contract, the City has certain minimum requirements for resurfacing. Thus, by the City's own specifications, resurfacing requires laying at least 1 1/2 inches of new asphalt, sealing open joints and cracks, and patching depressions of more than one inch. At issue in this appeal are those resurfacings which cover, at a minimum, an entire street from intersection to intersection. Thus, we are not called upon to decide whether minor repairs or maintenance trigger the obligations of accessibility for alterations under the ADA." (9 F.3d 1067)

In 2013, the Department of Justice (DOJ) provided an updated definition of alteration and the extent to which it affects the application of the ADA standards. The DOJ defined alteration as a process that affects the usability including "reconstruction, rehabilitation, resurfacing, widening, and projects of similar scale and effect". In addition, the DOJ provided additional clarification to the definition set by the case of Kinney versus Yerusalim and it specified that curb ramps should only be provided on the right of ways that are eligible for pedestrian use and that projects can be classified as resurfacing when the work is "on a street or roadway spanning from one intersection to another, and includes overlays of additional material to the road surface, with or without milling". The DOJ also clarified that procedures that are performed to enclose and polish the road surface are not considered an alteration but rather maintenance, and therefore they do not trigger the application of the ADA standards. The document also included a chart that compares maintenance and alteration activities according to the ADA, as shown in Figure 33 (DOJ/DOT 2013).

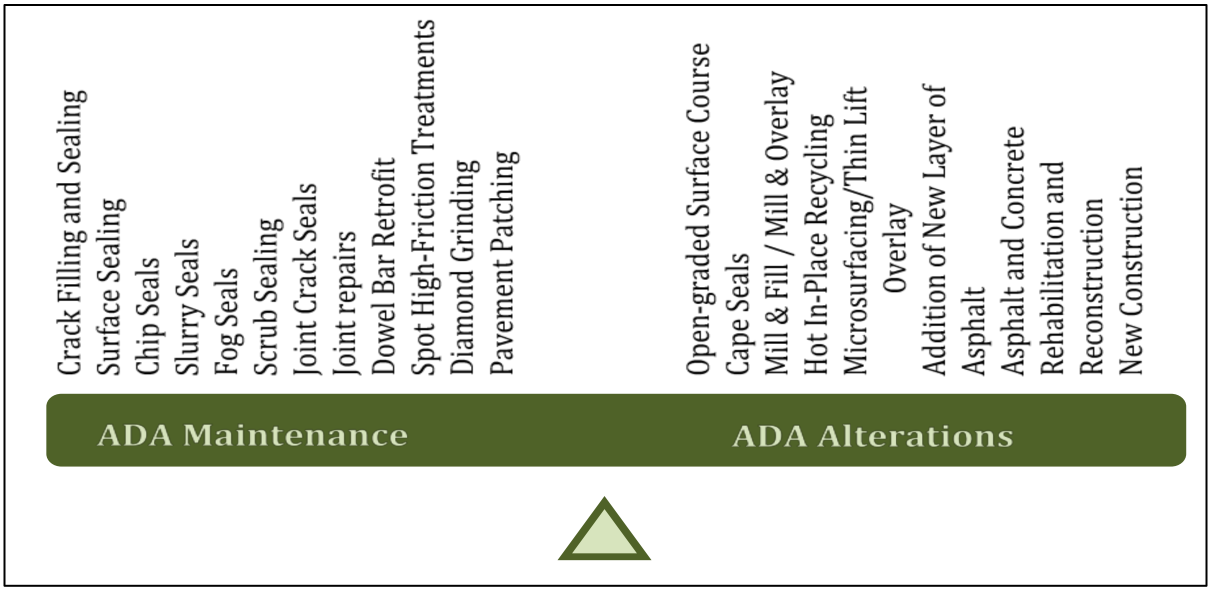


Figure 33: Maintenance vs. alterations under the ADA (DOJ/DOT 2013)

2.5.2. Settlement Agreements

When public entities do not fully comply with ADA regulations, they often face complaints and court cases that are filed by individuals and/or law-enforcing Federal agencies. Many of these cases are resolved by reaching a settlement or agreement before rendering a court decision. Although these settlements do not have the same power as a court decision, they provide a general understanding about the consequences of not complying with accessibility laws and regulations. These settlements often include financial and procedural terms. In this literature review, a total of 43 recent sidewalks and pedestrian facilities settlement agreements were collected and investigated including five that had financial terms, as shown in. The following sections provide a concise review of (a) five settlements that included financial terms, as shown in Table 6; (b) six recent settlements in Illinois; and (c) thirty two recent settlements in other states.

Table 6: Five Recent Settlements with Financial Terms (DOJ 2014)

City	State	Year	Financial Terms	Duration
City of Sacramento	California	2004	20% of Transportation Fund	30 years
City of Chicago	Illinois	2007	$50 million	5 years
City of Atlanta	Atlanta	2008	$3 million	Once
Caltrans	California	2010	$1.1 billion	30 years
City of Baltimore	Maryland	2011	$120,000	Once

2.5.2.1. Settlements with Financial Terms

The following five accessibility-related settlements included financial terms, as shown in Table 6.

2.5.2.1.1. City of Baltimore 2011 Settlement ($120,000)

In 2011, the City of Baltimore entered into settlement with an individual to avoid an accessibility related lawsuit. In this settlement, the City of Baltimore agreed to pay $120,000 to Ms. Anita Stevens as a compensation for the damage she was entitled due to an accident that occurred at Ednor Gardens that caused a serious injury to Ms. Stevens (Reuter 2014).

2.5.2.1.2. Caltrans 2010 Settlement ($1.1 Billion over 30 Years)

In 2010, the California Department of Transportation (Caltrans) entered into a settlement with Californians for Disability Rights and California Council for the Blind. In this settlement, Caltrans agreed to pay $1.1 billion of highway funds over the following 30 years to perform repair and construction projects that provide accessibility on their sidewalks and pedestrian facilities. Caltrans also accepted to accommodate the ADA requirements on its facilities that are both newly constructed or altered and allow personal requests and input using various communication methods including its website. This settlement agreement was "the largest architectural access settlement to date" as stated by Californians for Disability in 2014 (Californians for Disability 2014).

2.5.2.1.3. City of Atlanta 2008 Settlement ($3 Million)

In 2008, the City of Atlanta entered into a settlement with an individual who filed an accessibility related complaint. In this settlement, the City of Atlanta agreed to pay $3 million in compensation for the individual to avoid a lawsuit. The lawsuit was filed against the City of Atlanta as an individual with disabilities suffered severe injuries on a broken sidewalk that he had complained about for years. In addition, the City agreed to repair the sidewalk that caused the injuries and the lawsuit. The estimated cost of the sidewalk repairs was $2,000 and had the City completed that repair it could have avoided paying $3 million to settle the lawsuit. This clearly illustrates that the compliance cost with ADA regulations can be much less than the settlement cost of lawsuits that are caused by the failure of state and local governments to comply with ADA requirements (Diggs 2012).

2.5.2.1.4. City of Chicago 2007 Settlement ($140 Million over 5 Years)

In 2007, the Council for Disability Rights and the City of Chicago entered into a settlement agreement regarding the accessibility on sidewalks and pedestrian facilities in Chicago. In this settlement, the City of Chicago agreed to spend $10 million annually for five years following the agreement to ensure compliance with accessibility laws and regulations regarding existing curb ramps and sidewalks that were not originally planned to be modified. In addition, the City of Chicago agreed to spend approximately $18 million each year installing curb ramps and sidewalks as part of the City's annual resurfacing work. The city also agreed to provide accessibility in all alteration or resurfacing projects that are scheduled to start after the agreement date, and to seek input from people with disabilities (Class action settlement 2007).

2.5.2.1.5. City of Sacramento 2004 Settlement (20% of Transportation Fund for 30 Years)

In 2004, the City of Sacramento entered into a settlement agreement with various individuals with disabilities that filed complaints due to the lack of adequate accessibility of the facilities within its jurisdiction. In this settlement, the City of Sacramento agreed to allocate 20% of its annual Transportation Funds for the 30 years following the agreement to pay for required work on its facilities with pedestrian usage to comply with the ADA standards. The settlement agreement also emphasized the City's responsibility to provide sources of communication to account for the personal requests and opinions of accessibility on its facilities (Barden v. Sacramento, 2004).

2.5.2.2. *Recent Settlements in Illinois*

This section analyzes six recent accessibility related settlements that were reached between the U.S. Department of Justice and six public entities in Illinois over a period of nine years, as shown in Table 7. Four of these settlements addressed accessibility on sidewalks and pedestrian facilities, while the remaining two did not (see Table 7). The analysis of the four sidewalks and pedestrian facilities settlements reveals that they had many similar terms including:

- Within three months of the agreement, the city will file a report that illustrates their efforts to receive suggestions, opinions, and requests from persons with disabilities on the accessibility of its sidewalks.

- Within three months of the agreement, the city/county should file a written report of all streets, roads, highways, and street level walkways that have been constructed or altered since the ADA took effect on Jan 26, 1992.

- For existing facilities, the city will provide accessibility to sloped areas or curb ramps at all existing places where pedestrian walkway intersects with streets, roads, and highways within three years of the agreement. This includes intersections with curbs or other barriers to entry with regard to the 2010 ADA Standards.

- For new construction and alteration projects, accessibility on curb ramps or sloped areas complying with the 2010 ADA Standards will be provided at intersections with curbs or other barriers to entry from street level walkway of all newly constructed or altered streets, roads, or highways beginning no later than three months from the agreement date.

- The standards that were commonly used in these settlements were the 2010 ADA Standards and the UFAS.

Table 7: Settlements Between DOJ and Public Entities in Illinois Since 2001

Public Entity	Settlement Date	Address PROW
Warren County (DOJ 2001)	9/06/2001	No
Waukegan Park District (DOJ 2004)	2/27/2004	Yes
Will County (DOJ 2005a)	7/25/2005	Yes
City of Waukegan (DOJ 2005b)	12/15/2005	Yes
Village of Midlothian (DOJ 2009)	7/29/2009	No
St. Clair County (DOJ 2010a)	5/11/2010	Yes

2.5.2.3. Recent Settlements in Other States

This section analyzes thirty-two recent accessibility related settlements that were reached in other states over the last four years, as shown in Table 8. These settlement agreements were reached between the U.S. Department of Justice's Project Civic Access (PCA) and public entities in other states. The PCA was initiated by the DOJ to ensure that counties, cities, towns, and villages comply with the ADA by eliminating physical and communication barriers that prevent people with disabilities from participating fully in community life. The DOJ has conducted reviews in all 50 states, as well as Puerto Rico and the District of Columbia, and has posted its agreements with public entities on its website to help additional communities comply with the ADA (DOJ 2014). The analysis of the aforementioned 32 settlements that were reached in other states reveals that they included similar terms to those listed above in section 2.5.2.2 (DOJ 2014).

Table 8: List of Settlement Agreements Analyzed in the Study (DOJ 2014)

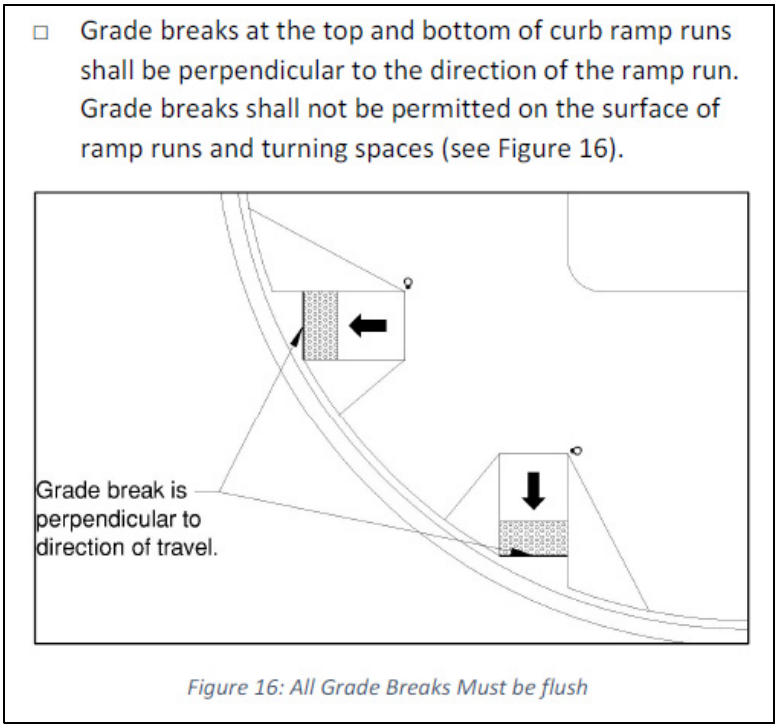
Public Entity	State	Settlement Date
City of Fort Morgan (DOJ 2013a)	Colorado	8/17/2013
Town of Poestenkill (DOJ 2013b)	New York	7/19/2013
City of West Columbia (DOJ 2013c)	South Carolina	5/31/2013
Stewart County(DOJ 2013d)	Georgia	5/9/2013
Jacksonville (DOJ 2013e)	Florida	4/19/2013
North Adams (DOJ 2012a)	Massachusetts	10/16/2012
Providence (DOJ 2012b)	Rhode Island	10/4/2012
Schuylkill County (DOJ 2012c)	Pennsylvania	9/13/2012
Kansas City (DOJ 2012d)	Missouri	7/25/2012
Randolph County (DOJ 2012e)	Georgia	7/24/2012
City of Wills Point (DOJ 2012f)	Texas	7/24/2012
Humboldt (DOJ 2012g)	Kansas	2/08/2012
Upshur County (DOJ 2011a)	Texas	11/22/2011
Town of Warrenton (DOJ 2011b)	Virginia	9/28/2011
Montgomery County (DOJ 2011c)	Maryland	8/16/2011
City of Madison (DOJ 2011d)	Indiana	7/26/2011
Daviess County (DOJ 2011e)	Kentucky	7/26/2011
Norfolk County (DOJ 2011f)	Massachusetts	7/26/2011
Van Buren County (DOJ 2011g)	Arizona	6/28/2011
The City of Independence (DOJ 2011h)	Kansas	4/28/2011
The City of Des Moines (DOJ 2011i)	Iowa	3/02/2011
The Town of Swansea(DOJ 2011j)	Massachusetts	2/15/2011
Fairfax County (DOJ 2011k)	Virginia	1/28/2011
Newport (DOJ 2010b)	Rhode Island	9/30/2010
Fort Myers (DOJ 2010c)	Florida	9/30/2010
Muskegon (DOJ 2010d)	Michigan	9/29/2010
Pearl River County (DOJ 2010e)	Mississippi	7/20/2010
Town of Pomfret (DOJ 2010f)	Connecticut	7/20/2010
Wilson County (DOJ 2010g)	North Carolina	7/20/2010
Smyth County (DOJ 2010h)	Virginia	6/09/2010
Lancaster County (DOJ 2010i)	Pennsylvania	6/09/2010
Wyandotte County & Kansas City (DOJ 2010j)	Kansas	4/07/2010

CHAPTER 3 - FIELD GUIDE DEVELOPMENT

This chapter presents the development of a comprehensive and effective field guide to overcome the limitations of existing field guides. A sample section of the developed field guide is in "Appendix A". The following sections highlight the design, content, and size of the developed field guide.

3.1. Design

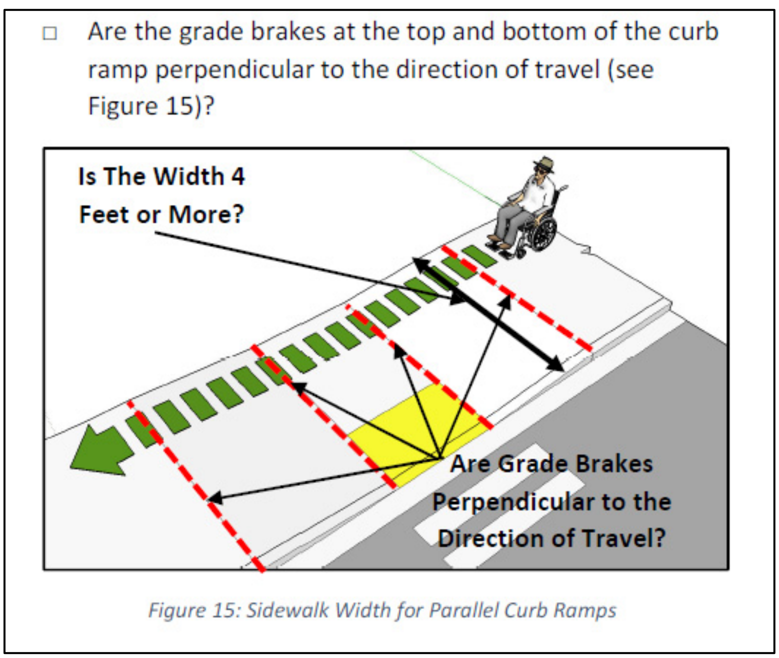
Two prototype designs for the field guide were developed to evaluate their practicality and effectiveness by an interdisciplinary team of engineers, designers, legal experts, and DOT administrators with expertise in the construction of accessible sidewalks and pedestrian facilities. The first prototype design used concise paragraphs to explain each requirement using text and figures, and it is designed to be used by field engineers on site and/or designers, as shown in Figure 34. The second prototype design use checklists that include brief questions to highlight each requirement with the aid of illustrative figures, and it is designed to be used by field engineers on site to inspect and verify compliance of existing and/or newly constructed sidewalks and pedestrian facilities with accessibility requirements, as shown in Figure 35.



□ Grade breaks at the top and bottom of curb ramp runs shall be perpendicular to the direction of the ramp run. Grade breaks shall not be permitted on the surface of ramp runs and turning spaces (see Figure 16).

Figure 16: All Grade Breaks Must be flush

Figure 34: Example of first design prototype for grade break requirement



□ Are the grade brakes at the top and bottom of the curb ramp perpendicular to the direction of travel (see Figure 15)?

Figure 15: Sidewalk Width for Parallel Curb Ramps

Figure 35: Example of second design prototype for grade break requirement

The interdisciplinary team members were asked to provide their feedback for each prototype regarding its comprehensiveness, clarity, size, and form factor. They were also asked to indicate for each prototype whether it is most suitable for design or on-site inspection use. Their feedback indicated that each prototype had advantages and disadvantages, as shown in Table 9. As shown in Table 9, the conclusion of the interdisciplinary team was that the second prototype provided the most effective design for field guides and therefore it was selected in the development of the present guide.

Table 9: Comments on and Ratings of Two Prototypes from Interdisciplinary Team

Design Criteria	First Prototype			Second Prototype		
	Rank		Comments	Rank		Comments
	D	I		D	I	
Comprehensiveness	1	1	Includes all accessibility requirements	1	1	Includes all accessibility requirements
Clarity	1	0	Provides clear and detailed explanation of accessibility requirements, which is more effective for designers. Using detailed description and paragraphs however makes it less effective for site inspection by field engineers.	0	1	Provides clear and concise checklists of accessibility requirements in the form of questions, which is more effective for field engineers. Using concise questions and checklists however makes it less effective for designers.
Effectiveness	1	0	Provides detailed explanation of accessibility requirements, which makes it more effective for designers.	0	1	Provides concise questions for inspecting the compliance of site conditions with accessibility requirements, which makes it more effective for field engineers.
Size	0	1	Pocket size is very practical for on-site inspection use, but not ideal for office design use.	0	1	Pocket size is very practical for on-site inspection use, but not ideal for office design use.
Conclusion	3	2	This prototype should be selected as a design manual	1	4	This prototype should be selected as a field guide

Table Key: "D" = performance for design use, "I" = performance for inspection use, "2" = most favorable performance, "1" = least favorable performance

3.2. Content

The content of the field guide is designed to include three main sections: (1) introduction, (2) accessibility requirements checklists, and (3) defined terms. The purpose of this content of the field guide is to ensure that it is comprehensive, concise and practical. The procedure for developing the organization and content of the field guide consists of the following eight steps.

Step 1: An introduction section was created to explain the purpose of the field guide and its organization.

Step 2: The 2011 PROWAG was identified as the main source for the contents of the field guide because it is the most recent and comprehensive federal guidelines that will be adopted soon as enforceable accessibility standards for sidewalks and pedestrian facilities (USAB 2011).

Step 3: The contents of PROWAG was analyzed and reorganized to combine the scoping requirements from its Chapter R2 with the technical requirements from Chapter R3 and supplementary technical requirements from Chapter R4 to produce a single and comprehensive list of accessibility requirements for each item in the PROWAG to facilitate the inspection of their compliance on site. For example, the scoping requirements of pedestrian access routes are located in Chapter R2, while technical requirements for the same item are located in Chapter R3, and supplementary technical requirements are located in Chapter R4. In this step, they are all combined and reorganized under one title “pedestrian access routes”.

Step 4: The accessibility requirements for each item in PROWAG were analyzed to identify any external references. These references were analyzed, summarized, and integrated to the content of the field guide to facilitate the use of the field guide on site without the need to use any additional standards or references during the inspection process. For example, accessible pedestrian signals and pedestrian pushbuttons requirements include reference to MUTCD, as shown in Figure 36. Accordingly, these external MUTCD requirements were identified and integrated in the content of the field guide.

R209 Accessible Pedestrian Signals and Pedestrian Pushbuttons

R209.1 General. Where pedestrian signals are provided at pedestrian street crossings, they shall include accessible pedestrian signals and pedestrian pushbuttons complying with sections 4E.08 through 4E.13 of the MUTCD (incorporated by reference, see R104.2). Operable parts shall comply with R403.

Figure 36: Sample requirement from PROWAG 2011

Step 5: Each of the identified accessibility requirements was subdivided into several brief questions to simplify it for site inspection without sacrificing the meaning and purpose of the requirement. Each question is designed to verify one required measurement or characteristic of an element of sidewalks and pedestrian facilities. For example, the requirement for a turning space at the top and bottom of a curb ramp which is stated in PROWAG, as shown in Figure 37, was subdivided into four brief questions, as shown in Figure 38.

R304.2.1 Turning Space. A turning space 1.2 m (4.0 ft) minimum by 1.2 m (4.0 ft) minimum shall be provided at the top of the curb ramp and shall be permitted to overlap other turning spaces and clear spaces. Where the turning space is constrained at the back-of-sidewalk, the turning space shall be 1.2 m (4.0 ft) minimum by 1.5 m (5.0 ft) minimum. The 1.5 m (5.0 ft) dimension shall be provided in the direction of the ramp run.

Figure 37: Sample requirement from PROWAG 2011

- ☐ Are there turning spaces at the top and bottom of the curb ramp ?
  - ○ Are the turning space dimensions 4 feet or more in any direction (see Figure 8)?
  - ○ Turning spaces can overlap other turning spaces.
  - ○ Is the turning space completely outside the nearest vehicular travel lane?

Figure 38: Sample of the brief questions in the field guide

Step 6: A clear and descriptive photograph or illustration was created for each brief question to provide visual explanation of the question. The pictures and illustrations are developed to provide specific guidance on how to inspect existing conditions on site to verify compliance with each requirement. Samples of the pictures and illustrations for the turning spaces at the top and bottom of the curb ramps are shown in Figure 39 and Figure 40.

- ☐ Are there turning spaces at the top and bottom of the curb ramp (see Figure 8 and Figure 9)?
  - Are the turning space dimensions 4 feet or more in any direction (see Figure 8)?
  - Turning spaces can overlap other turning spaces.
  - Is the turning space completely outside the nearest vehicular travel lane?

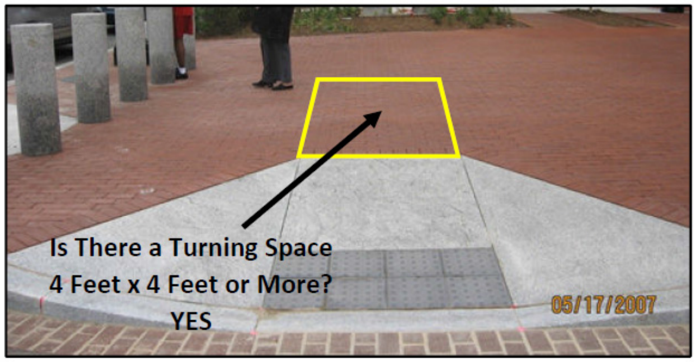


Figure 8: Complying Turning Spaces

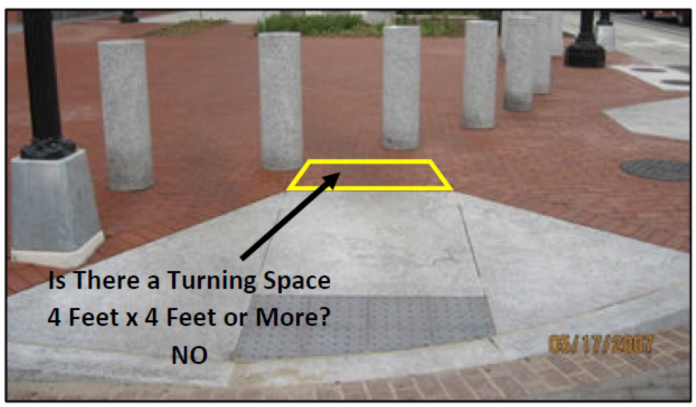


Figure 9: Non-Complying Turning Spaces

Figure 39: Sample pictures from the field guide

□ Are the turning spaces dimensions at the top and bottom of the curb ramp 4 feet or more in any direction (see Figure 11)?

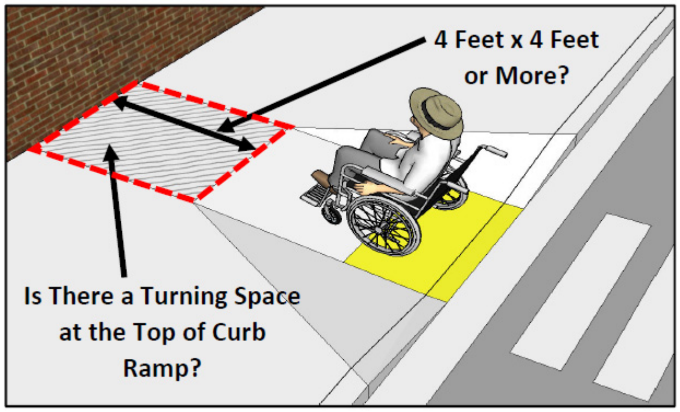


Figure 11: Turning spaces Dimensions

Figure 40: Sample illustration from the field guide

Step 7: The developed questions, pictures, and illustrations were organized in twenty checklists that were created to cover all the accessibility requirements in PROWAG. The identified twenty checklists in the field guide are designed to cover accessibility requirements for (1) pedestrian access routes, (2) alternate pedestrian access routes, (3) curb ramps, (4) detectable warning surfaces, (5) pedestrian street crossings, (6) accessible pedestrian signals and pedestrian pushbuttons, (7) transit stops and transit shelters, (8) on-street parking spaces, (9) passenger loading zones, (10) street furniture, (11) operable parts, (12) clear spaces, (13) knee and toe clearance, (14) reach ranges, (15) ramps, (16) stairways, (17) handrails, (18) doors, doorways, and gates, (19) visual characters on signs, and (20) international accessibility symbol.

Step 8: An additional section for defined terms was integrated at the end of the field guide to explain the technical terms of accessibility requirements, as shown in Figure 41.

3. Defined Terms

Accessible. A facility in the public right-of-way that complies with applicable accessibility laws and regulations in the state of Illinois.

Alteration. A change to a facility in the public right-of-way that affects or could affect pedestrian access, circulation, or use. Alterations include, but are not limited to, resurfacing, rehabilitation, reconstruction, historic restoration, or changes or rearrangement of structural parts or elements of a facility.

Blended Transition. A raised pedestrian street crossing, depressed corner, or similar connection between the

Figure 41: Sample of the Defined Terms section in the field guide

3.3. Size

Two sizes were investigated to determine the most effective size for the field guide. The first was letter paper size, which provided bigger space for the content. This size however might not be practical for use on site. The second was a custom paper size of 4.5 inches by 8.5 inches, which is practical for construction site conditions and can easily fit in the pocket of field engineers and/or their vehicles' glove compartments. This size however provides limited space per page for the contents of the field guide. Based on the feedback of the aforementioned multidisciplinary team, the second size was selected since it is more effective for a field guide, as shown in Figure 42. The field guide is also prepared in a digital form to facilitate its distribution electronically.

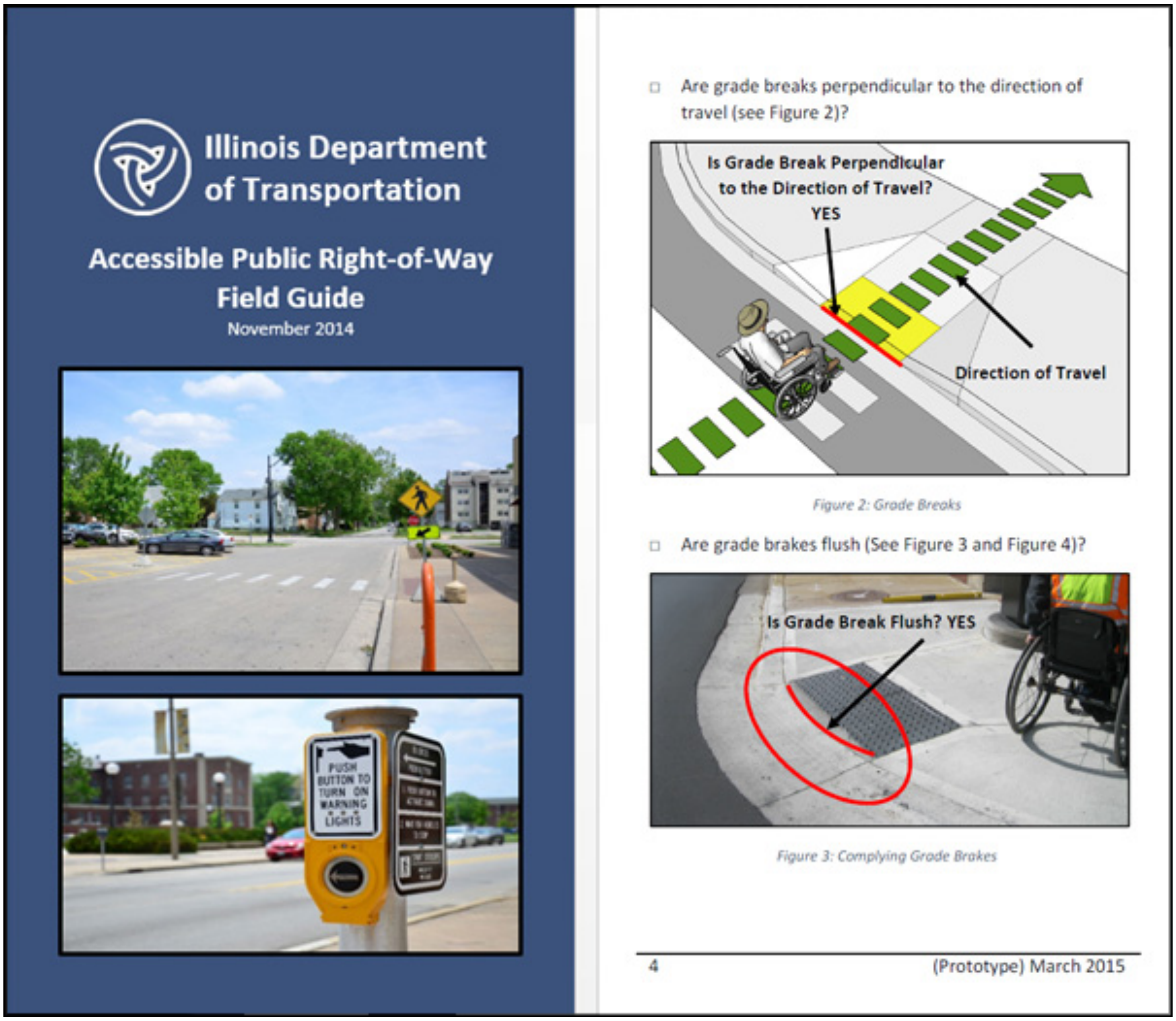


Figure 42: Example of the size and ratio of the field guide

CHAPTER 4 - AUTOMATED EXTRACTION OF SIDEWALK DIMENSIONS AND GEOMETRY FROM IMAGES

4.1. Introduction

This chapter presents the development of a novel and practical framework for automating the extraction and modeling of sidewalk conditions, dimensions and geometry from images. The framework provides decision makers in state and local governments with an automated methodology that overcomes the aforementioned limitations of existing self-evaluation techniques by (1) providing a practical and cost-effective procedure for conducting self-evaluations, (2) creating 3D models of existing sidewalks, and (3) identifying sidewalk dimensions and geometry from sidewalk images. The present framework is developed in three modules: (a) semantic segmentation module that uses Fully Convolutional Networks (FCNs) to recognize and mask sidewalks in input images, (b) 3D reconstruction module that builds a 3D point cloud of the recognized sidewalks, and (c) sidewalk dimensions module that fits a 3D surface to the reconstructed point cloud and extracts sidewalk dimensions and geometry from the 3D surface, as shown in Figure 43.

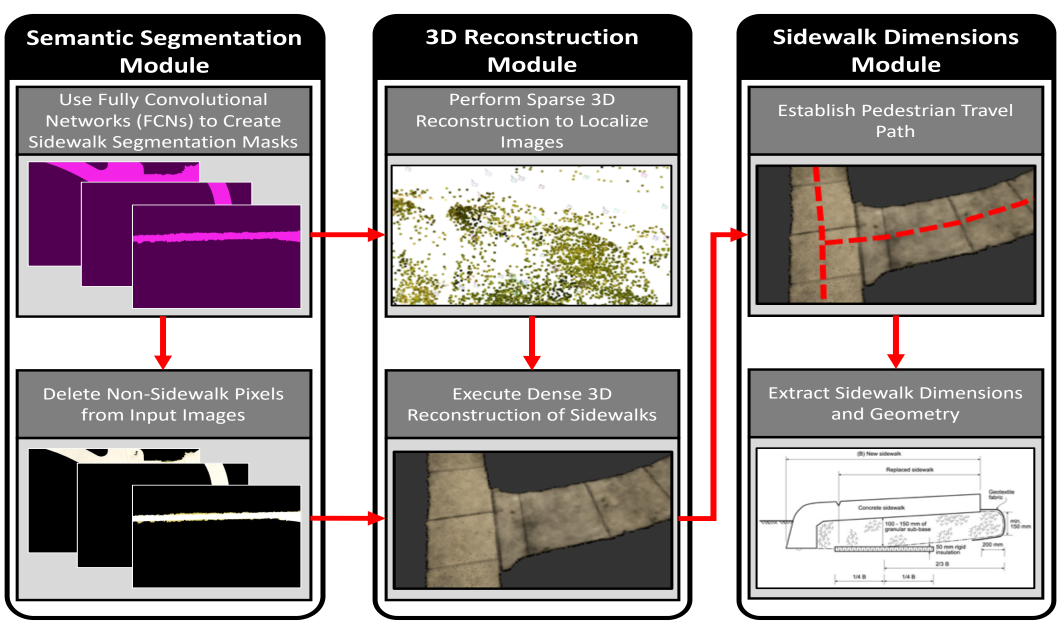


Figure 43. Framework development modules

4.2. Semantic Segmentation module

The purpose of the semantic segmentation module is to process captured sidewalk images to generate a set of masked images that include only sidewalk visual data after discarding all non-related pixels in the original images. To achieve this, the module integrates the development of a deep fully convolutional network (FCN) to automate the identification of sidewalk pixels from captured images. FCN is used in this module to perform binary dense pixel-wise image segmentation to classify all pixels in captured images as either sidewalk or background due to the reported capabilities of FCNs in (a) effectively capturing the 2-Dimensional nature of images, (b) utilizing sparsely connected neurons and pooling layers to minimize the required computational load, (c) differentiating between large number of classes, and (d) benefiting from parallel computation by utilizing graphic processing units (GPUs). Due to these capabilities, FCNs are reported to be an efficient and effective network architecture for image segmentation and analysis (Badrinarayanan et al. 2017; Chen et al. 2014; Ciresan et al. 2011; Couprie et al. 2013; Gupta et al. 2014; Krizhevsky et al. 2012; Long et al. 2015; Pakhomov et al. 2017; Sermanet et al. 2014).

The semantic segmentation module is developed in four steps (1) designing the image segmentation architecture of the neural network, (2) annotating sidewalk images to create a dataset with labeled ground truth and splitting it into training and testing datasets, (3) training the developed FCN to recognize sidewalks and identify all sidewalk related pixels using the training dataset, (4) testing the trained FCN and verifying its performance using the testing dataset, and (5) processing input images to generate a new set of images that include only sidewalk visual data, as shown in Figure 44.

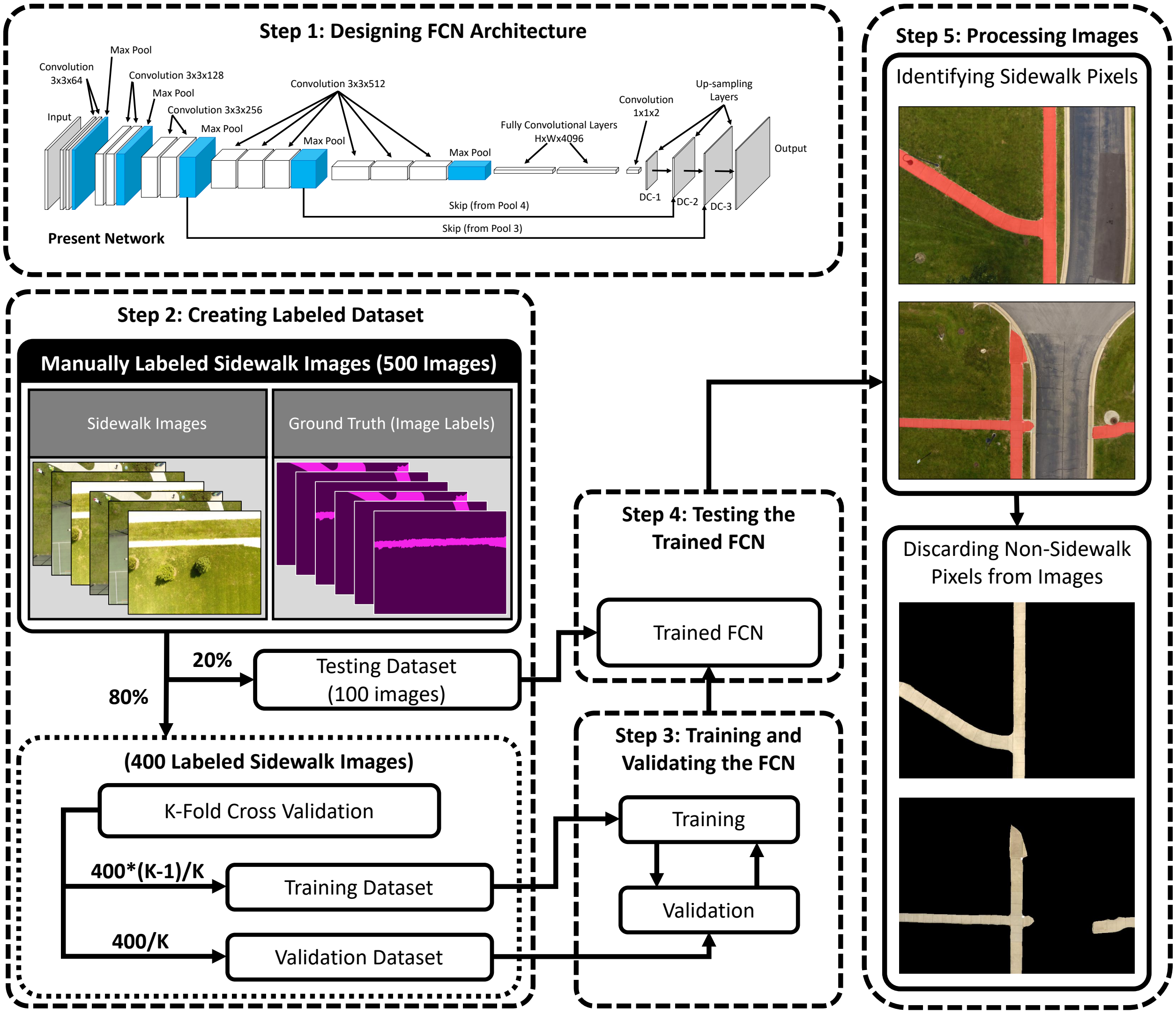


Figure 44. Development of Semantic Segmentation Module

4.2.1. Neural Network Architecture

The developed FCN modifies and expands the VGG-16 classifier architecture (Simonyan and Zisserman 2014) to enable sidewalk image segmentation. This is achieved in the developed FCN in five steps, as shown in Figure 45.

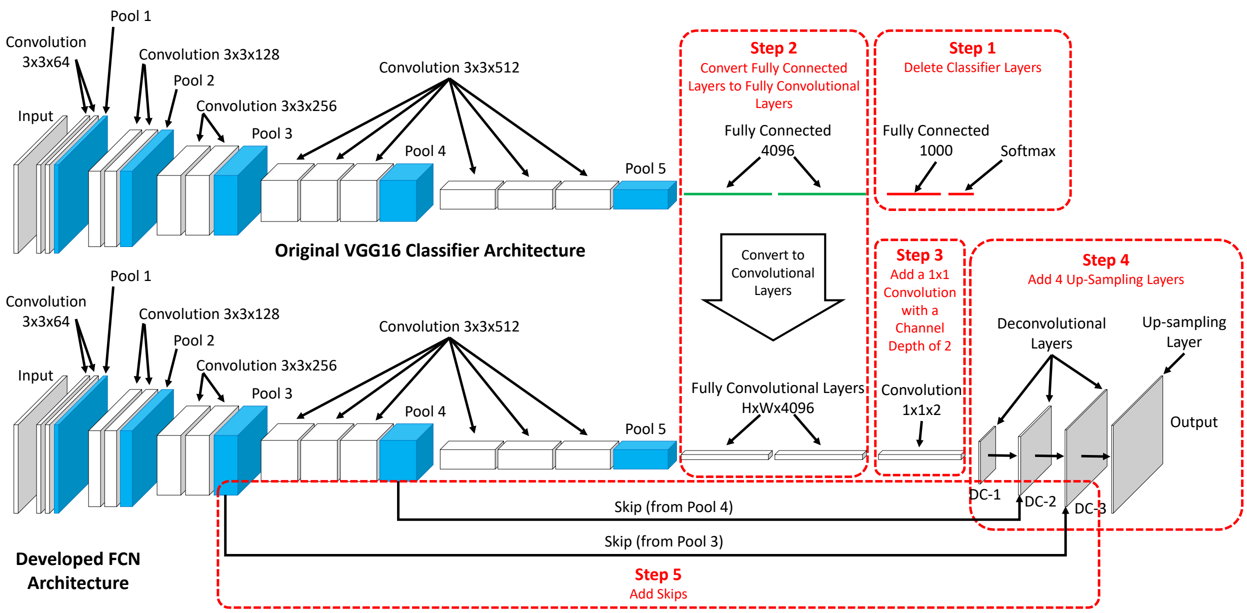


Figure 45. Architecture of the developed FCN

The first step discards the final classifier layers from the original VGG-16 architecture because they do not preserve the spatial data that is needed for image segmentation tasks. The second step converts both fully connected layers at the end of the original VGG-16 architecture to fully convolutional layers to preserve essential data that is required for segmentation because the two fully connected layers in the original architecture are incapable of preserving the spatial data of their input, as shown in Figure 45. The third step appends an additional 1x1 convolutional layer to the developed FCN with a channel dimension of 2 to represent the number of classes the FCN is trying to identify in input images (e.g. sidewalk and background). The fourth step adds four up-sampling layers at the end of the developed FCN to scale-up the predicted labels back to the original size of input images. Three of these up-sampling layers DC-1, DC-2, and DC-3 are "Deconvolutional" layers since they also use transposed convolution to create output with larger dimensions than their input. The fifth step adds "Skips" to improve the accuracy and detail of the predicted labels. Skips enable the developed FCN to combine information from two different layers as input for another layer. For example, the input for the up-sampling layer DC-2 includes the output of its predecessor layer DC-1 combined with information from a higher pooling layer Pool 4, which includes finer details, as shown in Figure 45 and

Figure 46. The aforementioned five steps enable the developed FCN architecture to preserve the spatial information from input images and utilize it in the up-sampling layers by introducing skips that help combine coarse semantic data from prediction layers (e.g. DC-2 and DC-3) with finer details from higher pooling layers (e.g. Pool 4 and Pool 3). In addition, the present architecture reduces the number of parameters in the FCN and enables it to accept variable input size images.

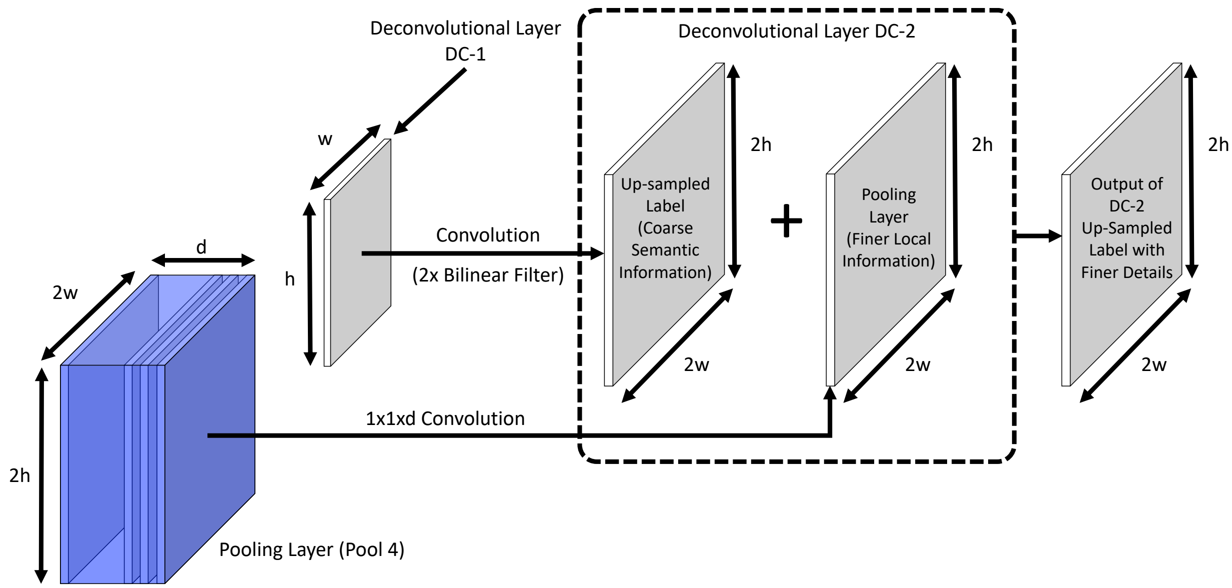


Figure 46. Up-sampling (deconvolutional) layers fusing coarse and fine information

4.2.2. Labeled Sidewalk Dataset Generation

A data set of 500 sidewalk images was captured to represent several conditions, dimensions, compliance statuses, and environments of existing sidewalks. All images were manually annotated to label each pixel as either sidewalk or background. These manually annotated images are then split into a training dataset that includes 400 images and a testing dataset that includes 100 images, based on recommendations for similar size datasets in the literature (Couprie et al. 2013; He et al. 2015). The training dataset is then split into two datasets for training and validation using the K-Fold Cross Validation methodology. This methodology requires splitting the dataset into K number of subsets where each include equal number of images, saving one of these parts for validation and using the remaining parts for training, as shown in Figure 44. It is recommended in the literature to set the value for K between 5 and 10 for best representative results (Rodriguez et al. 2010).

4.2.3. Training and Validation

The training of the developed FCN was performed using a computer with Intel 6-Core 8th generation i-7 processor, 16GB of DDR4 memory, Solid State Drive (SSD), and Nvidia GeForce GTX 1070 Max Q GPU with 8GB dedicated GPU memory. The training of the developed FCN was designed to execute repetitive iterations (epochs) of learning (forward) and back propagation (backward) passes until it achieves an average loss of 0.0055 or less. Every 10 epochs of the FCN training, a validation step was executed to test the network performance on a set of new images that were not used in the training process. The performance of the developed FCN (e.g. loss, average loss, and accuracy) was recorded to measure its progress in recognizing sidewalks in new images throughout the training duration. The FCN was set to use a fixed learning rate of $1 \times e^{-5}$, process three image per iteration (batch size=3 to avoid out-of-memory errors), and learn to look for only two classes (sidewalk and background). The training process was completed in 6 hours and 38 minutes, in which the network performed 31,185 epochs and was able to minimize the average loss for the training and validation datasets to 0.005453 and 0.004802, as shown in the orange and grey curves in Figure 47, respectively. This reflects the consistency of the network throughout the training process.

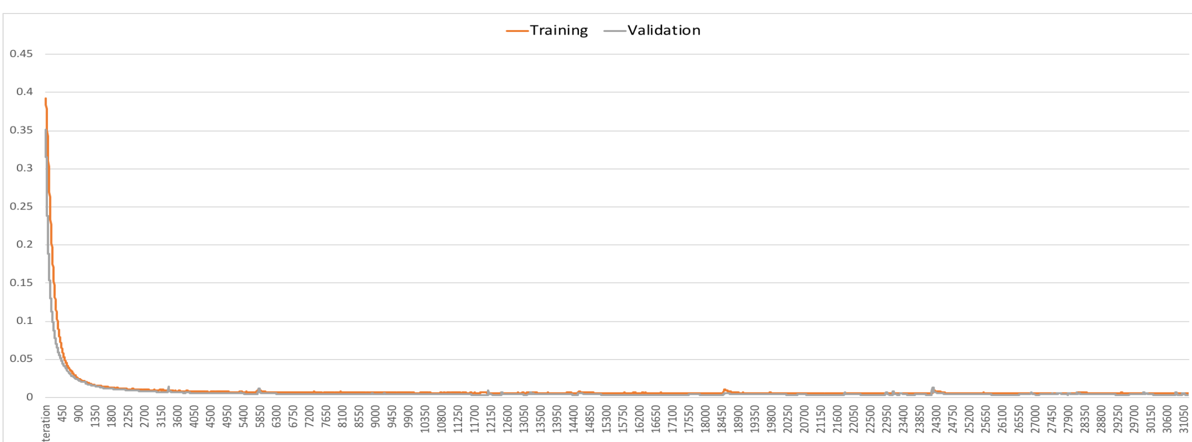


Figure 47. Prediction error (loss function) for training and validation datasets

4.2.4. Testing

The trained FCN was tested using a testing dataset that includes new images that were not seen by the FCN during its training and validation step, as shown in Figure 44. This testing dataset of 100 manually labeled images was used to determine (1) the network speed in predicting class labels for each pixel in input images, (2) the network accuracy in labeling the correct pixels with the correct labels for each class, and (3) the network overall accuracy for all classes. The methodology used to measure the accuracy of the network predictions is Intersection Over Union (IU) that calculates the intersection between prediction and ground truth (red) and divides it by the union of prediction and ground truth (all non-white pixels) (Long et al. 2015), as shown in Figure 48. The network was able to label all pixels in input images and classify them as either sidewalks or background in 13.51 seconds (average of 0.135 seconds per image) with an accuracy of 94.55% for sidewalks, 99.50% for background, and mean accuracy of 97.02 for both classes, as shown in Figure 48.

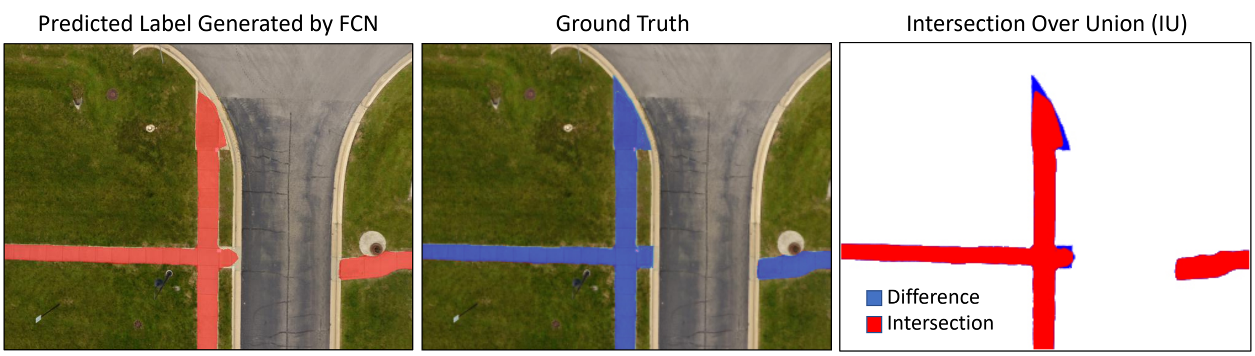


Figure 48. Prediction accuracy of sidewalk segmentation

4.2.5. Image Processing

After labeling all pixels in input images, the developed FCN processes each input image to create another image that includes only sidewalk visual data by discarding all pixels that have been labeled as background in the previous step, as shown in Figure 49.

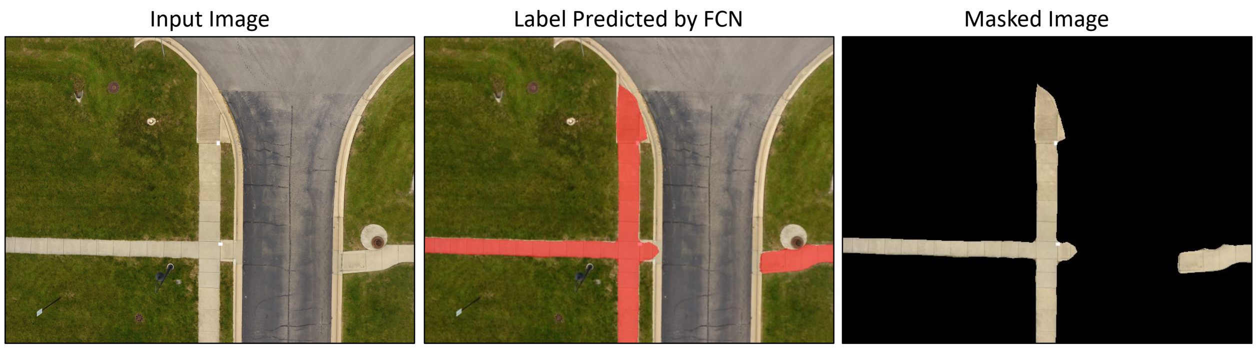


Figure 49. Processing input images to discard non-relevant pixels

4.3. 3D Reconstruction Module

The purpose of this module is to generate a dense 3D point cloud that represents the conditions, dimensions, and geometry of existing sidewalks using the masked images generated by the semantic segmentation module. To achieve this, the module focuses on (1) grouping input images into clusters based on their embedded GPS data, (2) creating a sparse 3D reconstruction based on input images, and (3) generating a dense point cloud based on the masked images, as shown in Figure 50.

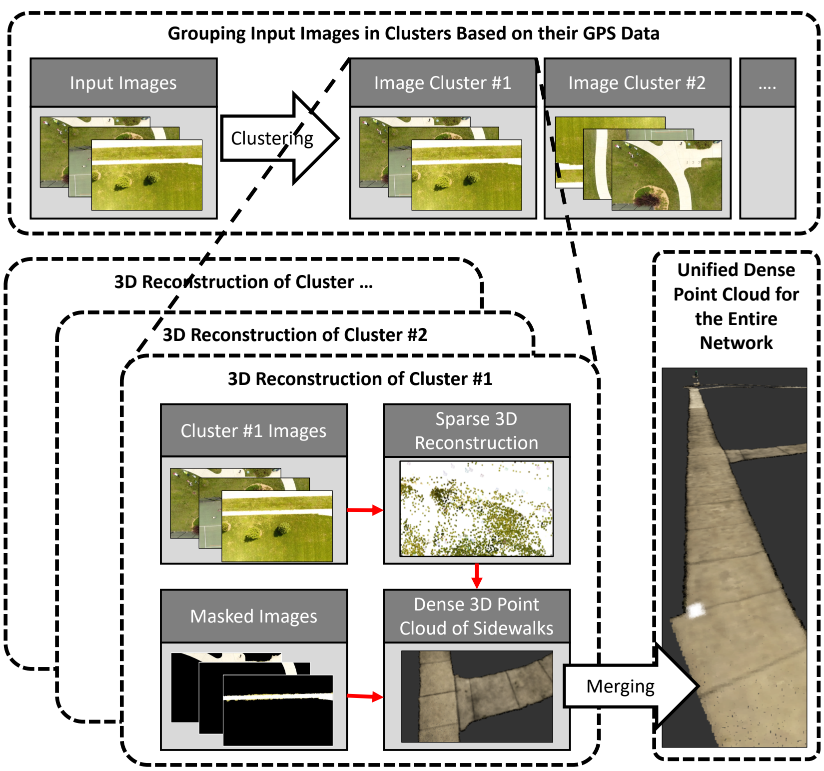


Figure 50. 3D Reconstruction module development steps

First, the present module reads the metadata of all input images to determine their GPS coordinates. It then analyzes these coordinates to group input images in clusters where each cluster includes images that focus on the same sidewalk. This clustering method helps divide the sparse reconstruction step into several smaller reconstruction processes that could be performed in parallel and require less processing time and computational power.

Second, a structure from motion algorithm (SFM) is utilized to calculate camera locations and generate a sparse point cloud from all input images, as shown in Figure 50. The SFM algorithm identifies camera locations by (1) using scale-invariant feature transform (SIFT) algorithm to identify features in each input image, (2) comparing features found in each of the images with all other images in the same cluster to identify matching features, (3) calculating camera locations based on matched features, and (4) generating sparse point cloud based on the calculated camera locations and pixel data from input images (Schonberger and Frahm 2016; Wu 2011, 2013; Wu et al. 2011).

Third, a multi-view stereo (MVS) algorithm is utilized to generate a dense point cloud based on the outputs of the first and second steps of this module. MVS generates additional points to represent objects and surfaces in the input images (Furukawa and Ponce 2010; Gong and Wang 2011). The present module utilizes the information in the sparse point cloud that was created in the previous step and the masked images that were generated by the image segmentation module to generate an accurate dense point cloud that only includes sidewalk visual data, as shown in Figure 50. The module then merges the generated dense point clouds of each cluster of images to create a single unified dense point cloud for the entire pedestrian network, as shown in Figure 50.

4.4. Sidewalk Dimensions Module

The purpose of the sidewalk dimensions module is to automate the extraction of sidewalk dimensions and geometry from the dense point cloud that was generated in the previous module. To achieve this, the module is designed to (1) fit a 3D surface to the dense point cloud, (2) establish pedestrian travel path in relation to the fitted surface, (3) generate longitudinal and cross profiles based on the established pedestrian travel path, and (4) extract sidewalk dimensions and slopes from the generated sidewalk profiles, as shown in Figure 51.

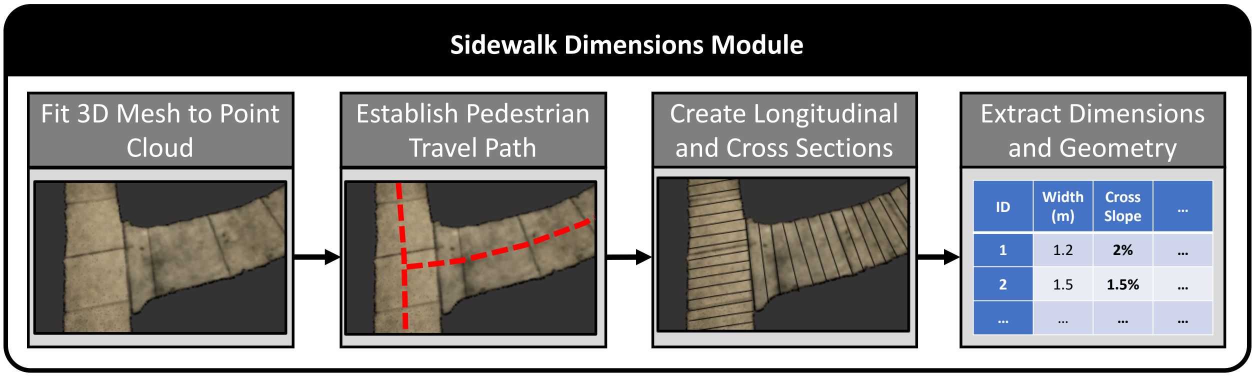


Figure 51. Sidewalk dimensions module development steps

First, the present module utilizes screened Poisson surface reconstruction algorithms to fit a 3D surface to the dense point cloud that was generated in the 3D reconstruction module, as shown in Figure 51. Screened Poisson surface reconstruction is used for this step due its reported performance in accurately fitting 3D surfaces to point clouds (Kazhdan and Hoppe 2013). Second, the module establishes pedestrian travel paths in relation to the fitted surface by utilizing (1) GPS metadata from input images, (2) camera locations from 3D reconstruction module, and (3) travel paths information that can be automatically imported from sidewalk layers in local GIS geodatabase files (e.g. state or local government database) or online GIS services such as Google Maps. This enables the module to accurately align the identified pedestrian travel path with the fitted 3D surface that was generated in the first step, as shown in Figure 51. Third, the module utilizes the established pedestrian travel path and the fitted 3D surface to automatically generate longitudinal and cross sections (profiles) of sidewalks every 2 feet, as shown in Figure 51. This 2-feet interval can be customized by decision makers to control the density of measurements based on sidewalk conditions. Fourth, these generated sidewalk profiles are then analyzed to automatically extract sidewalk width, length, running slope (the slope of the sidewalk along the direction of pedestrian travel), and cross slope (the slope of the sidewalk perpendicular to the direction of pedestrian travel), as shown in Figure 51.

4.5. Case Study

The purpose of this section is to analyze a real-life case study to illustrate the use of the developed framework and demonstrate its novel and practical capabilities. The case study required identifying and modeling the conditions, dimensions, and geometry of 830 meters of sidewalks which are required by the federally-mandated self-evaluations, as shown in Figure 52.

Figure 52. Example sidewalk network for the case study

For this case study, the required input data by the developed framework included a dataset of sidewalk images that were captured with a drone flying at altitudes of 65, 125, 250 feet while the camera angle is either 90 degrees (nadir) or 45 degrees. Each of the images has a resolution of 3000x4000 pixels and is saved in RGB color space. These input images were analyzed by the developed framework to efficiently extract and model sidewalk conditions, dimensions, and geometry. The framework was able to complete the semantic segmentation, 3D reconstruction, and sidewalk dimension modules for the entire case study in 327.5 minutes using a computer with Intel 6-Core 8^{th} generation i-7 processor, 16GB of DDR4 memory, Solid State Drive (SSD), and Nvidia GeForce GTX 1070 Max Q GPU with 8GB dedicated GPU memory.

The generated results of the framework for this case study illustrate its novel and practical contributions, including its ability to (1) provide a cost-effective and practical methodology for conducting self-evaluations using sidewalk images; (2) create 3D models of existing sidewalks that can be used in analyzing their conditions, as shown in Figure 53; and (3) automatically extract sidewalk dimensions and geometry from the generated 3D model.

First, the framework was able to extract and model sidewalk dimensions and geometry for all sidewalks in the case study in 327.5 minutes including 0.25 labor hours. This overall time consists of 12 minutes for setting up the drone and capturing all 602 images; 3 minutes for transferring image data from the drone to a computer; and 1.5, 301, and 13 minutes for the developed framework to identify sidewalk pixels in all 602 input images, reconstruct 3D point cloud of the sidewalk network, and extract sidewalk dimensions and geometry, respectively. The dimensions and geometry of the sidewalk network in this case study was manually measured on site to verify the results of the framework and evaluate its performance. The manual field measurement for this case study required 332 minutes (5.5 hours) by two field inspectors (11 labor hours) and was able to generate only paper reports and checklists that require additional time and effort to store it in digital format and/or generate 3D models of the sidewalk network. The manually generated measurements of the sidewalk dimensions and geometry for this case study were identical to those generated by the developed framework, which confirms its accuracy and validity. Furthermore, these results confirm that the developed framework provides significant efficiency and cost-effectiveness improvements compared to traditional field measurement methods as it reduced the required labor hours from 11 to 0.25 (4400%).

Second, the developed framework was able to generate dense 3D point cloud that included more than 24 million points representing all sidewalks in the case study (see Figure 53) compared to the paper forms and checklists generated by the traditional field measurement methods. Third, the developed framework was able to automatically extract dimensions and geometry data of all sidewalks in the case study without the need for field inspectors based on the generated 3D model.

Figure 53. Unified 3D model of all sidewalks in the case study

4.6. Summary and conclusions

This chapter presented the development of a novel framework for automating the extraction and 3D modeling of sidewalk conditions, dimensions, and geometry from sidewalk images. The framework was developed in three modules: (1) semantic segmentation module that used fully convolutional networks to identify sidewalk-related pixels in input images, (2) 3D reconstruction module that built 3D point clouds of sidewalks, and (3) sidewalk dimensions module that fitted 3D surfaces to the reconstructed point clouds to automatically extract sidewalk dimensions and geometry. The primary contributions of this research to the body of knowledge are its original methodology for: (1) providing a cost-effective and practical framework for conducting self-evaluations using sidewalk images, (2) creating 3D models of existing sidewalks that can be used in analyzing their conditions, and (3) automatically extracting sidewalk dimensions and geometry from the generated 3D models. These novel and practical capabilities should prove useful to decision makers in state and local governments and are expected to improve the efficiency and effectiveness of conducting the federally-mandated self-evaluations. The scope of this chapter covers extracting the dimensions and geometry of one type of pedestrian facilities, sidewalks. Future research should be conducted to expand the proposed methodologies to address extracting dimensions and geometry of other types of pedestrian facilities.

CHAPTER 5 - AUTOMATED NON-COMPLIANCE ASSESSMENT OF PEDESTRIAN FACILITIES

5.1. Introduction

This chapter presents the development of a novel model for automating the assessment of the degree of non-compliance of pedestrian facilities with accessibility requirements to enable public agencies to maximize their compliance with the ADA self-evaluation requirement. The model is designed to support decision makers in state and local governments in identifying non-compliant sidewalks and pedestrian facilities in their public right-of-way and evaluating the degree of non-compliance of each of these facilities with accessibility requirements. The model provides the capabilities of (1) efficiently quantifying the degree of non-compliance of all types of pedestrian facilities in the public right-of-way with accessibility requirements including transit shelters, on-street parking spaces, and passenger loading zones; (2) generating a pedestrian type non-compliance index for each type of pedestrian facility to enable decision makers to rank these facility types based on their degree of non-compliance with accessibility requirements; and (3) identifying a region non-compliance index for a specific geographical region that represents the overall degree of non-compliance of all pedestrian facilities in that region to enable decision makers to prioritize future upgrade projects by comparing the degree of non-compliance of these regions. These novel and unique capabilities of the developed model are designed to support decision makers in improving their efficiency and effectiveness in conducting the aforementioned federally-mandated self-evaluations and in prioritizing their planned upgrade projects to maximize compliance with accessibility requirements.

The model is developed in four main phases: (i) accessibility requirements analysis phase that identifies pedestrian facility types and their related accessibility requirements; (ii) non-compliance assessment phase that develops a Non-Compliance Index (NCI) to quantify the degree of non-compliance of each type of pedestrian facility in the public right-of-way with accessibility requirements; (iii) collective non-compliance phase that aggregates the individual non-compliance indices of a group of pedestrian facilities based on their type and/or geographical location to enable their ranking and prioritization for upgrades; and (iv) performance evaluation phase that analyzes a case study to illustrate the use of the developed model and demonstrate its novel capabilities. The following sections provide a concise description of these four model development phases, as shown in Figure 54.

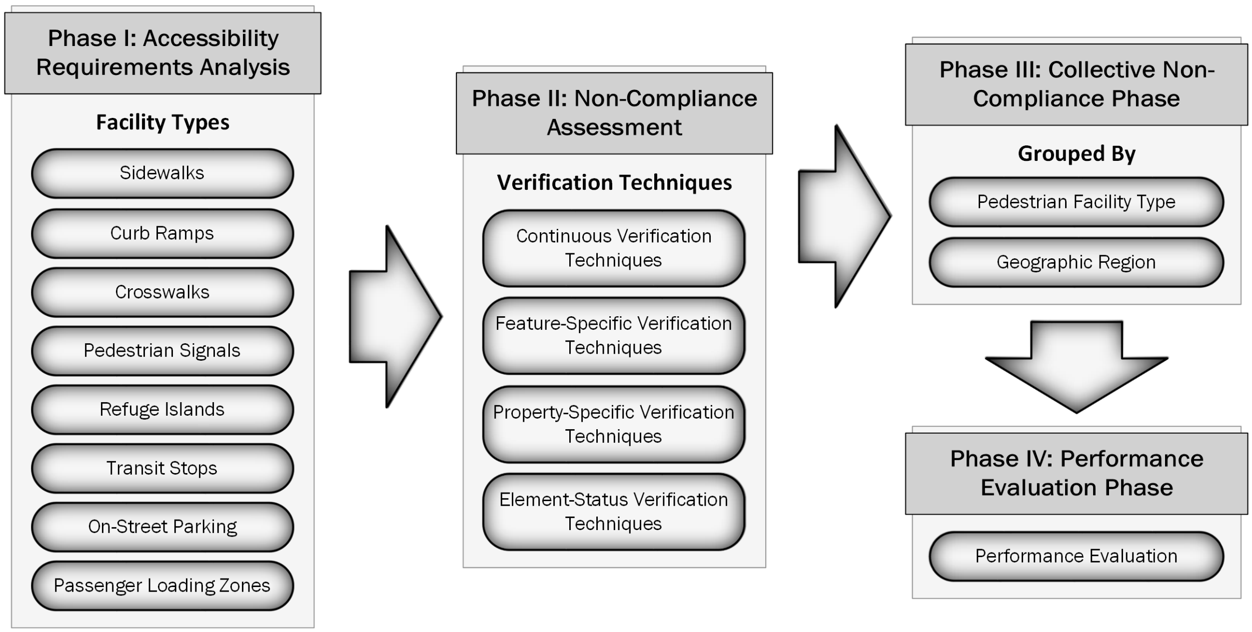


Figure 54: Model development phases

5.2. Accessibility Requirements Analysis

The purpose of this phase is to analyze all accessibility requirements and identify all relevant metrics that represent the degree of non-compliance of pedestrian facilities with accessibility requirements. The degree of non-compliance of a specific pedestrian facility can be determined by comparing the existing conditions and measurements of that facility with accessibility requirements (El-Rayes et al. 2016). When a pedestrian facility (e.g. a curb ramp or sidewalk) does not meet the minimum accessibility requirements specified by state and federal laws and regulations, the pedestrian facility is considered non-compliant (U.S. Access Board 2011). This binary classification of pedestrian facilities as either compliant or non-compliant was reported to be ineffective for assessing the degree of non-compliance of sidewalks and pedestrian facilities (CCRPC 2016; City of Clayton 2014). The cause of non-compliance for these non-compliant facilities can be due to major or minor deviations from the minimum accessibility requirements. While major deviations from accessibility requirements often render facilities to be fully inaccessible, minor deviations often enable facilities to be partially accessible. For example, a 2.0 feet wide and a 3.5 wide sidewalks are both classified as non-compliant because their width is less than the required 4.0 feet minimum width. In this example however, the 2.0 feet wide sidewalk is fully inaccessible while the 3.5 feet wide sidewalk can provide partial accessibility for pedestrians travelling in one direction (PROWAAC 2007).

To overcome the limitation of the aforementioned binary classification of compliant or non-compliant, the present model is designed to distinguish between varying degrees of non-compliance by developing a novel non-compliance index (NCI). NCI represents the degree of non-compliance for pedestrian facilities using a scale that ranges from 0.0% for fully compliant facilities to 100.0% for fully non-compliant. NCI of a given pedestrian facility is calculated in the present model by identifying the degree of deviation between its existing conditions, measurements, and geometry and its specified accessibility requirements. The model is designed to calculate NCI for all pedestrian facility types including (1) sidewalks, (2) curb ramps, (3) crosswalks, (4) pedestrian signals, (5) refuge islands, (6) transit stops, (7) on-street parking spaces, and (8) passenger loading zones (U.S. Access Board 2011). Each of these pedestrian facility types has accessibility requirements that must be satisfied in order to achieve compliance with accessibility laws and regulations, as shown in Figure 55.

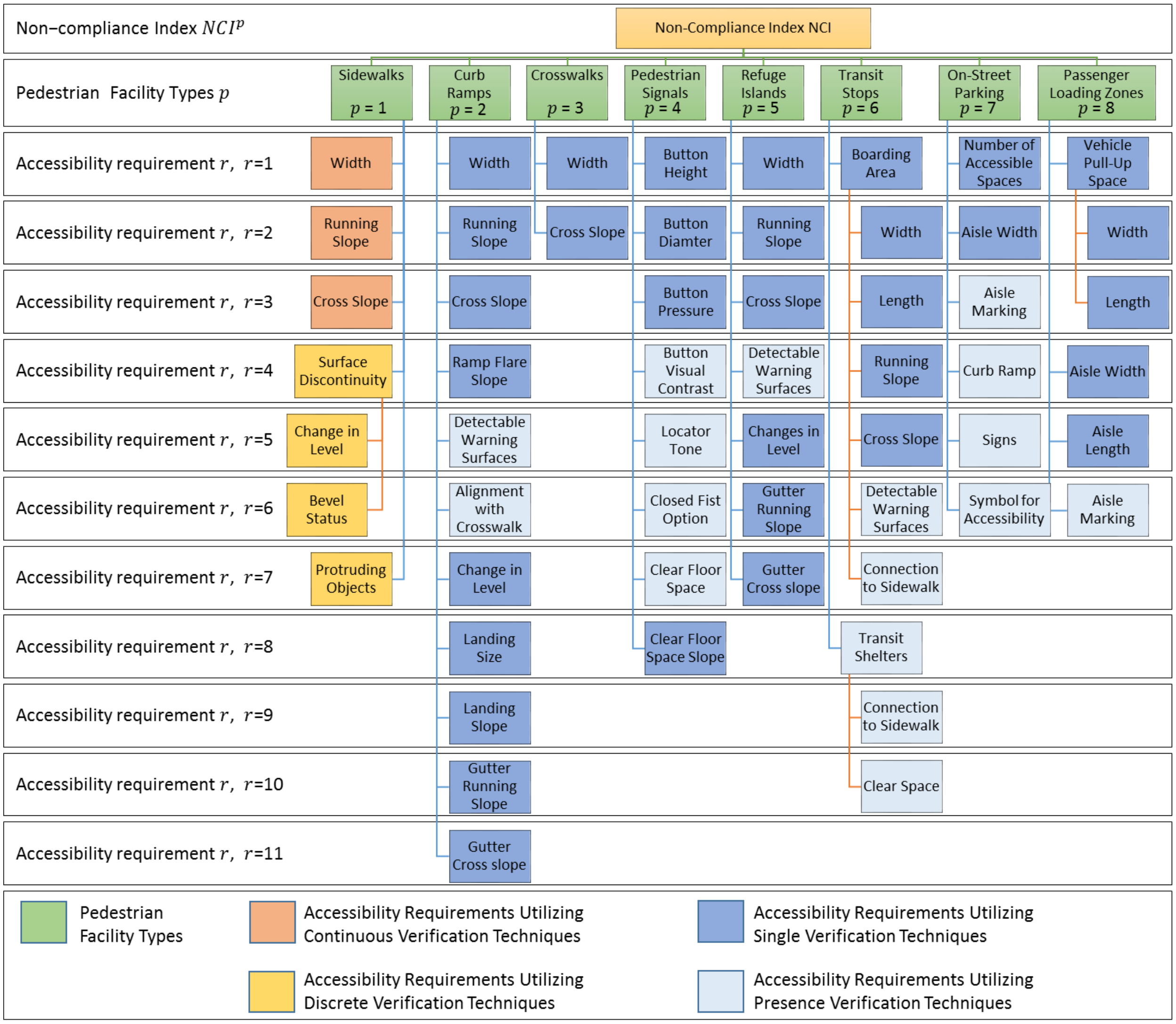


Figure 55: Accessibility requirements for pedestrian facility types

5.3. Non-Compliance Assessment

The purpose of this phase is to develop a novel non-compliance index NCI_i^p that represents the degree of non-compliance of each pedestrian facility type p with accessibility requirements, as shown in equation (1).

$$NCI_i^p = \sum_{r=1}^{R} W_r^p \times S_{i,r}^p \tag{1}$$

Where, NCI_i^p is non-compliance index for pedestrian facility of type p that is located in geographical location i, p is pedestrian facility type (see Figure 55), i is geographical location of pedestrian facility, r is accessibility requirement for each pedestrian facility type p (see Figure 55), R is total number of accessibility requirements for pedestrian facility type p (see Figure 55), W_r^p is relative importance weight of accessibility requirement r for pedestrian facility type p, and $S_{r,i}^p$ is non-compliance score of pedestrian facility type p with accessibility requirement r in geographical location i.

The non-compliance index NCI^p for each pedestrian facility type p represents the weighted average of non-compliance scores including all its accessibility requirements. For example, the non-compliance index for the sidewalk in location i (NCI_i^1) is determined by calculating the weighted average of non-compliance scores of all the sidewalk accessibility requirements ($r = 1\ to\ 5$) including its width, running slope, cross slope, surface discontinuities, and protruding objects (U.S. Access Board 2011). NCI_i^1 is calculated using equation (1) based on the weight of each accessibility requirement W_r^1 and its non-compliance score $S_{r,i}^1$. These weights W_r^p can be specified by decision makers to reflect the relative importance of each accessibility requirement r (see example in Table 10), and the non-compliance score $S_{r,i}^1$ can be determined based on the existing condition of the sidewalk and the specified ranges shown in Table 10. Similarly, a list of accessibility requirements and their non-compliance score ranges were developed for each of the remaining pedestrian facility types in Figure 55 ($p = 2\ to\ 8$), as shown in appendix C.

Table 10: Example Weights and Non-Compliance Scores for Sidewalk Requirements

Sidewalk Requirement	r	Weights (W_r^1)%	Range of Existing Conditions	Non-Compliance Score $(S_{i,r}^1)$%
Width	1	20	$Width < 3.00\ feet$	100
			$3.00 \leq Width < 3.5\ feet$	80
			$3.25 \leq Width < 3.5\ feet$	60
			$3.5 \leq Width < 3.75\ feet$	40
			$3.75 \leq Width < 4.00\ feet$	20
			$Width \geq 4.00\ feet$	0
Running Slope	2	20	$Running\ Slope > 12.5\%$	100
			$12.5\% \geq Running\ Slope > 10\%$	50
			$10\% \geq Running\ Slope > 8.33\%$	10
			$8.33\% \geq Running\ Slope > 5\%$	5
			$Running\ Slope \leq 5\%$	0
Cross Slope	3	20	$Cross\ Slope > 8\%$	100
			$8\% \geq Cross\ Slope > 6\%$	50
			$6\% \geq Cross\ Slope > 4\%$	25
			$4\% \geq Cross\ Slope > 2\%$	5
			$Cross\ Slope \leq 2\%$	0
Surface Discontinuities	4	20	$Vertical\ Change\ in\ Level > 1.0"$	100
			$1.0" \geq Vertical\ Change\ in\ Level > 0.75"$	80
			$0.75" \geq\ Vertical\ Change\ in\ Level > 0.5"$	25
			$0.5" \geq\ Vertical\ Change\ in\ Level > 0.25"$	5
			0.5≥ Change in Level>0.25, $Beveled$	0
			$Vertical\ Change\ in\ Level \leq 0.25"$	0
Protruding Objects	5	20	$Protrusion\ Distance > 7"$	100
			$7" \geq\ Protrusion\ Distance > 5"$	50
			$5 \geq Protrusion\ Distance > 4"$	5
			$Protrusion\ Distance \leq 4"$	0

The non-compliance score $S_{r,i}^p$ is calculated in the present model to represent the degree of non-compliance of pedestrian facility p in location i with accessibility requirement r. Compliance with the aforementioned accessibility requirements can to be verified using a wide range of techniques depending on the type of facility and its accessibility requirements. For example, the width requirement of the sidewalk needs to be verified by using continuous measurement of the sidewalk width along its entire length (U.S. Department of Justice 1994). On the other hand, the protrusion distance requirement of sidewalks needs to be verified by taking measurements of each protruding object along the length of the sidewalk (U.S. Access Board 2011). All these possible non-compliance verification techniques are organized in the present model in four main categories: (1) continuous verification, (2) discrete verification, (3) single verification, and (4) presence verification, as shown in Table 11. These four categories of verification techniques are used to (a) classify the aforementioned accessibility requirements of all pedestrian facilities into four categories as shown in Figure 55; and (b) calculate the non-compliance score $S_{r,i}^{p}$ for each of these accessibility requirement categories as described in the following sections.

Table 11: Compliance Verification Techniques for Pedestrian Facilities

Compliance Verification Technique	Description	Example
Continuous Verification	Collecting continuous measurements along the entire length of pedestrian facility.	Sidewalk Width
Discrete Verification	Conducting discrete measurements along the length of pedestrian facility.	Protruding Objects
Single Verification	Taking single measurement for the entire pedestrian facility.	Curb Ramp Width
Presence Verification	Verifying if the required features such as detectable warning surface is present, non-standard, or missing.	Detectable Warning Surfaces

5.3.1. Continuous verification

This compliance verification category requires collecting continuous measurements along the entire length of pedestrian facility to calculate its non-compliance score $S_{i,r}^{p}$. As shown in equation (2), $S_{i,r}^{p}$ is calculated in this category by dividing the pedestrian facility into several segments, determining non-compliance score $S_{i,r,a}^{p}$ for each segment a, and calculating the average of these scores to find $S_{i,r}^{p}$ for the entire pedestrian facility. For example, the non-compliance score $S_{i,1}^{1}$ for the sidewalk width located in geographical location i is calculated by (i) dividing the entire length of the sidewalk into several segments $a \in (1, 2, 3, \dots, A_{i}^{1})$ based on their width, as shown in Figure 56; (ii) determining the sidewalk width non-compliance score $S_{i,1,a}^{1}$ of each segment a based on its minimum width ($width_{a}$) and scoring criteria (see example in); and (iii) calculating an average $S_{i,1}^{1}$ for the entire sidewalk.

$$S_{i,r}^{p} = \frac{\sum_{a=1}^{A_i^p}\left(\frac{L_a}{BL_i^p} \times S_{i,r,a}^{p}\right)}{A_i^p} \quad (2)$$

Where, $S_{i,r}^{p}$ is non-compliance score for the requirement r of pedestrian facility located in geographical location i, a is segment of pedestrian facility, A_i^p is total number of segments in pedestrian facility of type p located in geographical location i, L_a is length of segment a of the pedestrian facility, BL_i^p is total length of pedestrian facility, and $S_{i,r,a}^{p}$ is non-compliance score of segment a of the pedestrian facility.

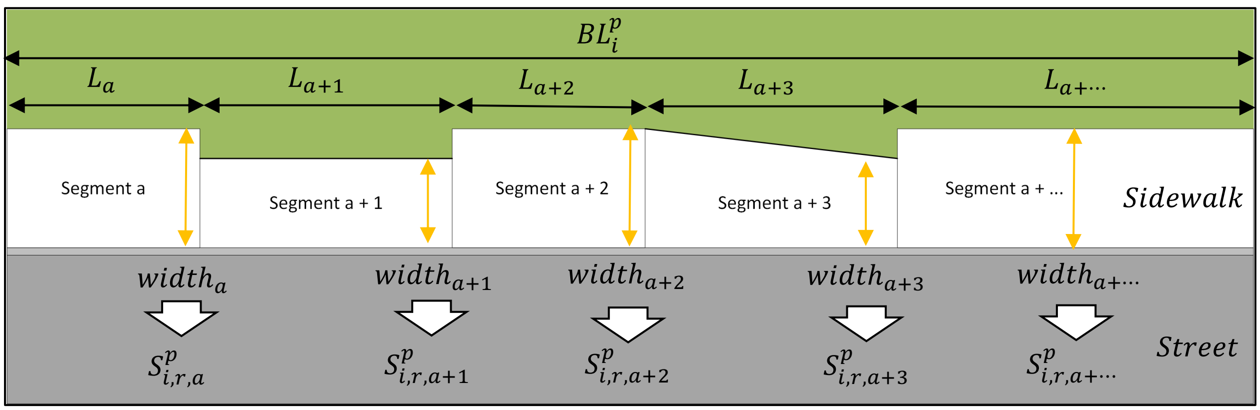


Figure 56: Continuous verification along the entire sidewalk length

5.3.2. Discrete verification

This compliance verification category requires conducting discrete measurements along the entire length of pedestrian facility to calculate its non-compliance score $S_{i,r}^{p}$. As shown in equation (3), $S_{i,r}^{p}$ is calculated in this category by identifying points $b \in (1,2,3,\dots,B_i^p)$ where a change in specific pedestrian facility dimensions occur, assigning a non-compliance score to each of these points based on its dimensions, and calculating the average of these scores to find $S_{i,r}^{p}$ for the entire pedestrian facility. For example, sidewalk surface discontinuity non-compliance score $S_{i,4}^{1}$ for a sidewalk in location i is calculated by (i) identifying surface discontinuities $b \in (1,2,3,\dots,B_i^1)$ in sidewalk, as shown in Figure 57; (ii) determining a non-compliance score $S_{i,4,b}^{1}$ for each surface discontinuity based on its vertical change in level SD_b and scoring criteria (see example in); and (iii) calculating an average sidewalk surface discontinuity non-compliance score $S_{i,4}^{1}$ for the entire sidewalk.

$$S_{i,r}^{p} = \frac{\sum_{b=1}^{B_i^p}\left(S_{i,r,b}^{p}\right)}{B_i^p} \times \frac{N_{i,r}^{p}}{N_{r,max}^{p}} \tag{3}$$

Where, $S_{i,r}^{p}$ is non-compliance index for requirement r of pedestrian facility located in geographical location i, b is a point where a change in the pedestrian facility dimension is recorded, B_i^p is total number of points b where a change in the pedestrian facility dimension is recorded, $S_{i,r,b}^{p}$ is non-accessibility score of requirement r of point b in pedestrian facility, $N_{i,r}^{p}$ is number of points b per linear foot in pedestrian facility, and $N_{r,max}^{1}$ is the maximum number of points b per linear foot for all pedestrian facilities of type p in the city.

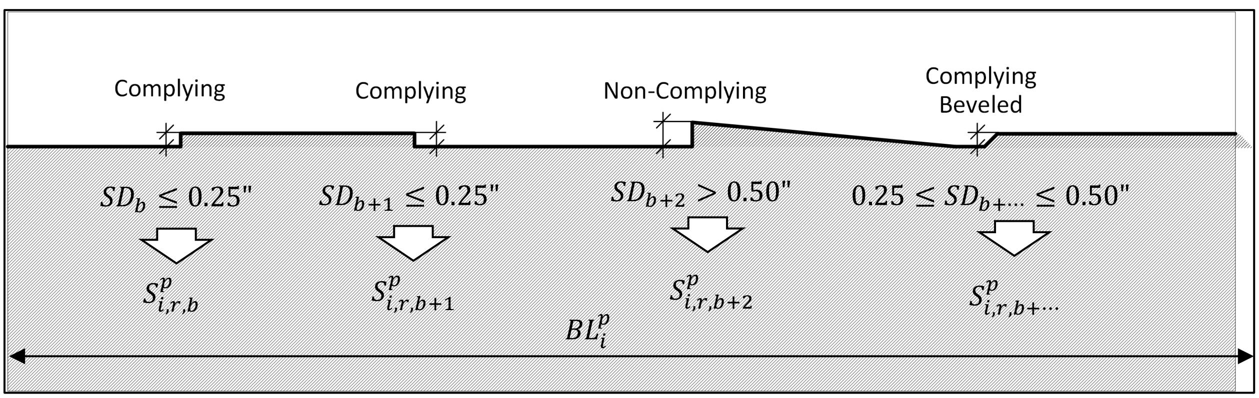


Figure 57: Longitudinal section of sidewalk showing surface discontinuities SD_b

5.3.3. Single verification

This compliance verification category requires conducting single measurements at each pedestrian facility to identify its non-compliance score $S_{i,r}^{p}$ by evaluating the compliance of its existing conditions with accessibility requirement r, as shown in the curb ramp cross slope example in Table 12.

Table 12: Example Non-Compliance Scores for Curb Ramp Cross Slope (CCRPC 2016)

Curb Ramp Cross Slope	**Non-Compliance Score $S_{i,3}^2$ (%)**
$Cross\ Slope > 10\%$	100
$10\% \geq Cross\ Slope > 8\%$	80
$8\% \geq Cross\ Slope > 6\%$	60
$6\% \geq Cross\ Slope > 4\%$	40
$4\% \geq Cross\ Slope > 2\%$	20
$Cross\ Slope < 2\%$	0

5.3.4. Presence verification

This compliance verification category requires verifying if the required feature is present, non-standard, or missing to identify its non-compliance score $S_{i,r}^p$ by evaluating the compliance of its existing condition with accessibility requirement r, as shown in the curb ramp detectable warning surface example in Table 13.

Table 13: Example Non-Compliance Scores for Curb Ramp Detectable Warning Surfaces

Curb Ramp DWS	**Non-Compliance Score $S_{i,5}^2$ (%)**
Missing	100
Non-Standard	50
Present	0

5.4. Collective Non-Compliance

The purpose of this phase is to aggregate the previously calculated individual non-compliance indices NCI_i^p of a group of pedestrian facilities based on their type p and/or geographical region g to enable their ranking and prioritization for upgrades. The two collective non-compliance indices calculated in this phase are (a) pedestrian facility type non-compliance index NCI^p, and (b) region non-compliance index NCI^g. First, pedestrian facility type non-compliance index NCI^p is calculated in the present model by averaging all the previously calculated individual non-compliance indices NCI_i^p for each pedestrian facility type p. Second, region non-compliance index NCI^g is calculated by (1) computing pedestrian facility type non-compliance indices $NCI^{p,g}$ for the subset of all pedestrian facility types p that are located in the user-specified geographical region g; and (2) computing a weighted average of all $NCI^{p,g}$ calculated in the previous step to identify a collective region non-compliance index NCI^{g}, as shown in equation (4).

$$NCI^{g} = \sum_{p=1}^{8} NCI^{p,g} \times W^{p} \tag{4}$$

Where, NCI^{g} is collective non-compliance index for all pedestrian facilities in region g, $NCI^{p,g}$ is collective non-compliance index for all pedestrian facilities of type p in the region g, and W^{p} is relative importance weight of pedestrian facility type p.

5.5. Performance Evaluation Phase

The purpose of this phase is to analyze a case study to illustrate the use of the model and demonstrate its novel and unique capabilities. The case study requires assessing the degree of non-compliance of 1327 pedestrian facilities in a small town that includes all pedestrian facility types, as shown in Table 14. Decision makers need to assess the degree of non-compliance of these pedestrian facilities in order to comply with the federal mandate to conduct self-evaluations and prioritize these facilities for future upgrade projects.

Table 14: Pedestrian Facilities in the Case Study

p	**Pedestrian Facility Type**	**Number of Facilities in the Case Study**
1	Sidewalks	864
2	Curb Ramps	384
3	Crosswalks	32
4	Pedestrian Signals	16
5	Refuge Islands	14
6	Transit Stops	10
7	On-Street Parking	4
8	Passenger Loading Zones	3
	Total	1327

For this case study, the required input data by the model include (1) dimensions and slopes of all sidewalks and pedestrian facilities that are readily available in most municipalities sidewalk network inventory databases (CCRPC 2016; City of Bellevue 2008; City of Clayton 2014); and (2) the geographical regions that decision makers need to calculate their collective non-compliance index NCI^g. The model utilizes this input data to calculate, (1) the non-compliance index NCI_i^p for each of the 1327 pedestrian facilities in this case study; (2) the collective non-compliance index NCI^p for each pedestrian facility type p; (3) the collective non-compliance index NCI^g for each user specified region g in the case study using the aforementioned calculation procedure.

The generated results for this case study illustrate the novel and unique capabilities of model that can be used by decision makers to (a) efficiently quantify the degree of non-compliance of all types of pedestrian facilities including transit shelters, on-street parking spaces, and passenger loading zones; (b) assess the degree of non-compliance of each pedestrian facility type to identify facility types that are in urgent need for upgrades; (c) prioritize pedestrian facilities upgrade projects in multiple regions based on their region non-compliance index; and (d) classify pedestrian facilities based on the severity of their non-compliance with accessibility requirements.

The capability of the present model to efficiently quantify the degree of non-compliance of pedestrian facilities can be illustrated by its ability to (a) analyze all types of pedestrian facilities (see Figure 54) including transit shelters, on-street parking spaces, and passenger loading zones using the aforementioned novel assessment methodology; and (b) complete the computational assessment of all the aforementioned 1327 pedestrian facilities in 2.053 seconds with an average computational time of 0.0015 seconds per pedestrian facility. This computational efficiency enables the model to perform compliance assessments for all types of pedestrian facilities for large datasets that are often encountered in larger cities. For example, the accessibility requirements for 48,334 pedestrian facilities that are included in a dataset for a city with a population of 204,897 residents (CCRPC 2016) can be assessed using the present model in approximately 75 seconds.

The model also provides the capability of assessing the collective degree of non-compliance for each pedestrian facility type to enable decision makers to prioritize the upgrade of these different types of facilities. For example, the case study results illustrate that on-street parking spaces suffer from the highest level of non-compliance and therefore they have the greatest need for upgrades as shown in Figure 58. In addition, the model calculates the ranges of non-compliance for each pedestrian facility type to highlight the deviation of individual facilities form the collective index. For example, the results indicate that pedestrian signals exhibit varying degrees of non-compliance ranging from 0.0% to 82.5%, while sidewalks exhibit a narrower range of 0.0% to 33.8% (see Figure 58).

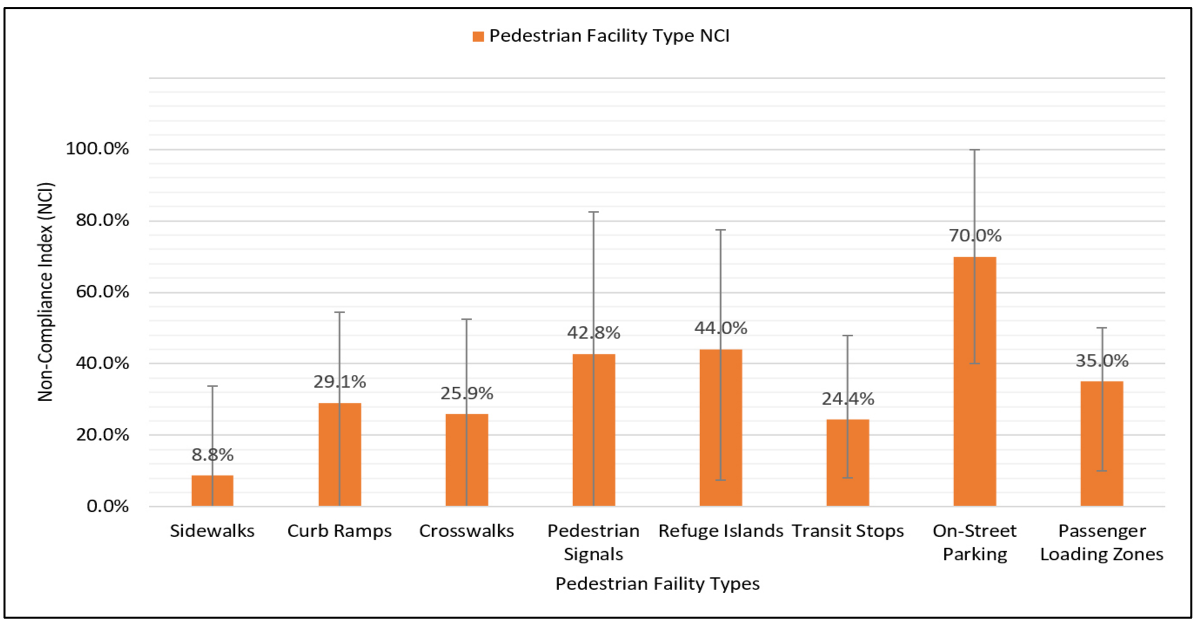


Figure 58: Non-compliance indices for all pedestrian facility types

The model can also be used to prioritize pedestrian facilities upgrade projects in multiple geographical regions based on their non-compliance index. This enables decision makers to rank upgrade projects based on the overall non-compliance in each region. For example, the second region in this case study has the highest non-compliance index of 39.1% and therefore it has the greatest need for upgrade, as shown in Figure 59. This region contains 59 pedestrian facilities including 37 sidewalks, 15 curb ramps, 2 crosswalk, 1 pedestrian signal, 1 refuge island, 1 transit stop, 1 on street parking, and 1 passenger loading zone.

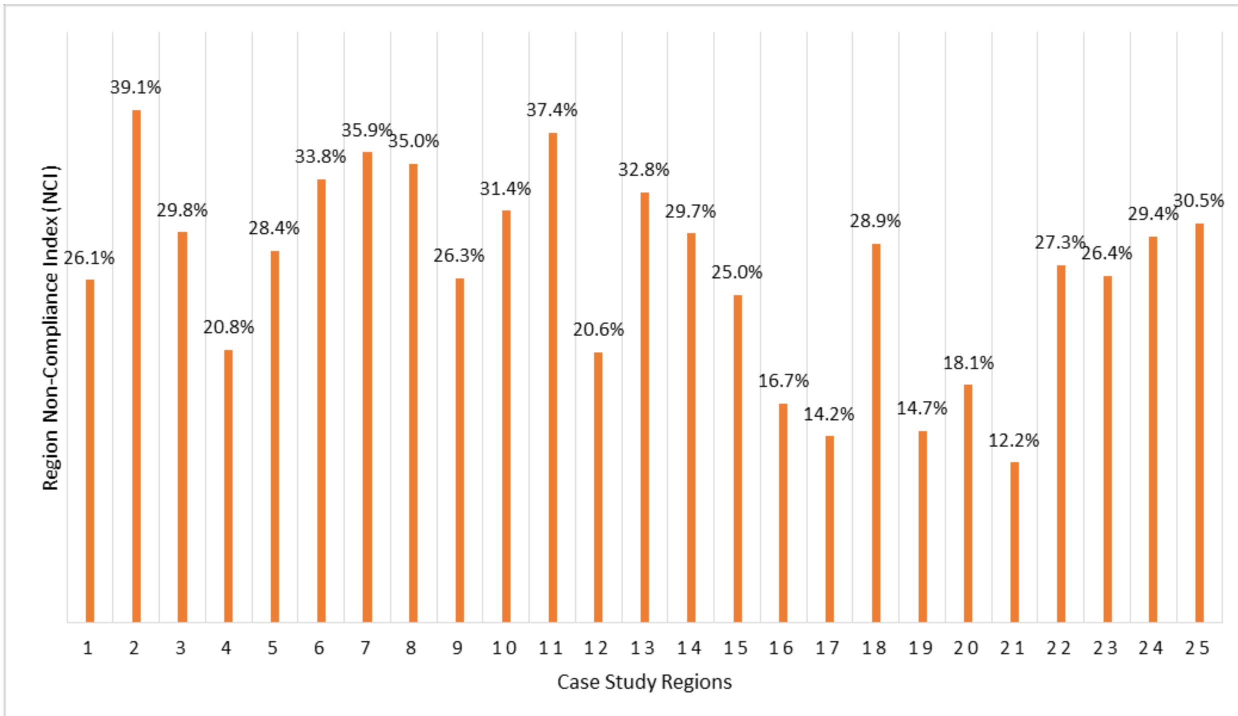


Figure 59: Region non-compliance indices of regions in the case study

Furthermore, the model enables decision makers to classify pedestrian facilities based on the severity of their non-compliance with accessibility requirements. This capability assists decision makers in state and local governments in evaluating and visualizing general conditions of each pedestrian facility type and determining the urgency of its upgrade. For example, the results of the case study indicate that 174 curb ramps are severely non-complying with accessibility requirements, as shown in Figure 60. The model also enables decision makers to classify all pedestrian facilities in the case study regardless of their type. For example, the total numbers of complying, mildly non-complying, and severely non-complying pedestrian facilities in the case study are 103, 998, and 226, respectively (see Figure 61).

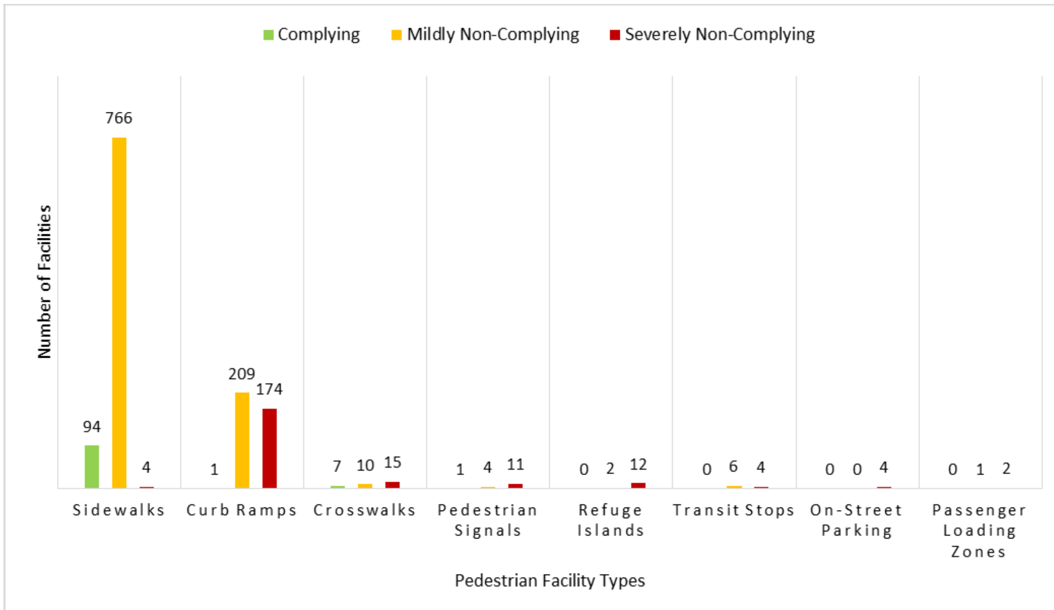


Figure 60: Classification of pedestrian facilities in each type

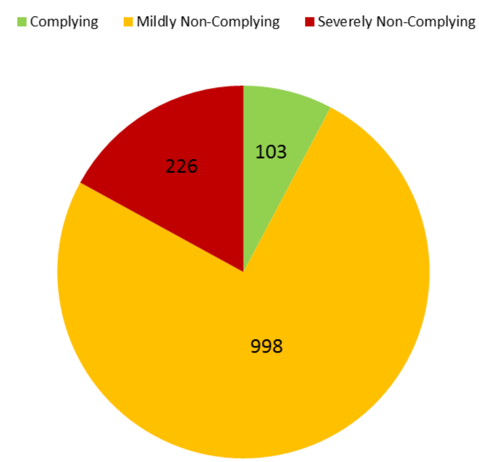


Figure 61: Classification of pedestrian facilities based on their degree of non-compliance

5.6. Summary

This chapter presented a novel model for automating the assessment of the degree of non-compliance of pedestrian facilities with accessibility requirements. The model was developed in four main phases: (1) accessibility requirements analysis phase that identifies pedestrian facility types and their related accessibility requirements, (2) non-compliance assessment phase that quantified the degree of non-compliance of each pedestrian facility with accessibility requirements; (3) collective non-compliance phase that aggregated the individual non-compliance indices of a group of pedestrian facilities based on their type and/or geographical region; and (4) performance evaluation phase that analyzed a case study to illustrate the use of the developed model and demonstrate its novel capabilities. The analysis of the case study illustrated the novel capabilities of the model in (a) efficiently quantifying the degree of non-compliance of all types of pedestrian facilities including transit shelters, on-street parking spaces, and passenger loading zones; (b) assessing the degree of non-compliance of each pedestrian facility type to identify facility types that are in urgent need for upgrades; (c) prioritizing pedestrian facilities upgrade projects in multiple regions based on their non-compliance index; and (d) classifying pedestrian facilities based on the severity of their non-compliance with accessibility requirements. The model was able to assess the degree of non-compliance with accessibility requirements for 1327 pedestrian facilities that cover all pedestrian facility types and calculate pedestrian facility type NCI^{p} and region NCI^{g}.

CHAPTER 6 - OPTIMIZING THE SCHEDULING OF SIDEWALK UPGRADE PROJECTS

6.1. Introduction

This chapter presents the development of a novel multi-objective optimization model for scheduling pedestrian facilities upgrade projects that is capable of generating optimal trade-offs among the three main objectives of (1) minimizing the total number of interrupted/canceled pedestrian trips due to non-compliance with accessibility requirements, (2) minimizing total upgrade duration, and (3) minimizing annual upgrade budgets. The model is also designed to support decision makers in (a) quantifying the impact of upgrading non-compliant pedestrian facilities on people with disabilities, (b) generating detailed optimal schedules for upgrading non-compliant pedestrian facilities to satisfy ADA transition plan requirements, and (c) generating visualizations, illustrations, and maps to facilitate the analysis and use of the optimization results.

The model is developed in four phases: (1) upgrade-impact quantification phase that analyzes and quantifies the impact of upgrading non-compliant pedestrian facilities on people with disabilities; (2) model formulation phase that identifies all relevant decision variables that affect this optimization problem and formulates the aforementioned three optimization objective functions and their relevant constraints; (3) model implementation phase that performs the optimization computations and specifies the model input and output data; and (4) case study phase that analyzes the performance of the optimization model using a case study of a city that includes 7193 pedestrian facilities, as shown in Figure 62.

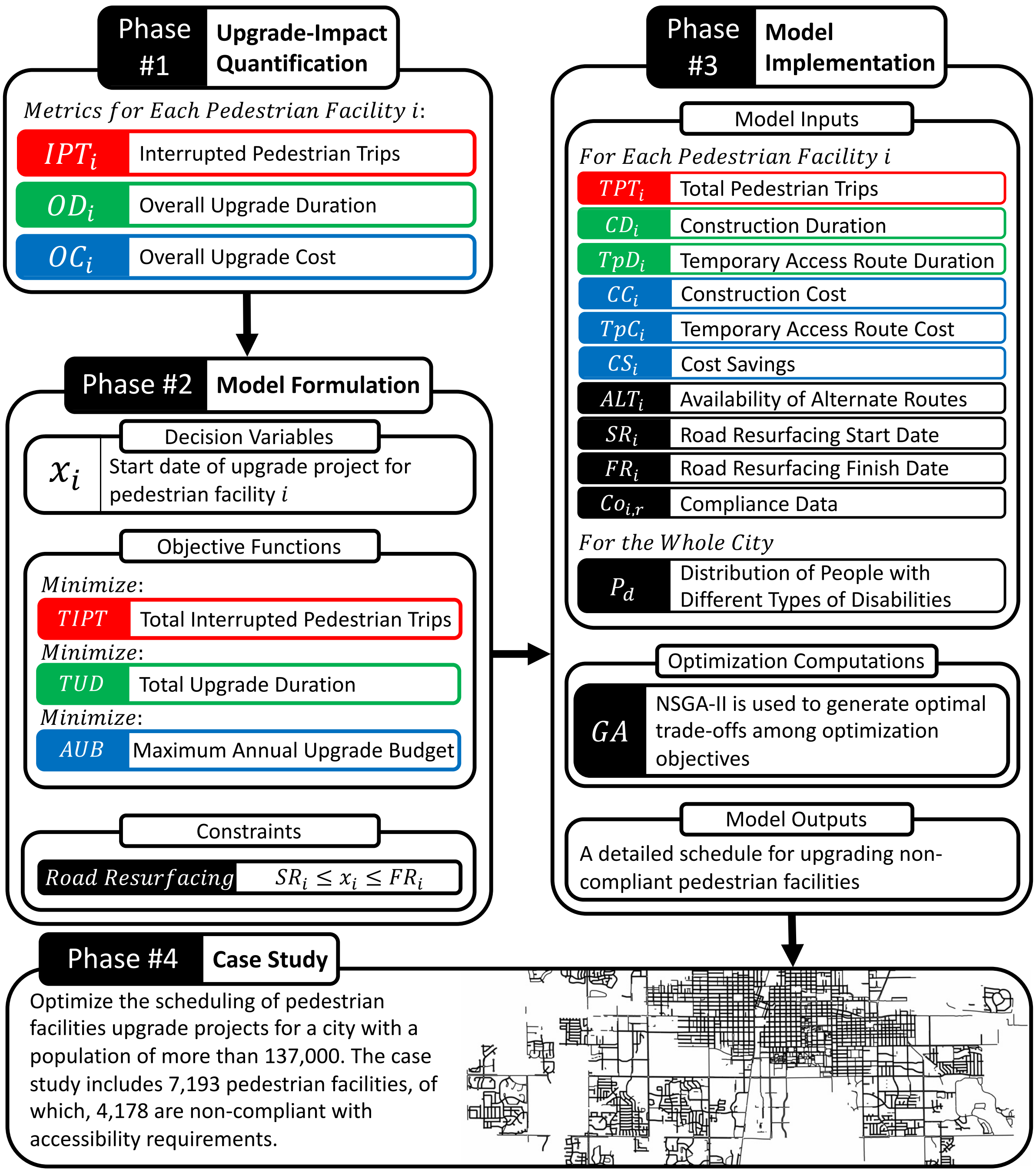


Figure 62. Model development phases

6.2. Upgrade-Impact Quantification

The purpose of this phase is to quantify the impact of upgrading non-compliant pedestrian facilities on people with disabilities. To achieve this purpose, three novel metrics were developed for each pedestrian facility to measure and quantify its (1) daily interrupted pedestrian trips, (2) overall upgrade duration, and (3) overall upgrade cost, as shown in Figure 63. The following sections concisely describe the development and calculation of these metrics.

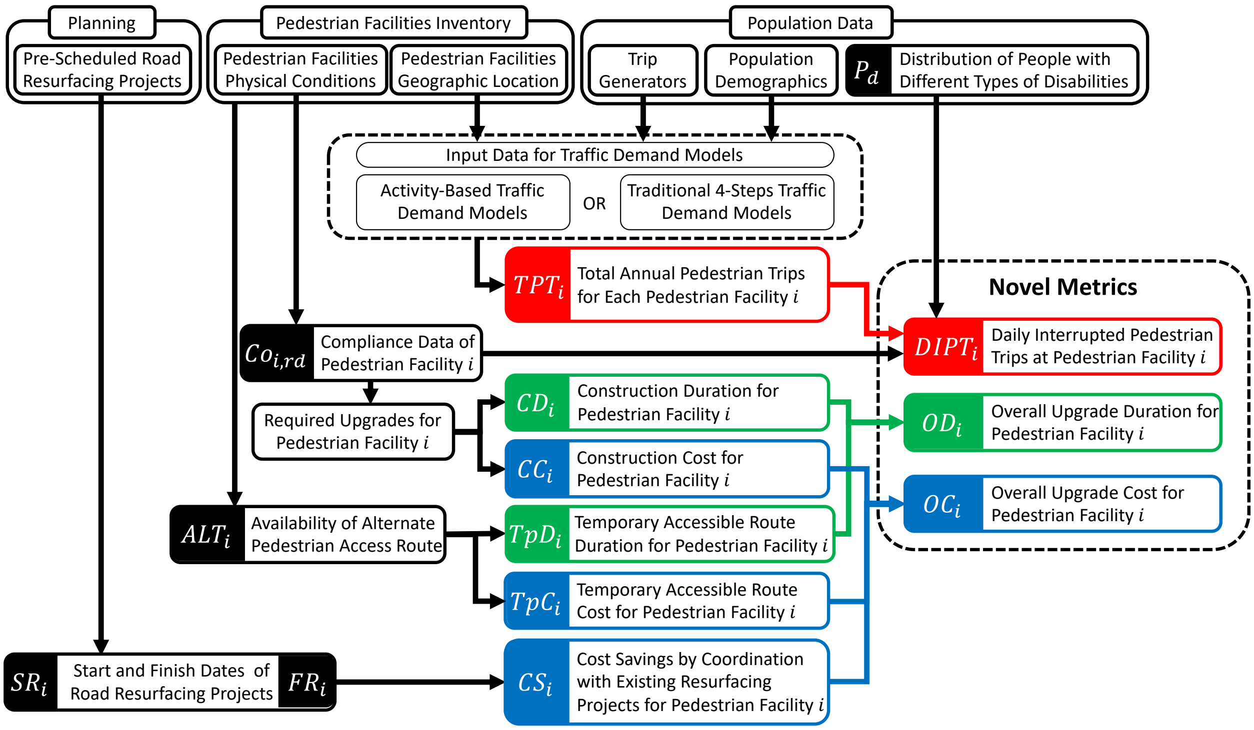


Figure 63. Upgrade-impact quantification and novel metrics

6.2.1. Daily Interrupted Pedestrian Trips ($DIPT_i$)

Daily Interrupted Pedestrian Trips ($DIPT_i$) represents the expected number of pedestrian trips that are interrupted/canceled at each pedestrian facility (i) every day due to non-compliance with accessibility requirements. This novel metric is designed to consider all relevant factors including (1) total expected pedestrian travel demand at each pedestrian facility (TPT_i), (2) percentages of population with different types of disabilities in the city (P_d), and (3) compliance of pedestrian facilities with accessibility requirements ($Co_{i,rd}$), as shown in Equation (5).

$$DIPT_i = \frac{TPT_i \times \sum_{d=1}^{3}\left(P_d \times \left(1 - \prod_{rd=1}^{Rd} Co_{i,r}\right)\right)}{365} \qquad (5)$$

$$d = \begin{cases} 1: Wheelchair\ Users \\ 2: Crutch\ Users \\ 3: Blind\ and\ Low\ Vision\ Pedestrians \end{cases}$$

Where,

$DIPT_i$ = daily interrupted/canceled pedestrian trips at pedestrian facility i;

TPT_i = estimated annual pedestrian trips at pedestrian facility i (i.e., expected travel demand);

d = type of disability;

P_d = percentage of population with disability of type d;

rd = accessibility requirement r that is required by pedestrians with disability type d;

Rd = total number of accessibility requirements R that are required by pedestrians with disability type d; and

$Co_{i,r}$ = a binary value that represents compliance of pedestrian facility i with accessibility requirement r, equals 1 if compliant and 0 if non-compliant.

Decision makers can estimate expected travel demand (TPT_i) at each pedestrian facility (i) using any of the existing pedestrian travel demand models that usually fall under one of two categories: traditional four-step models and activity-based models (Clifton et al. 2016; Davidson et al. 2007; Davis et al. 1988; Hankey et al. 2017; Ryus et al. 2014, 2017; Sanders et al. 2017; Schwartz et al. 1999). Models in both categories focus on estimating pedestrian travel demand at specific points in pedestrian networks based on land use, availability of pedestrian traffic generators, path selection, demographic aspects, and economic analysis of cities and local areas. Distribution of people with different types of disabilities in the city (P_d) can be found in the United States Census Bureau publications and supplemented by information from local sources to improve accuracy (U.S. Census Bureau 2012). Compliance of pedestrian facilities with accessibility requirements ($Co_{i,r}$) is readily available in sidewalk inventory data that are created and maintained by state and local governments as part of their self-evaluations that are required by accessibility laws and regulations (U.S. Department of Justice 2010a).

To calculate the number of pedestrian trips that are interrupted/canceled at each pedestrian facility (i), the present model integrates a novel methodology to identify the accessibility requirements

(r) that address the specific needs of people with varying types of disabilities (d). The developed methodology classifies people with disabilities based on their ability to use sidewalks and pedestrian facilities in three main types: (1) wheelchair users, (2) crutches users, and (3) blind/low vision pedestrians. A comprehensive analysis was conducted to determine the specific accessibility requirements (r) that are needed by people with these three types of disabilities (d), as shown in Table 15. The outcome of this analysis is combined with the earlier described compliance with accessibility requirements ($Co_{i,r}$) to determine the percentage of population that is denied access at each non-compliant pedestrian facility (i), as shown in Equation (5). An example of a non-compliant sidewalk is used to illustrate how the model identifies the percentage of population that is denied access due to the non-compliance of that sidewalk. The example sidewalk ($i = 43$) is used by an estimated 15,780 pedestrian trips annually ($TPT_{43} = 15{,}780$) and is located in a city with 5% wheelchair users, 3% crutch users, and 4% blind/low visibility pedestrians ($P_1 = 0.05, P_2 = 0.03, P_3 = 0.04$), as shown in Figure 64 (a). This sidewalk is compliant with all accessibility requirements except the ADA vertical fault requirement ($Co_{43,4} = 0$), as shown in Figure 64 (b). Based on this information and the data in Table 15, the present methodology identifies that this sidewalk will deny access to wheelchair users ($d = 1$) and crutches users ($d = 2$) while other pedestrians will be able to use it normally. Accordingly, the model estimates the total annual pedestrian trips interrupted by this non-compliant sidewalk to be ($1{,}263\ trips$) which represents the summation of the interrupted trips for wheelchair users ($0.05 \times 15780 = 789\ trips$) and crutches users ($0.03 \times 15780 = 474\ trips$), as shown in in Figure 64 (c).

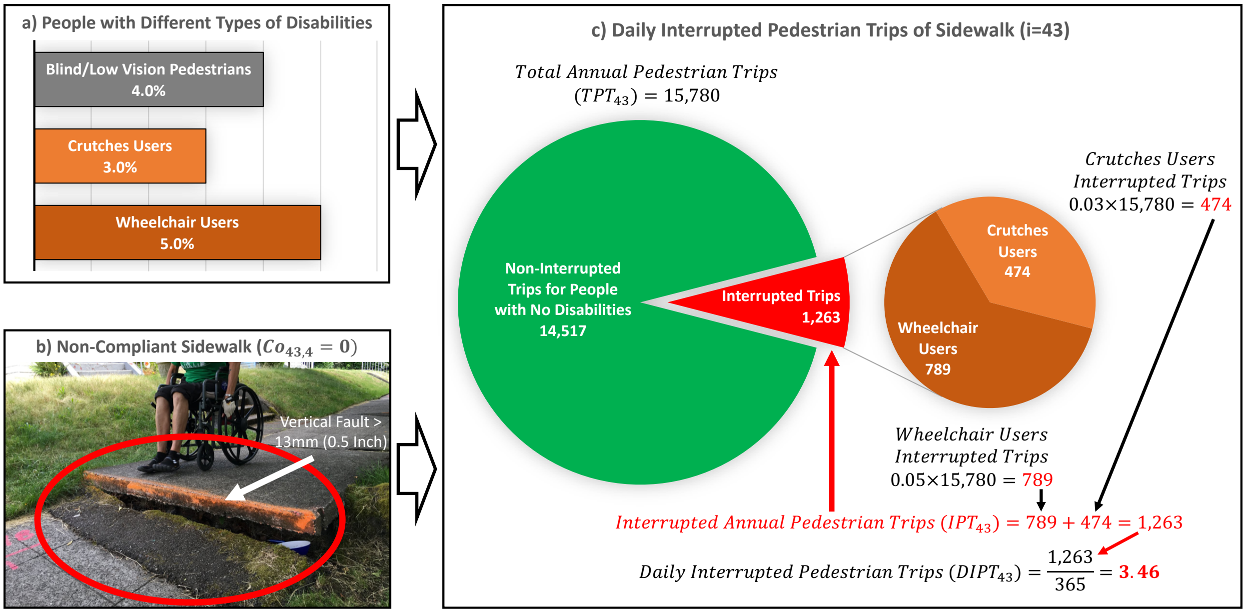


Figure 64. Example calculation of daily interrupted pedestrian trips ($DIPT_{43}$)

Table 15: Accessibility Requirements and Types of Disabilities

Pedestrian Facility (i)	Accessibility Requirements (r)	Types of Disabilities (d)		
		Wheelchair Users ($d = 1$)	Crutches Users ($d = 2$)	Blind & Low Vision (d=3)
Sidewalks	Width	✓		
	Running Slope	✓	✓	
	Cross Slope	✓	✓	✓
	Vertical Fault	✓	✓	
	Protruding Objects	✓	✓	✓
Curb Ramps	Width	✓		
	Running Slope	✓	✓	
	Cross Slope	✓	✓	✓
	DWS			✓
	Clear Space	✓	✓	✓
Crosswalks	Width	✓		
	Cross Slope	✓	✓	✓
Pedestrian Signals	Push Button	✓	✓	✓
	Locator Tone			✓
	Clear Space	✓		✓
Refuge Islands	Width	✓		
	Running Slope	✓	✓	
	Cross Slope	✓	✓	✓
	DWS			✓
	Vertical Fault	✓	✓	✓

Table 15 cont.

Pedestrian Facility (i)	Accessibility Requirements (r)	Types of Disabilities (d)		
		Wheelchair Users ($d = 1$)	Crutches Users ($d = 2$)	Blind & Low Vision (d=3)
Transit Stops	Boarding Area	✓		
	Transit Shelters	✓	✓	✓
On-Street Parking	Aisle	✓	✓	✓
	Curb Ramp	✓	✓	
	Signs	✓	✓	
Passenger Loading Zones	Aisle	✓	✓	✓
	Signs	✓	✓	

6.2.2. Overall Upgrade Duration (OD_i)

Overall upgrade duration (OD_i) represents the duration needed from the first day of the upgrade project until achieving full compliance of pedestrian facility (i) with accessibility requirements, and it includes construction duration (CD_i) and duration of building and removal of temporary pedestrian access route (TpD_i), as shown in Equation (6). These two durations (CD_i and TpD_i) can be estimated by planners based on the scope of the upgrade project and the construction of a temporary PAR, if needed.

$$OD_i = CD_i + TpD_i \times (1 - ALT_i) \tag{6}$$

Where,

OD_i = overall upgrade duration of pedestrian facility i;

CD_i = construction duration of pedestrian facility i;

TpD_i = duration of building and removal of temporary pedestrian access route needed during the upgrade of pedestrian facility i; and

ALT_i = a binary value that equals 1 if there is an alternate PAR for pedestrian facility i or 0 otherwise.

6.2.3. Overall Upgrade Cost (OC_i)

The overall upgrade cost (OC_i) represents the expenses incurred by local governments to achieve full compliance of each non-compliant pedestrian facility (i) with accessibility requirements and it includes: (1) construction cost (CC_i), (2) temporary pedestrian access route cost (TpC_i), and (3) cost savings from coordination with adjacent road-resurfacing projects (CS_i), as shown in Equation (7). These three types of cost/savings are explained in the following sections.

$$OC_i = CC_i + TpC_i \times (1 - ALT_i) - CS_i \times RR_i \tag{7}$$

Where,

OC_i = overall upgrade cost of non-compliant pedestrian facility i;

CC_i = construction cost of upgrading pedestrian facility i;

TpC_i = cost of establishing a temporary Pedestrian Access Route (PAR) for pedestrian facility i;

ALT_i = a binary value that equals 1 if there is an alternate PAR for pedestrian facility i or 0 otherwise;

CS_i = cost savings from coordination with road-resurfacing projects; and

RR_i = a binary value that equals 1 if decision makers select to coordinate upgrade projects with road-resurfacing projects for pedestrian facility i or 0 otherwise.

6.2.3.1. Construction Cost (CC_i)

Construction cost (CC_i) represents the cost of performing all the work needed to achieve full compliance of pedestrian facility (i) with accessibility requirements. The construction scope of work includes (1) adding missing elements and features (e.g. push buttons and detectable warning surfaces) to non-compliant pedestrian facilities, (2) partially rebuilding non-compliant pedestrian facilities (e.g. replacing pedestrian signals or clear spaces to achieve full compliance), and/or (3) fully rebuilding non-compliant pedestrian facilities. The scope of work for the upgrade process is determined based on the existing condition of the pedestrian facility and its degree of non-compliance with accessibility requirements. This cost (CC_i) can be estimated by decision makers based on their local construction cost rates.

6.2.3.2. Temporary Pedestrian Access Route Cost (TpC_i)

The need to build a temporary pedestrian access route (PAR) depends on the availability of an alternate route that pedestrians can use during the upgrade of non-compliant pedestrian facilities. Federal laws and regulations require municipalities to maintain the accessibility of their sidewalks and pedestrian facilities at all times (U.S. Department of Justice 2010a). If access to public programs, services, and activities can be established through existing alternate PARs, such as the sidewalks on the other side of the street, then there is no need for a temporary PAR. If these programs, services, and activities can only be accessed through the non-compliant pedestrian facility that will be upgraded, then a temporary PAR is required for the entire duration of the upgrade project. This required temporary PAR must comply with the same accessibility requirements as permanent pedestrian facilities (U.S. Department of Justice 2010a). This cost (TpC_i) can be estimated by decision makers based on their local rates for building and maintaining temporary PARs.

6.2.3.3. Cost Savings from Coordination with Road Resurfacing Projects (CS_i)

In the case that a non-compliant pedestrian facility is adjacent to a road that is scheduled to be resurfaced, this non-compliant facility must be upgraded to achieve full compliance with accessibility requirements either before or during the adjacent road-resurfacing project (DOJ/DOT 2013, 2015). Accordingly, if a non-compliant pedestrian facility falls in this category, decision makers often schedule its upgrade to occur simultaneously with that adjacent road-resurfacing project to pool resources and save on material, labor, equipment, and overhead costs. The present model enables decision makers to select to coordinate the upgrade of non-compliant pedestrian facilities with adjacent road resurfacing projects ($RR = 1$). This cost saving (CS_i) can be estimated by decision makers to present the potential savings that can be achieved by the coordination with existing or pre-scheduled road-resurfacing project.

6.3. Model Formulation Phase

The proposed optimization model is formulated in three steps that define the model decision variables, objective functions, and constraints. The following sections describe each of these three steps.

6.3.1. Decision Variables

The decision variables of the present optimization model include one set of positive integer decision variables (x_i) that represents the scheduled start date of the required upgrade project for each non-compliant pedestrian facility (i). For example, $x_{i=4} = 22$ means that the upgrade project of the fourth pedestrian facility in the city ($i = 4$) is scheduled to start on the 22nd day of the transition plan.

6.3.2. Objective Functions

The present multi-objective optimization model includes three objective functions for (1) minimizing interrupted pedestrian trips, (2) minimizing total upgrade duration, and (3) minimizing annual upgrade budgets.

6.3.2.1. Minimize Total Interrupted Pedestrian Trips (TIPT)

This objective function is designed to minimize the total number of pedestrian trips ($TIPT$) that are interrupted/canceled due to all non-compliances with accessibility requirements for the entire transition plan. In this model, $TIPT$ is calculated based on the earlier described daily interrupted pedestrian trips ($DIPT_i$), construction duration (CD_i), and duration of building and removal of temporary PAR metrics(TpD_i); total expected pedestrian trips (TPT_i); and the availability of alternate PAR (ALT_i); as shown in Equation (8). For example, the model is designed to calculate the total interrupted pedestrian trips ($TIPT_{27}$) caused by a non-compliant sidewalk ($i = 27$) as shown in Figure 65. This example sidewalk hosts 25,000 pedestrian trips per year ($TPT_{27} = 25{,}000$) and denies access to 5.48 pedestrian trips per day ($DIPT_{27} = 5.48$). The sidewalk has an overall upgrade duration of 15 days ($OD_{27} = 15$), an alternate route ($ALT_{27} = 1$), and the start date of its upgrade project is scheduled on the 32nd day of the transition plan ($x_{27} = 32$). Based on this information, the present model can calculate the total interrupted pedestrian trips ($TIPT_{27} = 1197.28$) for this sidewalk using Equation (8), as shown in Figure 65. Another example non-compliant sidewalk ($i = 82$) that does not have alternate routes ($ALT_{82} = 0$) is shown in Figure 66. This example sidewalk hosts 9,976 pedestrian trips per year ($TPT_{82} = 9{,}976$) and denies access to 3.28 pedestrian trips per day ($DIPT_{27} = 3.28$). The sidewalk has a construction duration of 18 days ($CD_{82} = 18$), temporary PAR installation duration of 7 days ($TpD_{82} = 7$), and the start date of its upgrade project is scheduled on the 393rd day of the transition plan ($x_{82} = 393$). Based on this information, the present model can calculate the total interrupted pedestrian trips ($TIPT_{82} = 1308.72$) for this sidewalk using Equation (8), as shown in Figure 66.

$$Minimize\ (TIPT) = \sum_{i}^{I}\left(\left(DIPT_i \times\ (x_i - 1)\right) + \left(\frac{TPT_i}{365} \times CD_i \times ALT_i\right) + \left(DIPT_i \times TpD_i \times (1 - ALT_i)\right)\right) \quad (8)$$

Where,
$TIPT$ = total interrupted pedestrian trips for the entire transition plan;
I = total number of pedestrian facilities in the entire transition plan;
$DIPT_i$ = daily interrupted pedestrian trips for pedestrian facility i, from Equation (5);
x_i = start date of the upgrade project for pedestrian facility i;
TPT_i = estimated annual pedestrian trips for facility i;
CD_i = construction duration of pedestrian facility i, from Equation (6);
TpD_i = duration of installation and removal of temporary PAR at pedestrian facility i; and
ALT_i = a binary value that equals 1 if there is an alternate PAR for pedestrian facility i or 0 otherwise.

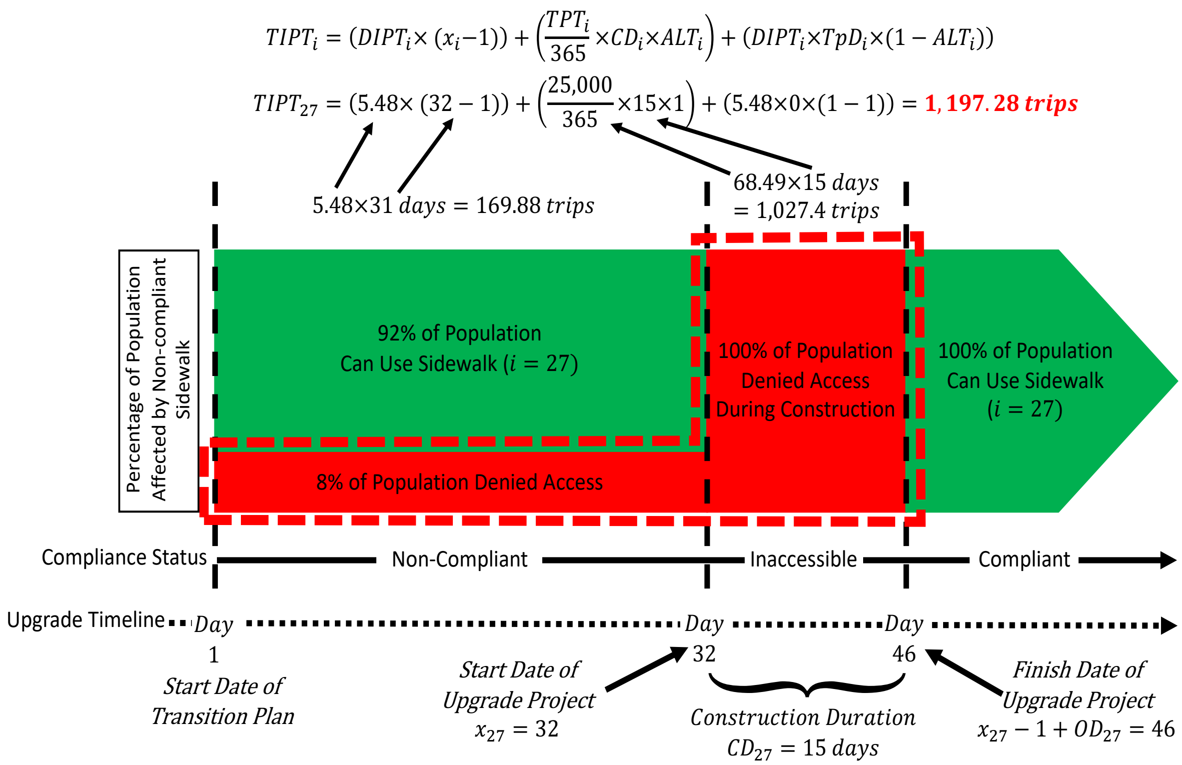


Figure 65. Example total interrupted pedestrian trips ($TIPT_{27}$) for a sidewalk with alternate routes

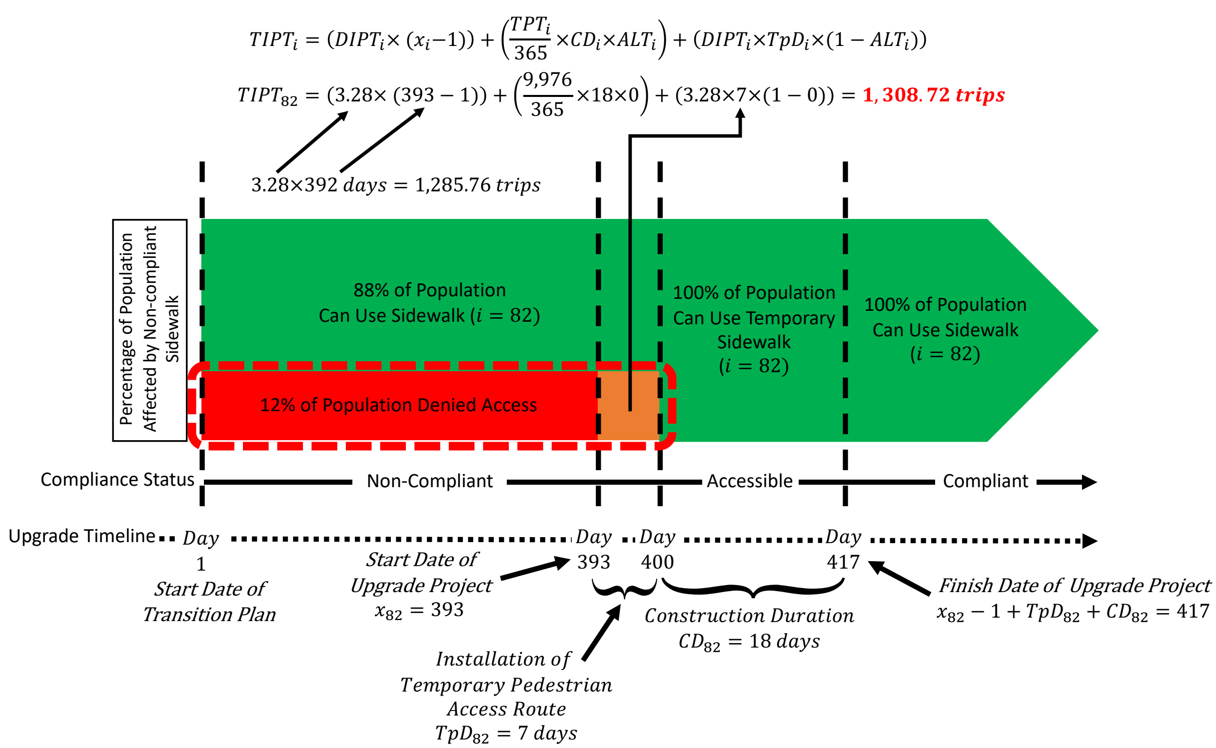


Figure 66. Example total interrupted pedestrian trips ($TIPT_{82}$) for a sidewalk with no alternate routes

6.3.2.2. *<u>Minimize Total Upgrade Duration (TUD)</u>*

This objective function is designed to minimize the overall duration of the transition plan to accelerate the completion of all required upgrade projects in order to achieve full compliance of all pedestrian facilities with accessibility requirements in the shortest possible duration. TUD represents the duration between the start date of the transition plan and the time of achieving full compliance with accessibility requirements. This duration is calculated in the present model as the difference between the latest finish date of all upgrade projects and the start date of the transition plan, as shown in Equation (9).

$$Minimize\ (TUD) = \max_{i=1\ to\ I} (x_i + OD_i) \tag{9}$$

Where,
TUD = total upgrade duration of the entire transition plan;
I = total number of pedestrian facilities in the entire transition plan;
x_i = start date of upgrade project for pedestrian facility i; and
OD_i = overall upgrade duration of pedestrian facility i, from Equation (6).

6.3.2.3. *<u>Minimize Annual Upgrade Budgets (AUB)</u>*

Non-compliant pedestrian facilities are upgraded by state and local governments within the limits of an approved annual upgrade budget (El-Rayes et al. 2016). This annual budget impacts the number of pedestrian facilities upgrade projects that can be scheduled every year. To enable decision makers to evaluate the impact of various annual upgrade budgets on the total interrupted pedestrian trips and the total upgrade duration, the present model integrates the annual upgrade budget (AUB) throughout the multi-year transition plan as a third objective function that needs to be minimized, as shown in Equation (10). This enables decision makers to generate optimal trade-offs among the three objectives of minimizing (1) total interrupted pedestrian trips, (2) total upgrade duration, and (3) annual upgrade budgets.

$$Minimize\ (AUB) = \max_{y=1\ to\ Y} \left(\sum_{i=1}^{I} OC_i \times CoC_{i,y} \right) \tag{10}$$

$$CoC_{i,y} = \begin{cases} 1 \; if \; x_i \in y \\ 0 \; if \; x_i \notin y \end{cases}$$

Where,
AUB = annual upgrade budget;
y = budget year y;
Y = total number of budget years in the transition plan;
I = total number of pedestrian facilities in the entire transition plan;
OC_i = overall upgrade cost for pedestrian facility i, from Equation (7);
$CoC_{i,y}$ = cost coefficient that equals 1 if x_i is in year y and 0 otherwise; and
x_i = start date of the upgrade project for pedestrian facility i.

6.3.3. Constraints

To ensure the practicality of the present model, it includes two sets of constraints that consider (1) non-negativity integer values for decision variables; and (2) road-resurfacing projects. The non-negativity integer constraints are designed to guarantee that values for decision variables are always positive integers to represent the planned start dates of all upgrade projects in the transition plan. The road-resurfacing projects constraint is an optional constraint that decision makers can elect to activate in order to enforce the coordination between upgrade projects of non-compliant pedestrian facilities and any adjacent pre-scheduled road-resurfacing projects to improve construction efficiency and achieve potential cost savings, as shown in Equation (11).

$$if \; RR_i = 1, \qquad then \; (SR_i \leq x_i \leq FR_i) \tag{11}$$

Where,
SR_i = start date of a road-resurfacing project adjacent to pedestrian facility i;
x_i = start date of the upgrade project for pedestrian facility i; and
FR_i = finish date of a road-resurfacing project adjacent to pedestrian facility i.

6.4. Implementation Phase

The present model is implemented in four steps: (1) specifying the model input data, (2) performing quantification calculations, (3) executing the optimization computations and algorithms, and (4) generating model outputs that provide detailed description of the optimization results, as shown in Figure 67. The following sections describe each of these steps.

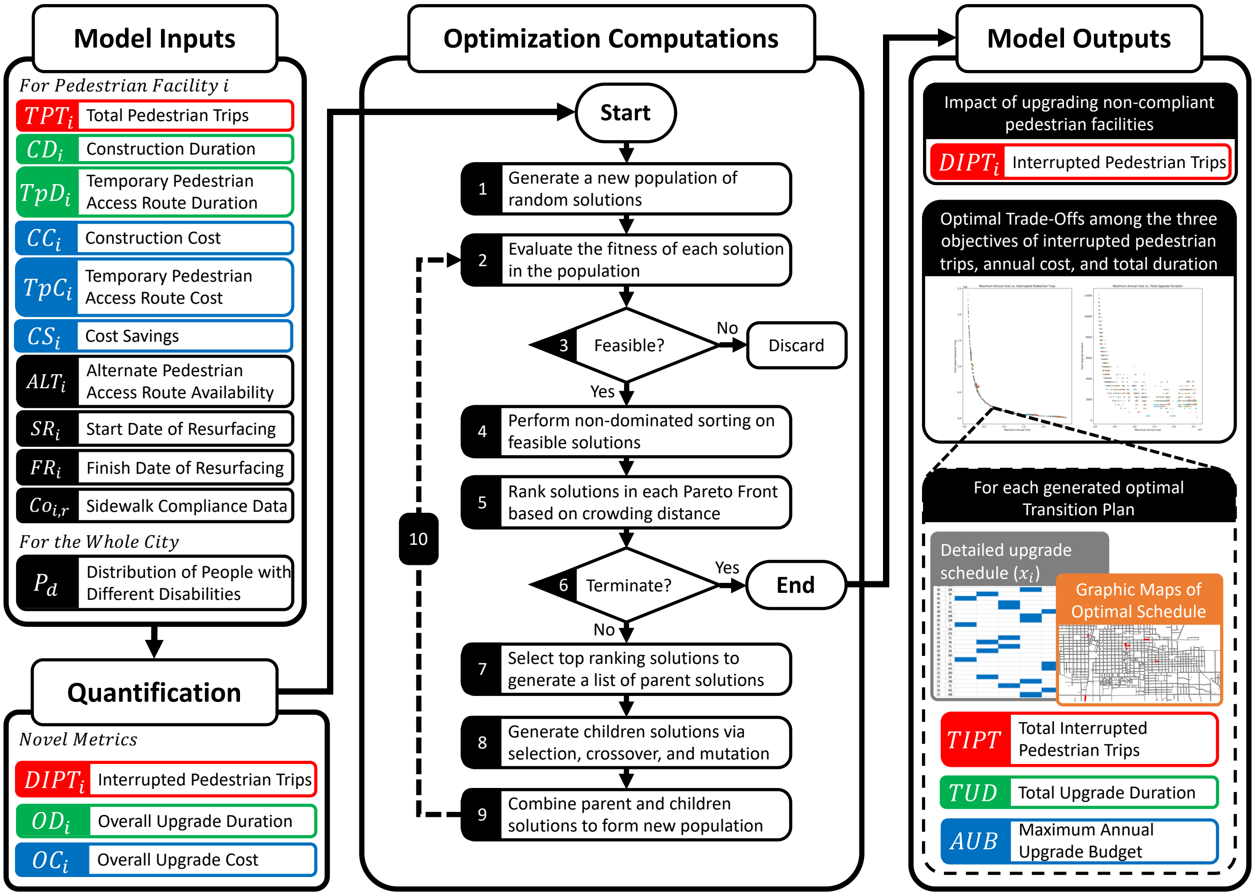


Figure 67. Model implementation steps

6.4.1. Specifying Model Input Data

This step specifies the input data required by the model to perform its optimization computations, including input data for each pedestrian facility (i) and input data for the whole city, as shown in Figure 67. The required input data for each pedestrian facility (i) are its (1) estimated pedestrian travel demand, (2) construction cost, (3) temporary PAR cost, (4) potential cost savings from coordination with adjacent road-resurfacing projects, (5) construction duration, (6) temporary PAR duration, (7) availability of alternate PAR, (8) start and finish dates of adjacent road-resurfacing project, if applicable, and (9) compliance with accessibility requirements. The required input data for the whole city is its distribution of people with different types of disabilities. This required input data is easily accessible and can be obtained from the databases of local, state and federal governments.

6.4.2. Quantification Calculations

This step utilizes the data provided by decision makers in the previous step to calculate the daily interrupted pedestrian trips for each pedestrian facility ($DIPT_i$), overall upgrade duration of each pedestrian facility (OD_i), and overall upgrade cost of each pedestrian facility (OC_i) using Equations (5), (6), and (7), respectively.

6.4.3. Optimization Computations

The model is designed to generate optimal trade-offs between the three aforementioned optimization objectives of minimizing (1) total interrupted pedestrian trips, (2) total upgrade duration, and (3) annual upgrade budgets. To accomplish this, the optimization computations are executed in the present model using Non-dominated Sorted Genetic Algorithms II (NSGA-II) due to its ability to (a) model non-linear and discrete variables and functions; (b) efficiently model the multi-objective optimization problem with the least number of decision variables and constraints given the potentially large number of non-compliant pedestrian facilities in need of upgrade; and (c) find near-optimum solutions for this optimization problem in a reasonable time (El-Rayes and Kandil 2005; El-Rayes and Khalafallah 2005; Kandil et al. 2010; Said and El-Rayes 2011, 2014).

The optimization computations in the present model are performed in ten steps, as shown in Figure 67. First, the model generates an initial population that includes a set of 100 randomly generated transition plans. The model then evaluates the fitness of each of these transition plans based on Equations (8), (9), and (10). Based on this evaluation, the model checks the feasibility of each generated transition plan and discards all those that do not satisfy the optimization constraints. Fourth, the model utilizes a newly developed and highly efficient non-dominated sorting algorithms to sort the feasible transition plans into multiple non-dominated Pareto Fronts (Zhang et al. 2015). In the next step, the model ranks all transition plans in each of these Pareto Fronts based on their crowding distance (Zhang et al. 2015). The model then checks for termination conditions and ends the computations if a termination condition is reached (15,000 generations) and all non-dominated transition plans are saved in the final results, otherwise the model moves on to the next step. Seventh, the model selects all transition plans in the first Pareto Front to form a list of parent transition plans for the next generation. If the number of transition plans in the first Pareto Front is less than 100, transition plans from lower Pareto Frons are added to the list of parent transition plans to complete 100 transition plans. Based on that list of parent transition plans, the model generates a new list of children transition plans by applying the basic GA operations such as selection (10%), crossover (60%), and mutation (30%) to the pre-established list of parent transition plans. Ninth, the model combines both lists of parents and children transition plans to generate a new population. The model then iterates the aforementioned steps 2 through 9, as shown in Figure 67.

6.4.4. Model Outputs

The present model uses the aforementioned input, quantification, and optimization computations to quantify the impact of upgrading non-compliant pedestrian facilities on people with disabilities; and generate optimal trade-offs between the three aforementioned optimization objectives. These trade-offs include non-dominated optimal solutions for scheduling the upgrade projects of all non-compliant pedestrian facilities in the transition plan. For each of these generated optimal transition plans, the model (a) develops detailed upgrade schedule for all non-compliant pedestrian facilities to partially fulfill the ADA transition plan requirements, (b) generates graphic maps representing the planned upgrades of all pedestrian facilities in the city, (c) calculates the total number of interrupted pedestrian trips in the entire city, (d) estimates the annual upgrade budget for each year in the transition plan, and (e) identifies the total upgrade duration needed to achieve full compliance with accessibility requirements. as shown in Figure 67.

6.5. Case Study Phase

The purpose of this phase is to analyze a real-life case study to illustrate the use of the model and demonstrate its novel and unique capabilities. The case study required developing a transition plan for upgrading 4,178 non-compliant pedestrian facilities in a city that has 7,193 facilities to achieve full compliance with accessibility requirements, as shown in Figure 68.

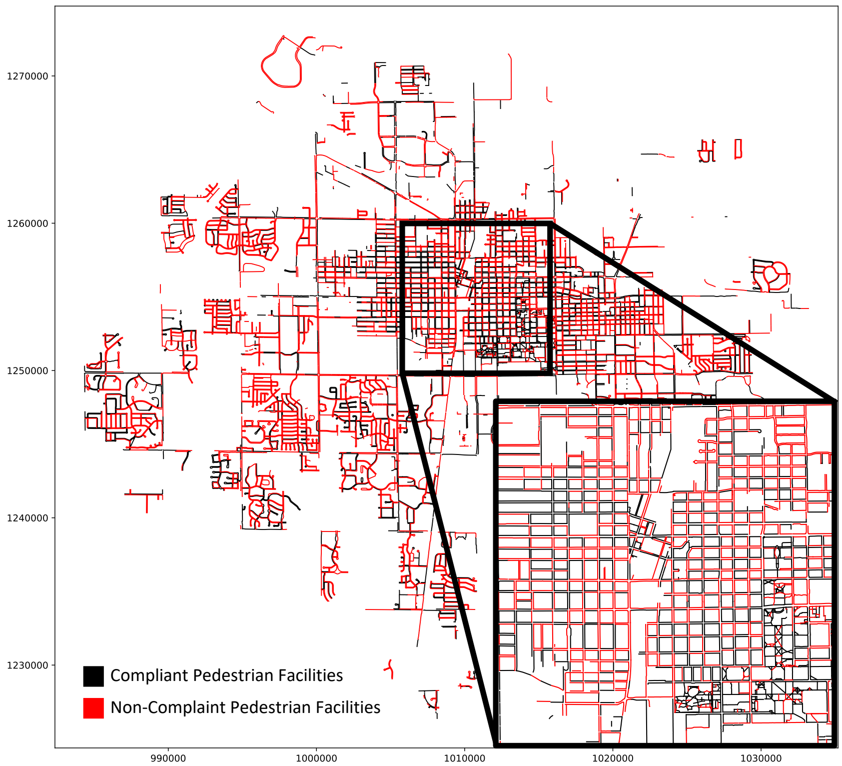


Figure 68. Map of all pedestrian facilities in the case study city

For this case study, the required input data by the model included (1) expected pedestrian travel demand, which was generated using an activity based model (Davidson et al. 2007); (2) estimated construction cost (RSMeans 2018); (3) cost to build, maintain, and/or remove temporary pedestrian access route (PAR) (RSMeans 2018); (4) cost savings from coordination with adjacent road-resurfacing projects (RSMeans 2018); (5) construction duration (RSMeans 2018); (6) duration of building and/or removal of temporary PAR (RSMeans 2018); (7) availability of alternate PAR, which was identified based on the maps of the sidewalk network in the city; (8) start and finish dates of adjacent road-resurfacing projects; (9) compliance with accessibility requirements (CCRPC 2016); and (10) the distribution of people with different types of disabilities in the whole city (U.S. Census Bureau 2012). This input data was used by the present model to quantify the impact of upgrading non-compliant pedestrian facilities on people with disabilities and generate optimal trade-offs between the three aforementioned optimization objectives. The model was able to complete all quantification and optimization computations for this case study in 10 hours and 45 minutes using a computer with Core i7 Processor and 16GB of memory.

The generated optimization results for this case study illustrate the novel and unique contributions of the model, including its ability to (1) quantify the impact of upgrading non-compliant pedestrian facilities on people with disabilities, as shown in Figure 69; (2) identify optimal trade-offs among the aforementioned three objectives of minimizing total number of interrupted pedestrian trips, minimizing total upgrade duration, and minimizing annual upgrade budgets, as shown in Figure 70 and Figure 71; (3) generate detailed optimal schedules for upgrading non-compliant pedestrian facilities to satisfy ADA transition plan requirements, as shown in Figure 72 and Figure 73; and (4) create graphic maps of the generated optimal transition plans, as shown in Figure 74.

First, the model was able to quantify the impact of upgrading non-compliant pedestrian facilities in the analyzed case study on people with disabilities by calculating the number of daily interrupted pedestrian trips ($DIPT_i$) caused by each non-compliant pedestrian facility (i) in the whole city using Equation (5), as shown in Figure 69.

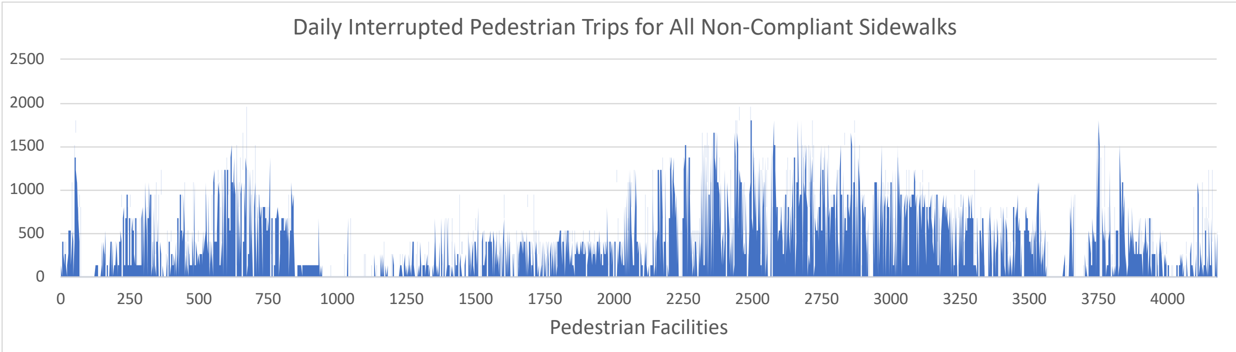


Figure 69. The impact of upgrading all non-compliant pedestrian facilities ($DIPT_i$)

Second, the model utilized Non-dominated Sorted Genetic Algorithms II (NSGA-II) to generate optimal trade-offs among the three aforementioned optimization objectives of minimizing (1) total number of interrupted pedestrian trips, (2) total upgrade duration, and (3) annual upgrade budgets, using Equations (8), (9), and (10). For this case study, the model generated 1,275 non-dominated transition plans that provided a wide range of optimal trade-offs among the three main optimization objectives, as shown in Figure 70. This unique capability of the model enables decision makers to analyze the generated trade-offs and select an optimal transition plan based on one, two, or all three optimization objectives, as shown in Figure 70 and Figure 71. For example, Transition Plan #1 achieved the lowest number of interrupted pedestrian trips (19,952,119) and the shortest total upgrade duration (172 days), while requiring the highest annual upgrade budget ($84,088,895.23). This extreme transition plan requires all upgrade projects to start simultaneously on the first day of the transition plan, which achieves the least number of interrupted pedestrian trips, but requires funding all upgrade projects in the first year. Another example is illustrated in Transition Plan #2 that requires the least annual upgrade budget ($1,724,956.36), however it caused a significant increase in the number of interrupted pedestrian trips (14,112,376,123 trips), and the total upgrade duration (17,610 days), as shown in Figure 70 and Figure 71.

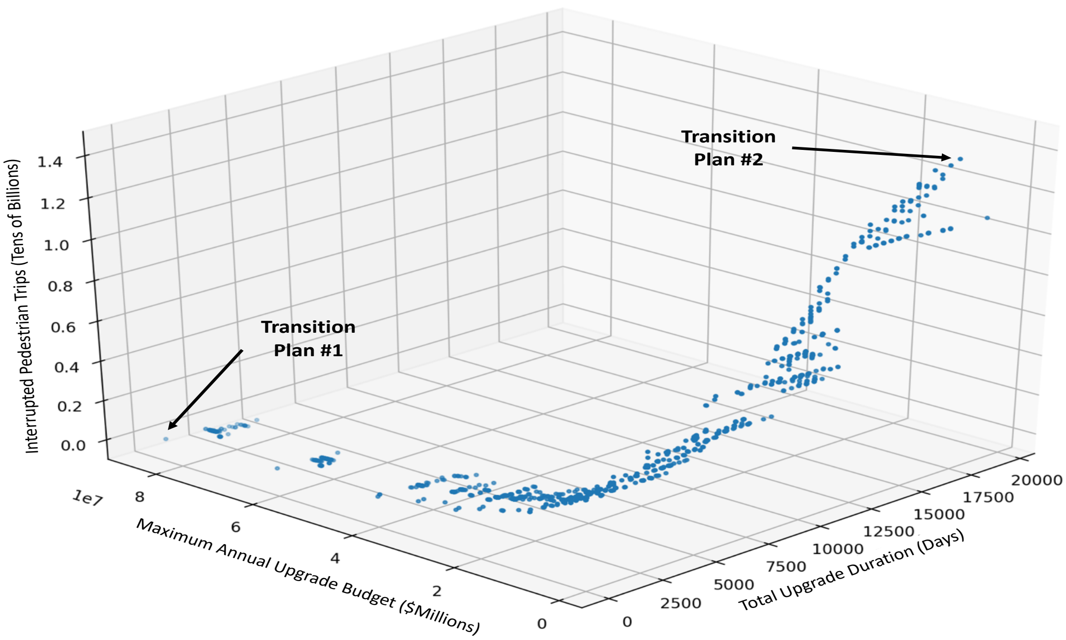


Figure 70. Optimal trade-offs among the three optimization objectives

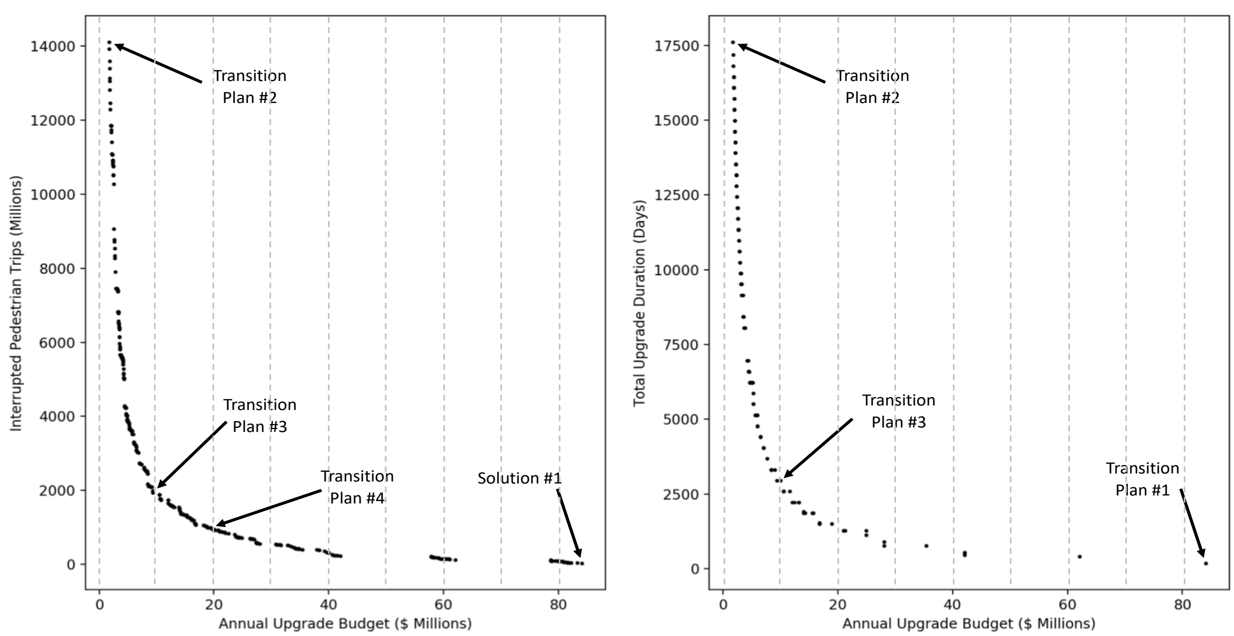


Figure 71. Optimal trade-offs between two objectives

Third, the model developed a detailed schedule for each of the 1,275 generated optimal transition plans to satisfy the ADA transition plan requirements. For example, in Figure 71, Transition Plan #3 represents the best solution for a state or local government with an annual upgrade budget of

$10 million. Based on that transition plan, the model generated a detailed schedule for upgrading all non-compliant pedestrian facilities in the whole city, as shown in Figure 72. The developed schedule achieved full compliance with accessibility requirements by upgrading all non-compliant pedestrian facilities in the whole city in 9 years (2,957 days) and minimizing the total number of interrupted pedestrian trips to (1,940,707,933 trips), while requiring a maximum annual upgrade budget of ($9,346,585.19), as shown in Figure 73. Decision makers can analyze these trade-offs and evaluate the impact of adjusting the maximum limit of their annual upgrade budget to better address the specific requirements of their city. For example, decision makers can compare the previous transition plan to Transition Plan #4, which achieves a significantly lower number of interrupted pedestrian trips (992,790,904 trips), and shorter total upgrade duration (1,497 days), but requires 90% higher annual upgrade budget ($18,966,403.87).

Pedestrian Faility (i)	Start Date	Budget Year #1	Budget Year #2	Budget Year #3	Budget Year #4	Budget Year #5	Budget Year #6	Budget Year #7	Budget Year #8	Budget Year #9
1844	2921									■
1845	2556								■	
1846	1461					■				
1847	1826						■			
1848	1	■								
1849	2215							■		
1850	2191							■		
1851	1944						■			
1852	822			■						
1853	731			■						
1854	1502					■				
1855	3055									■
1856	887			■						
1857	3134									■
1858	2234							■		
1859	366		■							
1860	123	■								

Figure 72. Sample scheduled start dates for upgrade projects in optimal transition plan #3

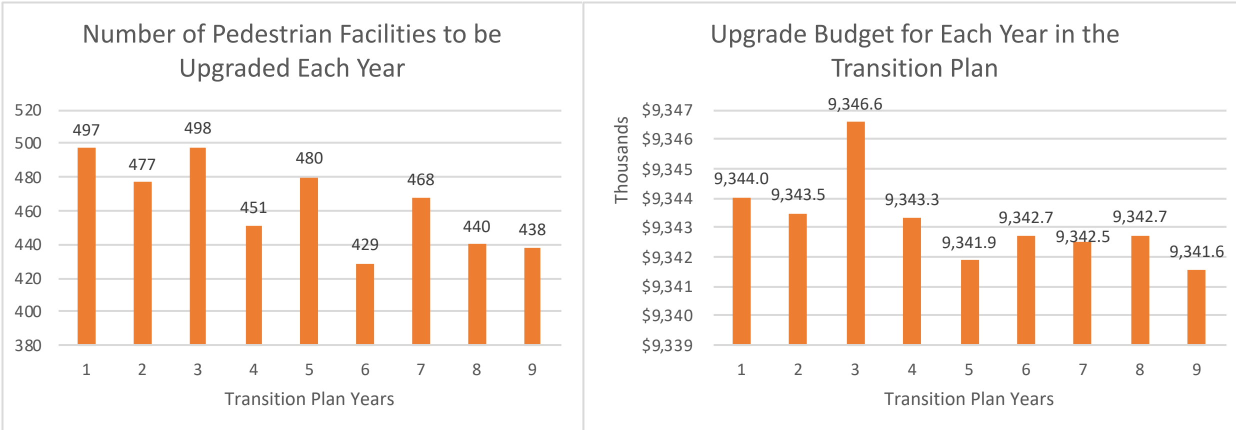


Figure 73. Number of upgrade projects and budget for each year in optimal transition plan #3

Fourth, the model enables decision makers to generate graphic maps to visually analyze the geographical location of all planned upgrade projects of non-compliant pedestrian facilities during each year of the multi-year optimal transition plan, as shown in Figure 74.

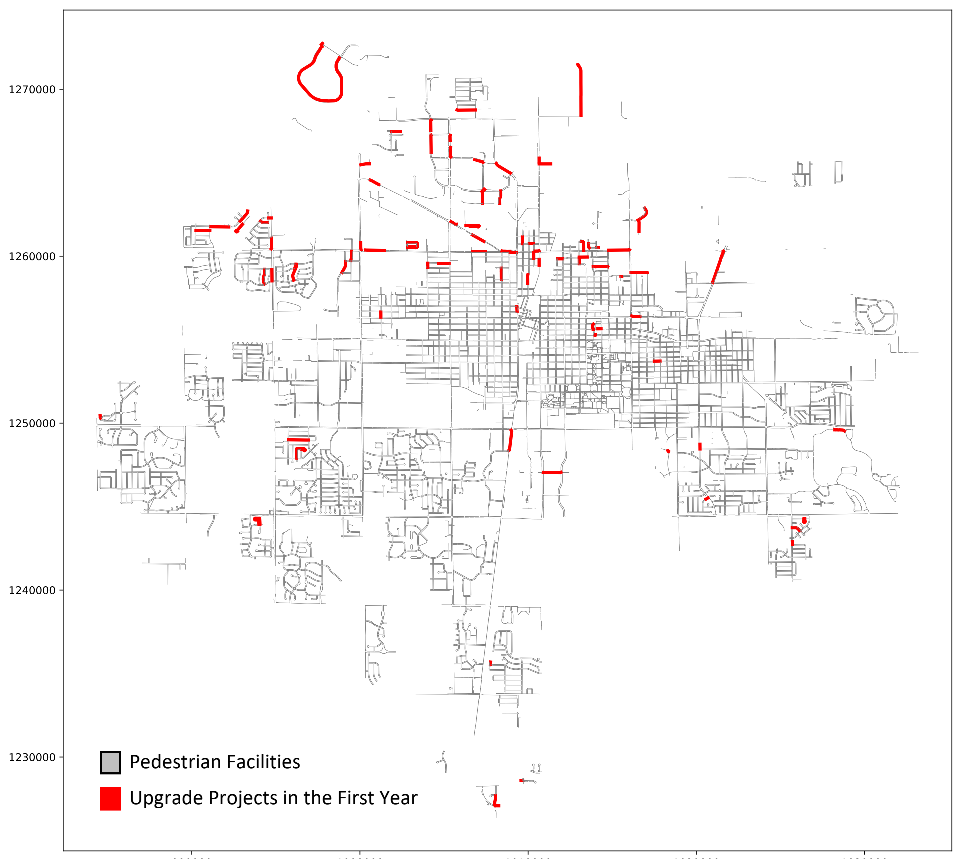


Figure 74. Map of upgrade projects scheduled in the first year of optimal transition plan #3

6.6. Summary

This chapter presented a novel multi-objective model for optimizing the scheduling of upgrade projects for non-compliant pedestrian facilities to achieve full compliance with accessibility requirements for people with disabilities. The model was developed in four phases: (1) upgrade-impact quantification phase that analyzed and quantified the impact of upgrading each pedestrian facility on people with disabilities; (2) model formulation phase that identified all relevant decision variables that affect this optimization problem and formulated the optimization objective functions and constraints; (3) model implementation phase that performed the optimization computations and specified the model input and output data; and (4) case study phase that analyzed the performance of the optimization model using a real-life case study of a city with 4,178 non-compliant pedestrian facilities. The analysis of the case study illustrated the use of the model and its novel and unique capabilities. The primary contributions of this research to the body of knowledge are its original methodology for: (1) quantifying the impact of upgrading non-compliant pedestrian facilities on people with disabilities; (2) identifying optimal trade-offs among the three objectives of minimizing total number of interrupted pedestrian trips, total upgrade duration, and annual upgrade budgets; (3) generating detailed optimal schedules for upgrading non-compliant pedestrian facilities to satisfy all accessibility requirements; and (4) generating graphic maps that illustrate the geographical locations of all planned upgrade projects during each year of the multi-year optimal transition plan. These novel and unique capabilities should prove useful to decision makers in state and local governments and are expected to minimize the required duration for achieving full compliance with all accessibility requirements while minimizing required annual upgrade budgets and the total number of interrupted pedestrian trips during the transition plan.

CHAPTER 7 - SUMMARY AND CONCLUSIONS

7.1. Summary

The present research study focused on assisting decision makers in state and local governments in achieving full compliance with accessibility requirements while considering the availability of their budgets and resources. The new research developments of this study include: (1) a comprehensive and effective field guide; (2) a novel and practical framework for automating the extraction and modeling of sidewalk conditions, dimensions and geometry from images; (3) a novel methodology to assess the degree of non-compliance of pedestrian facilities with accessibility requirements; and (4) an innovative model to optimize the development and execution of transition plans.

First, a practical and comprehensive field guide was created to improve the understanding and communication of accessibility requirements for field engineers and inspectors. The developed field guide included three main sections: (1) introduction, (2) accessibility requirements checklists, and (3) defined terms. The second section included a comprehensive list of all accessibility requirements to assist field engineers and inspectors in verifying the compliance of sidewalks and pedestrian facilities and avoid the need to review any additional resources during the inspection. Second, a novel framework was developed to automate the extraction and 3D modeling of sidewalk conditions, dimensions, and geometry from sidewalk images. The framework was developed in three modules: (1) semantic segmentation module that used fully convolutional networks to identify sidewalk-related pixels in input images, (2) 3D reconstruction module that built 3D point clouds of sidewalks, and (3) sidewalk dimensions module that fitted 3D surfaces to the reconstructed point clouds to automatically extract sidewalk dimensions and geometry.

Third, a novel model was developed to automate the assessment of the degree of non-compliance of pedestrian facilities with accessibility requirements. The model was developed in four main phases: (1) accessibility requirements analysis phase that identifies pedestrian facility types and their related accessibility requirements, (2) non-compliance assessment phase that quantified the degree of non-compliance of each pedestrian facility with accessibility requirements; (3) collective non-compliance phase that aggregated the individual non-compliance indices of a group of pedestrian facilities based on their type and/or geographical region; and (4) performance evaluation phase that analyzed a case study to illustrate the use of the developed model and demonstrate its novel capabilities. The analysis of the case study illustrated the novel capabilities of the model in (a) efficiently quantifying the degree of non-compliance of all types of pedestrian facilities including transit shelters, on-street parking spaces, and passenger loading zones; (b) assessing the degree of non-compliance of each pedestrian facility type to identify facility types that are in urgent need for upgrades; (c) prioritizing pedestrian facilities upgrade projects in multiple regions based on their non-compliance index; and (d) classifying pedestrian facilities based on the severity of their non-compliance with accessibility requirements. The model was able to assess the degree of non-compliance with accessibility requirements for 1327 pedestrian facilities that cover all pedestrian facility types and calculate non-compliance indices for pedestrian facility types NCI^p and regions NCI^g.

Fourth, a novel multi-objective model was developed to optimize the scheduling of upgrade projects for non-compliant pedestrian facilities to achieve full compliance with accessibility requirements for people with disabilities. The model was developed in four phases: (1) upgrade-impact quantification phase that analyzed and quantified the impact of upgrading each pedestrian facility on people with disabilities; (2) model formulation phase that identified all relevant decision variables that affect this optimization problem and formulated the optimization objective functions and constraints; (3) model implementation phase that performed the optimization computations and specified the model input and output data; and (4) case study phase that analyzed the performance of the optimization model using a real-life case study of a city with 4,178 non-compliant pedestrian facilities. The analysis of the case study illustrated the use of the model and its novel and unique capabilities.

7.2. Research Contributions

The main research contributions of this study include the development of:

1. Comprehensive and effective field guide to assist site engineers and inspectors in verifying the compliance of sidewalks and pedestrian facilities with accessibility requirements.

2. Cost-effective and practical framework for automating the extraction and 3D modeling of sidewalks conditions, dimensions, and geometry.

3. Deep fully convolutional neural network FCN that is capable of identifying sidewalk pixels in input images and isolating these pixels by discarding all non-relevant pixels in these images.

4. Innovative automated assessment model that is capable of assessing the degree of non-compliance for sidewalks and pedestrian facilities with accessibility requirements.

5. New metrics to quantify the degree of non-compliance for all types of pedestrian facilities.

6. Original metrics that are capable of quantifying the impact of upgrading non-compliant pedestrian facilities on people with disabilities by calculating the expected number of pedestrian trips that will be interrupted or cancelled due to non-compliance with accessibility requirements.

7. Novel multi-objective optimization model that is capable of generating optimal trade-offs between the three objectives of minimizing interrupted pedestrian trips, total upgrade durations, and annual upgrade budgets.

7.3. Research Impact

The implementation of the proposed models, methodologies, and frameworks can lead to broad and profound impacts on sidewalks and pedestrian facilities construction, alteration, and maintenance. These impacts include: (1) improving understanding of accessibility requirements and improving the accuracy of their inspection in the field, (2) maximizing the efficiency and effectiveness of performing self-evaluations, (3) generating accurate 3D models of the existing conditions of sidewalks and pedestrian facilities in a reliable digital format, and (4) streamlining and optimizing the development and execution of transition plans to ensure achieving maximum compliance with accessibility requirements while minimizing total upgrade duration and annual upgrade budgets.

7.4. Future Research Work

While the present study fully achieved its research objectives, additional research areas have been identified to expand and build upon the completed research work. These future research opportunities include: (1) expanding the developed fully convolutional network, (2) automating the capture of sidewalk images, and (3) creating a real-time compliance assessment system for sidewalks and pedestrian facilities.

7.4.1. Expanding the Fully Convolutional Network

The developed FCN utilizes its efficient architecture to identify and isolate sidewalk pixels in input images. The methodology developed in the present study yields highly accurate image segmentation analysis, as shown in the previous chapters. Expanding the capabilities of this FCN beyond isolating sidewalk pixels might improve the overall efficiency of the self-evaluation. These additional FCN capabilities may include (1) directly identifying sidewalk dimensions from images without the need to reconstruct a 3D model, (2) automatically analyzing vertical fault to identify non-compliant sidewalk segments, and (3) identifying protruding objects such as tree branches that overlap the sidewalk and highlight them for removal.

7.4.2. Automating the Capture of Sidewalk Images

The research study focuses on utilizing visual data from sidewalk images that can be captured by drone, ground robot, handheld camera, and/or cell phone. The developed methodology in its current state is agnostic to the source of input sidewalk images. Expanding the capabilities of this methodology to automate capturing sidewalk images using Unmanned Aerial Vehicles (UAVs) and/or Unmanned Ground Vehicles (UGVs) will enable decision makers and field inspectors to cover larger areas of sidewalk networks while reducing the required time, cost, and labor hours. This automation will also enable decision makers to repeat the same flight patterns or ground robot paths to update their sidewalk inventory data.

7.4.3. Creating a Real-Time Sidewalk Compliance Assessment System

The present research study provides an end-to-end sidewalk compliance assessment and verification system that can be used to supplement or replace existing traditional methods. The developed models, methodologies, and frameworks provide significant time, cost, and accuracy improvement over traditional manual measurement and analysis methods. The present study highlights the capabilities of state-of-the-art tools such as neural networks in efficiently performing complicated tasks that were impossible a few years ago. Considering the latest advancement in the fields of deep convolutional networks, a fast FCN might be developed to analyze sidewalk images and predict their degree of non-compliance with accessibility requirements in real time. This potential research direction might currently be difficult due to the limitations in existing hardware configurations and network architectures, but it is expected to become more efficient with the continuous advancement in mobile hardware and neural network implementation.

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APPENDIX A: SAMPLE OF THE FIELD GUIDE

1. Introduction

This field guide is intended for use by construction inspectors to identify and evaluate issues that must be addressed along pedestrian access routes that are directly affected or altered by a project. The field guide includes checklists that are developed to verify compliance with all applicable accessibility laws and regulations in the State of Illinois, including the 2011 Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG), Illinois Accessibility Code (IAC), and IDOT standards. The following two sections in the field guide include accessibility requirements checklists and defined terms. Users of this Field Guide should review the defined terms section and the state standards for curb ramps before applying the requirements described herein.

2. Accessibility Requirements Checklists

The checklists in this section are mostly presented in the form of questions that should have an answer of "yes" (i.e., checked box) to evaluate and verify compliance of the listed items with accessibility requirements.

If the evaluation of an item results in an answer of "no" (i.e., box not checked), the element shall be identified as non-compliant for correction or for recordkeeping in the ADA transition plan.

5

2.1. Pedestrian Access Route (PAR)

- ☐ Does the pedestrian circulation path (PCP) include a 4 feet minimum width PAR (see Figure 1)?

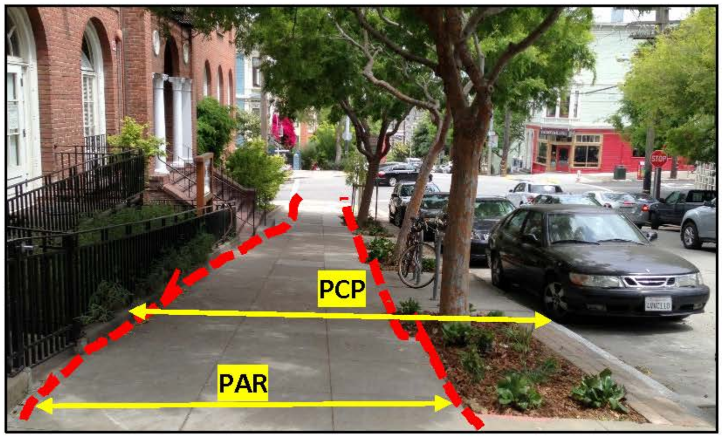


Figure 1: PAR within Pedestrian Circulation Path

- ☐ Is there a PAR provided within pedestrian street crossings, including medians and pedestrian refuge islands?
- ☐ Is there a PAR provided within pedestrian at-grade rail crossings (see Figure 2)?

Figure 2: PAR within Pedestrian At-Grade Rail Crossings

- ☐ Is there a PAR provided within overpasses, underpasses, bridges, and similar structures that contain a PCP?
- ☐ Where an overpass, underpass, bridge, or similar structure is designed for pedestrian use only and the approach slope to the structure exceeds 5%, is there a provided ramp, elevator, or limited use/limited application elevator?

2.1.1. Continuous Width

- ☐ Is the continuous width of the PAR 4 feet or more (minimum 5 feet recommended), exclusive of the width of the curb (see Figure 3)?

Figure 3: PAR Continuous Width

- ☐ If the PAR width is less than 5 feet, are there passing spaces provided that satisfy the following requirements?
    - Cross slope of passing space is 2% or less.
    - Dimensions of each passing space are 5 feet x 5 feet or more (see Figure 4).
    - Intervals between passing spaces are 200 feet or less (see Figure 4).

Note: Passing spaces are allowed to overlap PAR (see Figure 4).

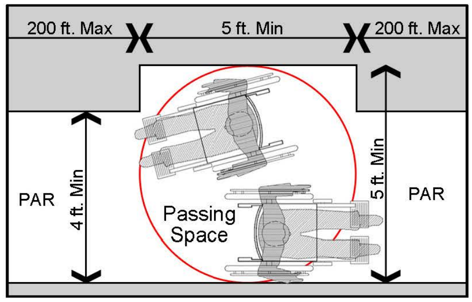


Figure 4: Passing Space Dimensions and Intervals

- ☐ Is the clear width of the PAR 4 feet minimum and free of street furniture or any other objects (see Figure 5)?

Figure 5: PAR Width and Street Furniture

☐ Is the minimum clear width of the PAR within medians and pedestrian refuge islands 5 feet or more (see Figure 6)?

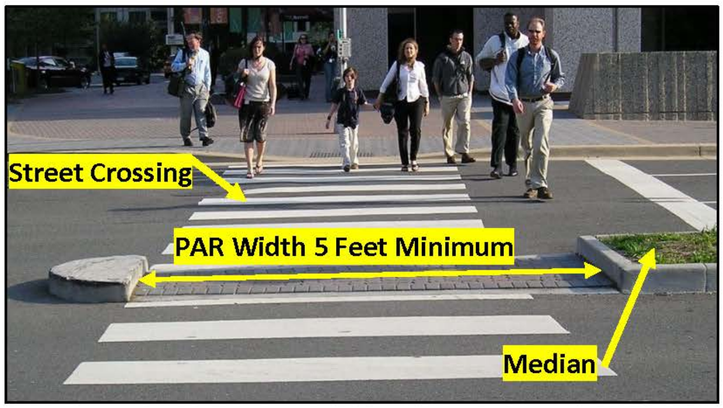


Figure 6: PAR Width within Medians

2.1.2. Required Vertical Clearance

☐ Is the PAR vertical clearance 84 inches for signs and 80 inches for all other objects (see Figure 7)?

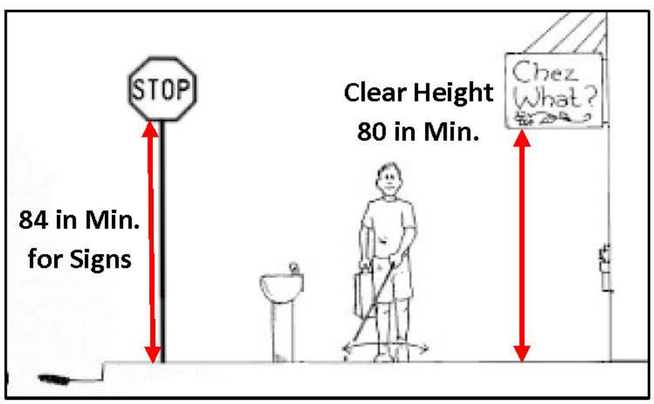


Figure 7: PAR Vertical Clearance

2.1.3. Grade

2.1.3.1. Running slope

- ☐ Is the PAR running slope 5% or less, where running slope is measured in the direction of pedestrian travel (see Figure 8)?

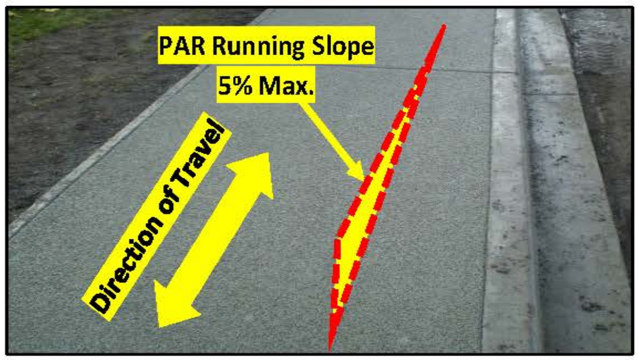


Figure 8: PAR Running Slope

- ☐ Where the PAR is contained within a street or highway right-of-way, is the grade of PAR less than or equal to the general grade of the adjacent street or highway (see Figure 9)?

Figure 9: PAR Running Slope Shall Not Exceed Grade of Adjacent Street

- ☐ Where the PAR is contained within the pedestrian street crossing, is the PAR running slope 5% or less (see Figure 10)?

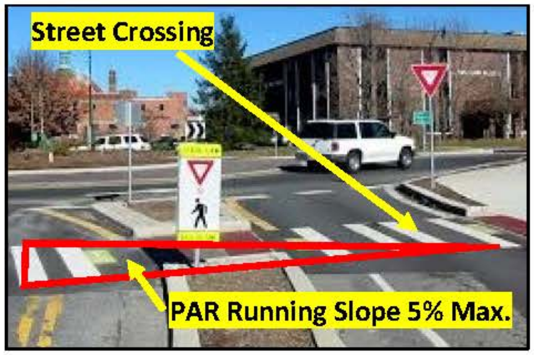


Figure 10: PAR Running Slope within Street Crossings

2.1.3.2. Cross slope

- ☐ Is the PAR cross slope 2% or less (1.5% recommended), where PAR cross slope is measured perpendicular to the direction of pedestrian travel (see Figure 11)?

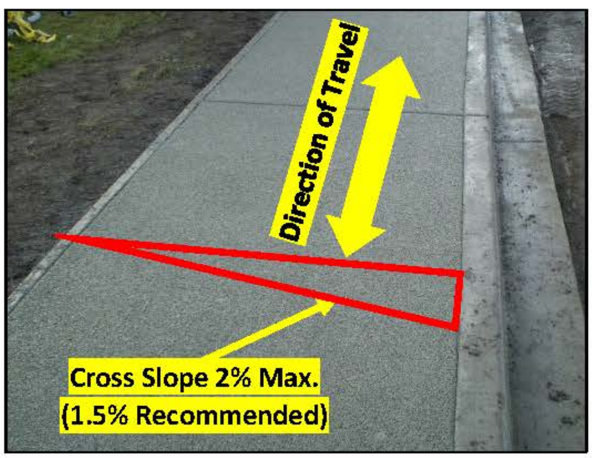


Figure 11: PAR Cross Slope

- ☐ Where the PAR is contained within pedestrian street crossings with yield or stop control, is the cross slope of PAR 2% or less (see Figure 12)?

Figure 12: Pedestrian Street Crossing With Stop Control

- ☐ Where the PAR is contained within pedestrian street crossings without yield or stop control, is the cross slope of PAR 5% or less (see Figure 13)?

Figure 13: Pedestrian Street Crossing Without Yield or Stop Control

- □ Door closers shall be adjusted to take 5 seconds or more to move the door from the open position of 90 degrees to 12 degrees from the latch.
- □ Spring hinges shall be adjusted to take 1.5 seconds or more to move the door from the 70 degrees open position to closed position.

3. Defined Terms

Accessible. A facility that complies with applicable accessibility laws and regulations.

Alteration. A change to a facility in the public right-of-way that affects or could affect pedestrian access, circulation, or use. Alterations include, but are not limited to, resurfacing, rehabilitation, reconstruction, historic restoration, or changes or rearrangement of structural parts or elements of a facility.

Blended Transition. A raised pedestrian street crossing, depressed corner, or similar connection between the pedestrian access route at the level of the sidewalk and the level of the pedestrian street crossing that has a grade of 5% or less.

Cross Slope. The grade that is perpendicular to the direction of pedestrian travel.

Curb Line. A line at the face of the curb that marks the transition between the curb and the gutter, street, or highway.

Curb Ramp. A ramp that cuts through (or is built up to) the curb. Curb ramps can be perpendicular or parallel, or a combination of parallel and perpendicular ramps.

Detectable warnings. A distinctive surface pattern of domes detectable by cane or underfoot that alert people with vision impairments of their approach to street crossings and hazardous drop-offs.

Element. An architectural or mechanical component of a building, facility, space, site, or public right-of-way.

Facility. All or any portion of buildings, structures, improvements, elements, and pedestrian or vehicular routes.

Grade Break. The line where two surface planes with different grades meet.

Operable Part. A component of an element used to insert or withdraw objects, or to activate, deactivate, or adjust the element.

Parallel Curb Ramp. A ramp that is aligned so that the general pedestrian travel is parallel to the curb.

Pedestrian Access Route (PAR). A continuous and unobstructed path of travel provided for pedestrians with disabilities within or coinciding with a pedestrian circulation path.

Pedestrian Circulation Path (PCP). A prepared exterior or interior surface provided for pedestrian travel.

Perpendicular Curb Ramp. A ramp that is aligned so that the general pedestrian travel is perpendicular to the curb.

Public Right-of-Way. Public land or property, usually in interconnected corridors, that is acquired for or dedicated to transportation purposes.

APPENDIX B: SAMPLE OF CITY OF URBANA TRANSITION PLAN

CITY OF URBANA
DEPARTMENT OF PUBLIC WORKS

CITY OF URBANA

ADA TRANSITION PLAN

2012 UPDATE

PUBLIC RIGHTS OF WAY

AND

SIDEWALK

TABLE OF CONTENTS

I. INTRODUCTION

The 2012 ADA Transition Plan supersedes and takes the place of Section IV. Title II: G. Curb and sidewalk ramps; and, H. Parking accessibility of the City of Urbana Americans With Disabilities Act Compliance Plan, in effect since July, 1993. This plan is in accordance with the guidelines of the Illinois Department of Transportation (IDOT), Americans with Disabilities Act (ADA). When the City of Urbana Transition Plan is in conflict with the IDOT guidelines, IDOT guidelines shall take precedence.

The purpose of this transition plan is to:

- Conduct a new self-assessment and inventory of needs.
- Solicit public input to increase awareness and effectiveness of the plan.
- Incorporate new practices and procedures into the plan.
- Develop an implementation schedule for the plans.
- Compliance attainment with IDOT ADA guidelines.

II. BACKGROUND.

The City of Urbana Department of Public Works surveyed all its sidewalk ramps in 1991 to assess ADA compliance.

In 1993 the city adopted an ADA compliance plan to reconstruct non-compliant sidewalks to meet the then current ADA standards.

III. SELF-EVALUATION

Public Works Department staff will begin a new inventory survey in the summer of 2012. The Public Works Department will create a geographic information system (GIS) based map and database to inventory ramp data. The GIS database will also be utilized to prioritize and track ramp reconstruction activities.

Ramp survey forms are presented in Appendix A.

IV. COMPLIANCE PROGRAM

Priority system

Priorities can be set by addressing both the needs and physical conditions of the ramps.

From a needs perspective the following should be considered:

A. Presence of a disabled population or specific complaints and/or requests from a disabled person or advocacy group (10 points).

B. High volume of pedestrians, such as in the Central Business District or University District, schools (8 points), public buildings, hospitals, senior housing, libraries, public transportation facilities, or parks (6 points).

C. Low volume pedestrian use areas such as residential subdivisions (2 points).

D. Alternative ADA compliant sidewalk route within 1 block radius (-3 points). (Deduction meant to lower priority based on close proximity to a compliant route).

From a ramp condition perspective the following should be considered:

1. There is no ramp at a pedestrian crossing in an area with sidewalks (8 points).

2. Existing ramp which is unsafe due to deterioration (1 to 3 points), excessive slopes (1-3 points), or abrupt changes in the surface elevations (maximum of 7 points total).

3. Where ramps are generally safe and in good condition but do not fully comply (no detectable warnings with domes, side tapers are out of compliance, etc.) (1 point).

Each ramp location will be rated according to these criteria. Specific projects designed to replace ramps to correct deficiencies will address those rated numerically highest until budgeted funds are exhausted.

Requirement to Act

All new development and redevelopment must have accessible walks and ramps in full compliance with accessibility standards as required in the city's Subdivision and Land Development Code (Section 21-58).

Alterations of facilities in the public right-of-way must make changes to sidewalks and ramps to meet current ADA standards. Alterations are changes which affect the usability and are broadly interpreted to include work such as road reconstruction, sidewalk repairs, asphalt overlay of the street, or utility repairs that affect the sidewalks or ramps. When work involves one corner of an intersection only that corner must have the curb ramps improved to current ADA standards and the adjacent pavement must be resurfaced as necessary to provide for a flush transition. All sidewalk work greater than 10' in length that abuts a curb ramp shall be extended to include affected ramps and those ramps must be improved to current ADA standards.

The city will also reconstruct all non-compliant sidewalk ramps during adjacent street reconstruction and resurfacing projects. The city estimates approximate (40) sidewalk ramps will be reconstructed each year as part of street construction resurfacing projects.

V. IMPLEMENTATION SCHEDULE

Winter 2012 – Spring 2012

- Create GIS based inventory system of all Urbana sidewalk ramps.

Spring 2012 – Fall 2014

- Survey all Urbana sidewalk ramps

Fall 2014 – Winter 2015

- Rank and prioritize all non-compliant sidewalk ramps.

Spring 2014 - ???

- Implement sidewalk ramp reconstruction efforts based on inventory priority ranking system.

After completion of the sidewalk ramp survey the City will know how many non-compliant ramps exist and can then finalize a ramp reconstruction schedule to bring those ramps up to current ADA standards.

Sidewalk ramp reconstruction efforts will be tracked in the GIS based sidewalk inventory system to maintain a current list of non-compliant sidewalk ramps and track the number of sidewalk ramp reconstructions that the City has completed as part of its ADA Transition Plan efforts.

VI. PROGRAM RESPONSIBILITY

The official responsible for implementation of the City's ADA Transition Plan in Public Rights-of-Way is:

William R. Gray
Director of Public Works
706 South Glover Avenue
Urbana, Illinois 61802
Telephone: (217) 384-2342
Fax: (217) 384-2400
Web site: www.urbanaillinois.us

The City of Urbana ADA Coordination is the responsibility of the Engineering Division of the Public Works Department.

VII. PUBLIC INVOLVEMENT

A meeting was held with the Bike and Pedestrian Advisory Committee (BPAC) on February 21, 2012 to solicit their input on the ADA Transition Plan. The BPAC members did not have any comments regarding the Transition Plan.

The Transition Plan was also reviewed by a member of the Champaign Urbana Urbanized Transportation Study (CUUATS) group. The CUUATS review comments are provided in Appendix B.

The ADA Transition Plan was also posted on the city website for public review and comment from May 11, 2012 to June 15, 2012.

VIII. ACCOMMODATION PROCEDURE

The accommodation process is an integral part of the ADA Transition Plan. Accommodations will be evaluated according to the policies, practices, and available funding sources. Within the Department of Public Works, the Engineering Division will receive and evaluate accommodation requests.

Accommodation Process: The Engineering Division acts as the central clearinghouse for curb ramp and sidewalk accommodation requests. Citizens with disabilities requiring curb ramps are encouraged to contact the office directly at 217-384-2342. Accommodation requests received by other departments or agencies will be routed to the Engineering Division. This central accommodation request processing procedure ensures that the specific needs of each individual are accurately understood and recorded. The deficiency and specific location are then entered into a log and the matter referred to the Engineering Division for inspection and possible action. The Engineering Division then coordinates any work and keeps a record of all formal responses to the requester. A request for accommodation form is provided in Appendix C.

Accommodation requests may be received through a variety of communication methods:

John Lyons, P.E.
Civil Engineer
Department of Public Works
706 South Glover Avenue
Urbana, Illinois 61802
Telephone: (217) 384-2342
Fax: (217) 384-2400
email: jglyons@urbanaillinois.us

Website www.urbanaillinois.us

IX. APPENDICES

Appendix A Inspection Forms

Appendix B. CUUATS Comments on ADA Transition Plan

Appendix C. Request for Accommodation / Sidewalk Repair Form

Appendix D. City Design Standards

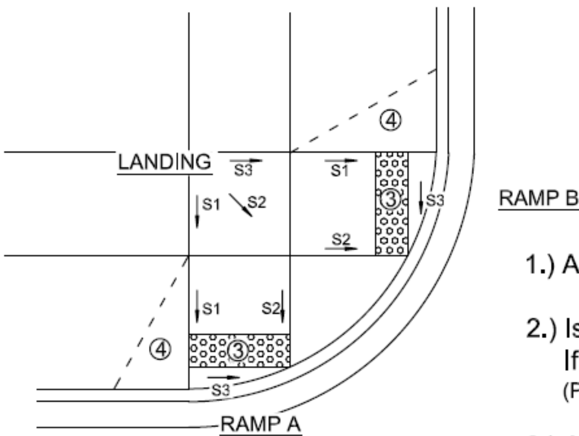
ADA CURB RAMP
EVALUATION CHECKLIST

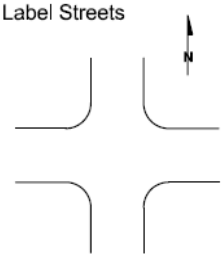
PERPENDICULAR RAMPS AT CORNER

Inspection Date:____________________ Location:____________________

Inspected By: ____________________ ____________________

Note location on Map, Label Streets





1.) Are there existing ramps? Yes / No

2.) Is either existing ramp deteriorated? Yes / No
If Yes, which one? A / B / Both
(Panels broken into three or more pieces)

3.) Are truncated domes present and in satisfactory condition? Yes / No If No, which one? A / B / Both

4.) If side tapers are present, are they less than or equal to a 10:1 slope?
Ramp A: Yes / No / Not Present If No, what is the slope?________
Ramp B: Yes / No / No Present If No, what is the slope?________

5.) Are manholes, handholes or valves located within the ramps or landing?
Ramp A: Yes / No Ramp B: Yes / No Landing: Yes / No

6.) Do heaved panels exist within the ramps or landing?
Ramp A: Yes ☐ 0.5"-1" / No ☐ 1"-2" ☐ >2"
Ramp B: Yes ☐ 0.5"-1" / No ☐ 1"-2" ☐ >2"
Landing: Yes ☐ 0.5"-1" / No ☐ 1"-2" ☐ >2"

7.)

	RAMP A	RAMP B	LANDING
SLOPE 1 (S1)			
SLOPE 2 (S2)			
SLOPE 3 (S3)			

8.) Use back of sheet for additional comments

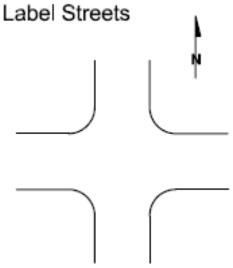
ADA CURB RAMP
EVALUATION CHECKLIST

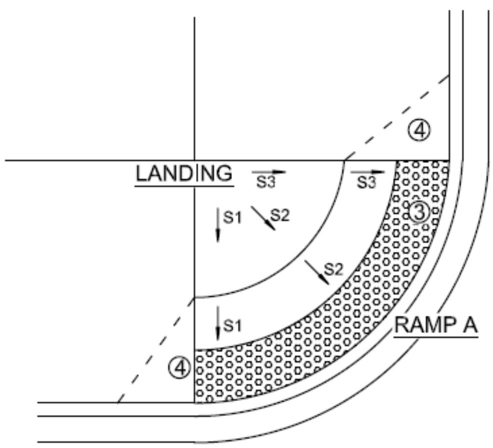
BLENDED TRANSITION AT CORNER

Inspection Date:____________________ Location:____________________

Inspected By: ____________________ ____________________

Note location on Map, Label Streets





1.) Is there an existing ramp? Yes / No

2.) Is the existing ramp deteriorated? Yes / No
(Panels broken into three or more pieces)

3.) Are truncated domes present and in satisfactory condition? Yes / No

4.) If side tapers are present, are they less than or equal to a 10:1 slope? Yes / No / Not Present
If No, what are the slopes?_________

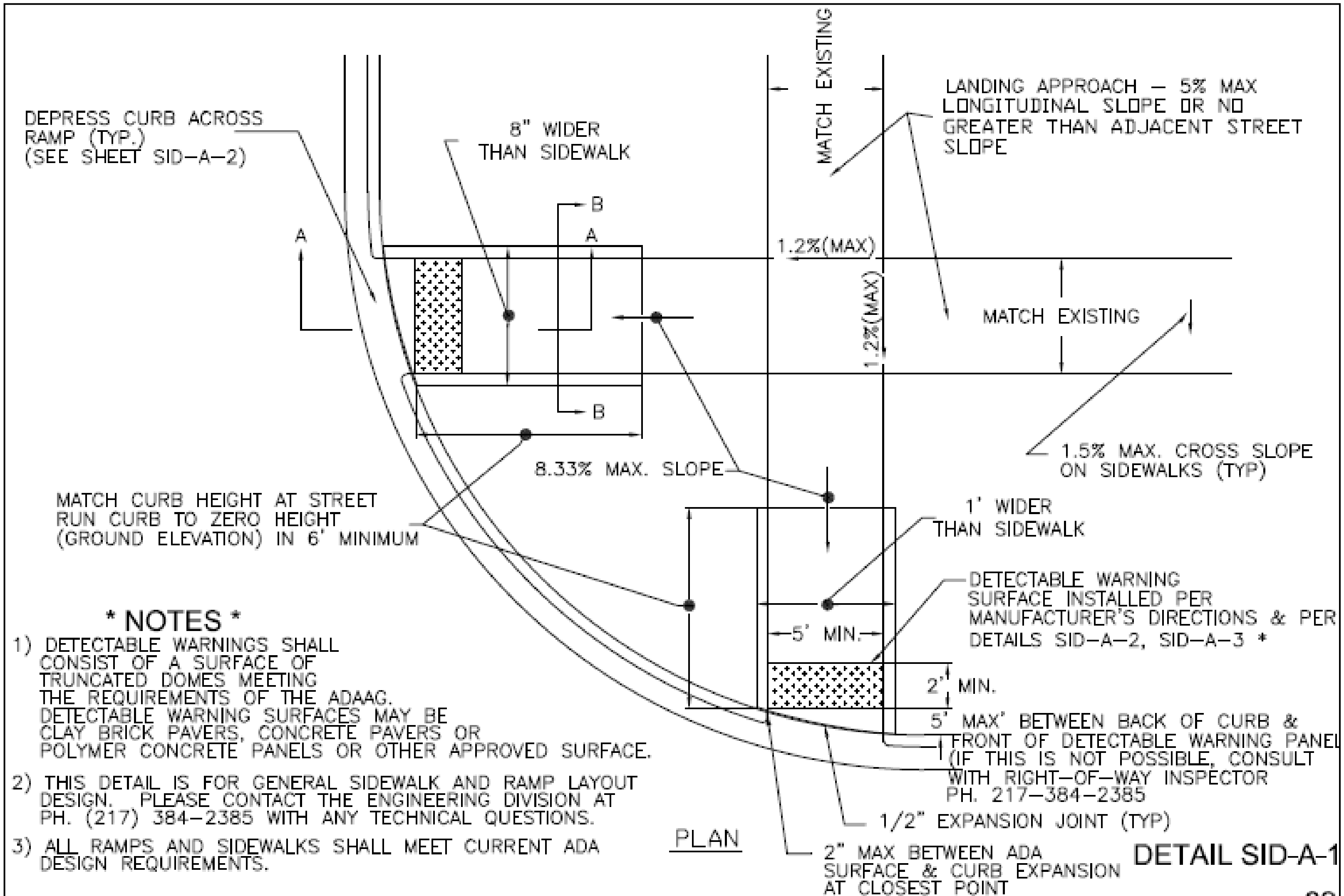
5.) Are manholes, handholes or valves located within the ramp or landing?
Ramp: Yes / No Landing: Yes / No

6.) Do heaved panels exist within the ramp or landing?
Ramp : Yes ☐ 0.5"-1" / No Landing: Yes ☐ 0.5"-1" / No
☐ 1"-2" ☐ 1"-2"
☐ >2" ☐ >2"

7.)

	RAMP A	LANDING
SLOPE 1 (S1)		
SLOPE 2 (S2)		
SLOPE 3 (S3)		

8.) Use back of sheet for additional comments



*** NOTES ***

1) DETECTABLE WARNINGS SHALL CONSIST OF A SURFACE OF TRUNCATED DOMES MEETING THE REQUIREMENTS OF THE ADAAG. DETECTABLE WARNING SURFACES MAY BE CLAY BRICK PAVERS, CONCRETE PAVERS OR POLYMER CONCRETE PANELS OR OTHER APPROVED SURFACE.

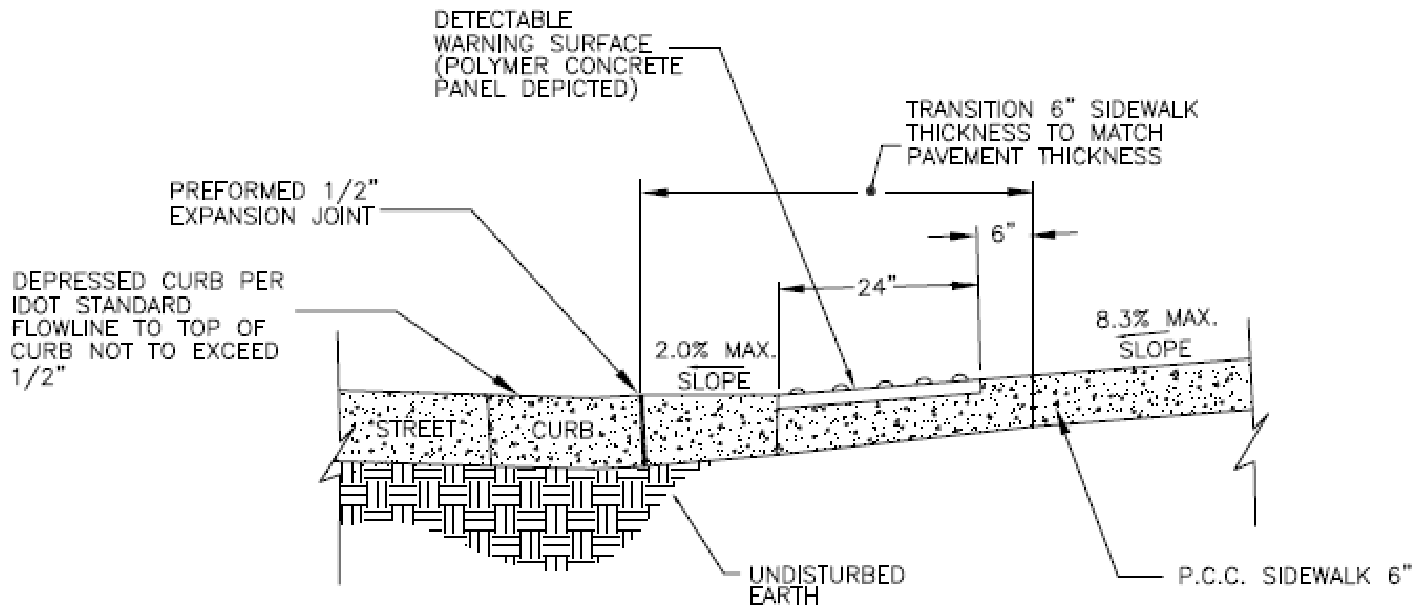
2) THIS DETAIL IS FOR GENERAL SIDEWALK AND RAMP LAYOUT DESIGN. PLEASE CONTACT THE ENGINEERING DIVISION AT PH. (217) 384–2385 WITH ANY TECHNICAL QUESTIONS.

3) ALL RAMPS AND SIDEWALKS SHALL MEET CURRENT ADA DESIGN REQUIREMENTS.

DETAIL SID-A-1

32

CITY OF URBANA Public Works Department	RIGHT-OF-WAY STANDARD DRAWING ADA DETECTABLE WARNING RAMP PLAN	DATE	REVISIONS
		11/30/11	



SECTION A-A

NOTES:

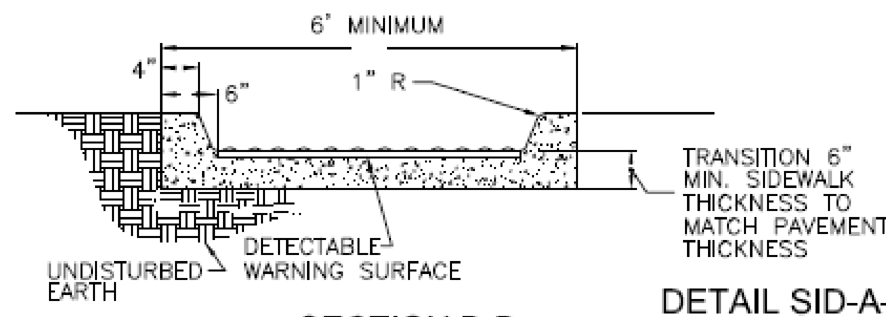
1.) DETECTABLE WARNING SURFACE PANELS SHALL BE INSTALLED PER MANUFACTURERS DIRECTIONS.

2) INSTALL 3/8" THICK COMPACTED SAND LEVELING BED UNDER PCC & BRICK ADA PAVERS

3) JOINTS BETWEEN PCC AND BRICK PAVERS SHALL BE 1/8" TO 1/4" WIDE

4) SWEEP FINE GRAIN SILICA SAND INTO PCC & BRICK PAVER JOINTS.

5) SIDEWALKS AND RAMPS SHALL MEET CURRENT ADA DESIGN GUIDELINES.



SECTION B-B

DETAIL SID-A-2
33

CITY OF URBANA Public Works Department	RIGHT-OF-WAY STANDARD DRAWING ADA DETECTABLE WARNING RAMP DETAILS	DATE 11/23/11	REVISIONS

APPENDIX C: ACCESSIBILITY REQUIREMENTS AND NON-COMPLIANCE SCORE

Table 16: Example weights and limits for curb ramp requirements

Curb Ramp Requirement	r	Weight s(W_r^2) %	Range of Existing Conditions	Non-Compliance Score ($S_{i,r}^2$)%
Width	1	10	$Width < 3.00\ feet$	100
			$3.00 \leq Width < 4.00\ feet$	50
			$Width \geq 4.00\ feet$	0
Running Slope	2	10	$Running\ Slope > 12$	100
			$12\% \geq Running\ Slope > 8.33\%$	50
			$Running\ Slope \leq 8.33\%$	0
Cross Slope	3	10	$Cross\ Slope > 4\%$	100
			$4\% \geq Cross\ Slope > 2\%$	50
			$Cross\ Slope \leq 2\%$	0
Ramp Flare Slope	4	10	$ramp\ flare\ slope > 12\%$	100
			$12\% \geq ramp\ flare\ slope > 10\%$	50
			$ramp\ flare\ slope \leq 10\%$	0
Detectable Warning Surfaces	5	10	$DWS\ is\ non-standard$	100
			$DWS\ is\ present$	0
Alignment with Marked Crosswalk	6	10	$not\ aligned$	100
			$aligned$	0
Vertical Changes in Level	7	10	$change\ in\ level > 0.5"$	100
			$0.5" \geq change\ in\ level > 0.25"$	50
			$0.25" \geq change\ in\ level > 0.0"$	0
Landing Size	8	10	$landing\ is\ missing$	100
			$2.00 \leq landing < 3.00\ feet$	60
			$3.00 \leq landing < 4.00\ feet$	40
			$landing \geq 4.00\ feet$	0
Landing Slope	9	10	$Cross\ Slope > 4\%$	100
			$4\% \geq Cross\ Slope > 2\%$	50
			$Cross\ Slope \leq 2\%$	0
Gutter Running Slope	10	5	$running\ slope > 8\%$	100
			$8\% \geq running\ slope > 5\%$	50
			$5\% \geq running\ slope > 0.0"$	0
Gutter Cross Slope	11	5	$running\ slope > 5\%$	100
			$5\% \geq running\ slope > 2\%$	50
			$2\% \geq running\ slope > 0.0"$	0

Table 17: Example weights and scores for pedestrian signals requirements

Pedestrian Signal requirement	$\boldsymbol{r}$	**Weights ($\boldsymbol{W_r^4}$)%**	**Range of Existing Conditions**	**Non-Compliance Score ($\boldsymbol{S_{i,r}^4}$)%**
Button Height	1	15	$height < 25"$	100
			$27" \leq height < 30"$	50
			$30" \leq height < 42"$	0
			$42" \leq height < 48"$	50
			$height \geq 48"$	100
Button Diameter	2	10	$diameter \geq 2"$	100
			$diameter < 2"$	0
Button Pressure	3	15	$pressure \leq 5\text{lbs}$	100
			$pressure > 5\text{lbs}$	0
Button Visual Contrast	4	10	$no\ button\ contrast\ with\ background$	100
			$button\ contrasts\ with\ background$	0
Locator Tone	5	10	$no\ locator\ tone\ present$	100
			$locator\ tone\ present$	0
Closed Fist Option	6	15	$closed\ fist\ option\ not\ provided$	100
			$closed\ fist\ option\ present$	0
Clear Floor Space	7	15	$no\ clear\ floor\ spcae\ present$	100
			$clear\ floor\ spcae\ present$	0
Clear Floor Space Slope (in any direction)	8	10	$Cross\ Slope > 6\%$	100
			$6\% \geq Cross\ Slope > 4\%$	40
			$4\% \geq Cross\ Slope > 2\%$	20
			$Cross\ Slope \leq 2\%$	0

Table 18: Example weights and scores for refuge islands requirements

Refuge Islands Requirements	r	Weights (W_r^5)%	Range of Existing Conditions	Non-Compliance Score ($S_{i,r}^5$)%
Width	1	15	$Width < 4.00\ feet$	100
			$4.00 \leq Width < 5.00\ feet$	50
			$Width \geq 5.00\ feet$	0
Running Slope	2	15	$Running\ Slope > 12$	100
			$12\% \geq Running\ Slope > 8.33\%$	50
			$Running\ Slope \leq 8.33\%$	0
Cross Slope	3	15	$Cross\ Slope > 4\%$	100
			$4\% \geq Cross\ Slope > 2\%$	50
			$Cross\ Slope \leq 2\%$	0
Detectable Warning Surfaces	4	15	$DWS\ is\ non-standard$	100
			$DWS\ is\ present$	
Vertical Changes in Level	5	15	$change\ in\ level > 0.5"$	100
			$0.5" \geq change\ in\ level > 0.25"$	50
			$0.25" \geq change\ in\ level > 0.0"$	0
Gutter Running Slope	6	15	$running\ slope > 8\%$	100
			$8\% \geq running\ slope > 5\%$	50
			$5\% \geq running\ slope > 0.0"$	0
Gutter Cross Slope	7	10	$running\ slope > 5\%$	100
			$5\% \geq running\ slope > 2\%$	50
			$2\% \geq running\ slope > 0.0"$	0