

**SIDEWALK ASSET MANAGEMENT: FINANCIAL MODELING THE
TOTAL COST OF SIDEWALKS**

A Dissertation
Presented to
The Academic Faculty

by

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In Partial Fulfillment
of the Requirements for the Degree
Master of Science in the
School of Civil and Environmental Engineering

Georgia Institute of Technology
December 2018

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ACKNOWLEDGEMENTS

First, I would like to thank my wife, Lizzie, for her blessing to pursue this endeavor and her patience through both the good and the difficult times. I would like to thank my parents for never placing barriers on the bounds of my education. I greatly appreciate the research advice and mentorship I have received from Dr. Aaron Larosche and Dr. David Ederer. None of this would be possible without the contributions of past and present members of the Georgia Tech Sidewalks Lab as well as the unrelenting support of Marjorie Jorgenson. Thank you to my advisors, Dr. Randall Guensler, Dr. Adjo Amekudzi-Kennedy, and Dr. Kari Watkins for their generous advice, time, and confidence. Their contributions to my education and personal growth, both in and out of the classroom, did not go unnoticed. Finally, I must acknowledge the good people at Cypress Street Pint & Plate and my cat, Kyle, who have kept me sane and honest throughout this experience.

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LIST OF SYMBOLS AND ABBREVIATIONS

ADA	Americans with Disabilities Act
ADAAG	Americans with Disabilities Act Accessibility Guidelines
AASHTO	American Association of State Highway Traffic Officials
BUILD	Better Utilizing Investments to Leverage Development
CFR	Code of Federal Regulations
CMAQ	Congestion Mitigation & Air Quality
EAC	Equivalent Annualized Cost
EPA	Environmental Protection Agency
FAST	Fixing America's Surface Transportation Act
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
HSIP	Highway Safety Improvement Program
MAP-21	Moving Ahead for Progress in the 21st Century Act
MPO	Metropolitan Planning Organization
NHS	National Highway System
NPV	Net Present Value
TCO	Total Cost of Ownership
SPLOST	Special Purpose Local Interest Sales Taxes
STBG	Surface Transportation Block Grant Program
USAB	United States Access Board
USDOT	United States Department of Transportation

SUMMARY

Agencies are beginning to recognize transportation asset management benefits, either from starting programs by choice or because of federal and state requirements. Managing transportation facilities as assets helps reduce the total cost of ownership by funding and programming routine, preventative, and corrective maintenance through a facility's lifecycle. This process also leads to increased benefits returned to stakeholders. Pedestrian infrastructure often lacks such a centralized management practice, for both funding and maintenance. This research identifies pedestrian infrastructure elements as assets and defines construction costs, common issues, repair costs, and maintenance practices. Element costs are used to create a model estimating the total cost of ownership for pedestrian infrastructure. Next, various practices and sources for funding pedestrian infrastructure are discussed. Finally, the total cost of ownership model is applied in a case study that investigates the implications of adequate centralized funding based on available funding practices.

CHAPTER 1. INTRODUCTION

Pedestrian infrastructure is an oft-misunderstood community asset. Municipalities have the choice to cultivate and enrich the walking environment to the benefit of residents and visitors or overlook the final link between all transportation modes and destinations. Quality pedestrian infrastructure fosters universal mobility (1), community engagement (2), and overall health improvement (3). A good walking environment also generates these positive externalities without discrimination or negative consequences. Still, it can sometimes be difficult to convince transportation engineers and other professionals that sidewalks are transportation assets, perhaps in part due to the myriad of funding mechanisms and management practices utilized by communities around the world. The research presented in this thesis examines funding and management practices then develops a method of valuing pedestrian infrastructure to properly budget for managing pedestrian infrastructure as assets.

Successful agencies have practiced transportation asset management for thousands of years. C.E. van Sickle describes the extensive maintenance activities undertaken for Roman roads in Spain between the first and third centuries A.D., with repair frequency largely determined by the ruler at the time (4). In the United States, maintenance often takes a back seat to new construction (5), but in the last decade federal requirements instituted rules for states to develop asset management plans (6). Congress and state Legislatures typically acknowledge the benefit of maintenance for long-term assets, such as pavements and bridges, considering their relative permanence in our transportation networks. The necessity for mandatory out-year planning rises from the short-sighted

funding most infrastructure receives from annual budgets that may change drastically. While this process is necessary for many government functions, it does not benefit public works in general. Asset management helps agencies recognize the economic value of their assets and achieve economic efficiency over the assets' lifecycle (7). Even though elected officials may not view this practice as worthy of a ribbon cutting, transportation asset management can better allocate public money and improve the level of service of transportation systems.

Sidewalk networks constitute a considerable use of land in cities. Through research conducted for this thesis, we determined the sidewalk network may take up 1-2% of the land within the city of Atlanta. The total cost of ownership may exceed \$250,000 per sidewalk mile. Pedestrian networks, however, offer huge mobility benefits for community members and are rarely removed without being replaced. Given their economic value and community benefits, cities should consider treating sidewalks as transportation assets.

The Americans with Disabilities Act requires agencies with more than 50 people to develop transition plans to improve pedestrian infrastructure to meet accessibility design standards (8), but it does not specify how communities should fund improvements. A 2008 study by the Los Angeles Bureau of Street Services surveying 82 cities in 45 states, described by Donald Shoup in "Putting Cities Back on their Feet," found only 13% of cities paid for sidewalk repairs (9). Most cities either require adjacent property owners to "foot the bill" for pedestrian improvements or have developed a cost sharing program (with varying levels of support).

The impetus for the research presented in this thesis comes from recognizing the role sidewalks play in creating community wealth (2) and the mismatch of asset management support. While the legal precedent for providing accessible pedestrian infrastructure has been established in courts around the United States (8), this thesis outlines an approach for valuing pedestrian infrastructure that may be used to develop permanent funding sources to meet the anticipated financial needs for adequate pedestrian infrastructure management, and offers an example to demonstrate how one might go about estimating this value.

The remainder of this thesis is organized as follows. Chapter 2 provides a background on pedestrian infrastructure requirements and asset management practices as well as a review of relevant pedestrian infrastructure research. Chapter 3 examines construction and repair costs associated with pedestrian infrastructure and presents a methodology for calculating the total cost of ownership. Chapter 4 discusses the different funding mechanisms available for pedestrian asset management. Chapter 5 presents a case study application of the total cost of ownership model for the city of Atlanta. Concluding remarks follow in Chapter 6.

CHAPTER 2. BACKGROUND & LITERATURE REVIEW

Like healthcare, education, and other difficult and divisive policy issues, communities choose to address pedestrian infrastructure in different ways, with varying results and opinions of those results (9). As is typical of complex societal problems, not much is universally agreed upon when it comes to managing the walking environment. Some communities see the pedestrian right-of-way as the responsibility of adjacent property owners while others see sidewalks as a public conveyance and take on the burden of ownership. While financial responsibility is a source of contention, communities' responsibility to adhere to the Americans with Disabilities Act (ADA) has legal precedence.

This chapter provides an overview of the ADA and its goals, communities' share of liability, and the benefits of the walking environment. Then it will discuss current pedestrian infrastructure research and introduce asset management practices.

2.1 The Americans with Disabilities Act

In 1990, Congress passed and President George H. W. Bush signed into law the Americans with Disabilities Act (ADA). The goals of the ADA are: 1) to reduce the frequency of unemployment and isolation of disabled persons and 2) to make society as a whole more accessible for those with disabilities (8). While the ADA was practically applied more so to building access at its inception, in 2002, the U.S. Access Board (USAB) published the first definitive ADA Accessibility Guidelines (ADAAG) addressing accessibility in pedestrian infrastructure design (10). These design guidelines were

amended by the USAB in 2004, 2006, and 2010 (8). The various iterations of the ADAAG design standards are incorporated by reference into Title 28 of the Code of Federal Regulations (28 CFR 305.104 and 28 CFR 35.151(c)), which implement the Americans with Disabilities Act (8). In this fashion, the ADAAG constitutes the body of regulatory design standards that must be met.

A summary of the ADAAG-required criteria for widths, surface condition, grade, and cross-slope for all accessible routes, including sidewalks is presented in Table 1 (10, 11). These federal guidelines for accessible design under the ADA apply to all federal, state, and local activities under the ADA. However, as with almost every major federal initiative, the federal design standards serve as minimum requirements. State and local agencies are free to adopt design guidelines that provide greater accessibility. For example, the City of Atlanta requires 60-inch sidewalks and the Florida DOT requires minimum sidewalk widths of 48 inches, plus 12 inches for buffer strips (12).

Table 1. Standards for Sidewalk Design Features (13)

Sidewalk Design Feature	Federal Standards
Clear Sidewalk Width	<ul style="list-style-type: none"> • 36 inches minimum • If the width is less than 60-inch width, a 60-inch by 60-inch passing space must be provided every 200 feet
Running Slope	<ul style="list-style-type: none"> • 5% maximum slope or equal to roadway slope
Cross-Slope	<ul style="list-style-type: none"> • 2% maximum cross-slope
Obstructions	<ul style="list-style-type: none"> • No obstructions may be present within the pedestrian access route
Pavement material	<ul style="list-style-type: none"> • Surface must be “firm,” “stable,” and “slip-resistant”
Changes in Level	<ul style="list-style-type: none"> • Vertical displacements up to 1/4 inch are allowed • Vertical displacements from 1/4 to 1/2 inch must be beveled to a slope no greater than 1:2 • Vertical changes greater than 1/2 inch must be smoothed so as not to exceed a ramp slope of 8.33%
Vertical Clearance	<ul style="list-style-type: none"> • 80-inch minimum vertical clearance

The sidewalk standards in Table 1 also apply for curb ramps, which connect sidewalks with street crossings, except the minimum standard for running slope (5% for sidewalks) is increased to 8.33% for grade transition from the sidewalk surface to the street.

Table 2, describes the criteria curb ramps are required to meet per Federal Standards.

Table 2. Standards for Ramp Design Features (13)

Sidewalk Design Feature	Federal Standards
Clear Ramp Width	<ul style="list-style-type: none"> • 36 inches minimum (same value as for sidewalks)
Passing Area on the Top Ramp Landing	<ul style="list-style-type: none"> • 36 inches behind ramp
Ramp Running Slope	<ul style="list-style-type: none"> • 8.33% maximum slope
Ramp Cross-Slope	<ul style="list-style-type: none"> • 2% maximum cross-slope (same value as for sidewalks)
Gutter Slope	<ul style="list-style-type: none"> • 5% maximum slope from the bottom of the ramp up into the street (in the direction of wheelchair travel)
Ramp Obstructions	<ul style="list-style-type: none"> • No obstructions may be present within the pedestrian access route
Ramp Pavement Material	<ul style="list-style-type: none"> • Surface must be “firm,” “stable,” and “slip-resistant”
Changes in Level on Ramp and at Ramp Transitions: Street to Gutter Gutter to Ramp Ramp to Sidewalk	<ul style="list-style-type: none"> • Vertical displacements up to 1/4 inch are allowed • Vertical displacements from 1/4 to 1/2 inch must be beveled to a slope no greater than 1:2 • Vertical changes greater than 1/2 inch must be smoothed so as not to exceed a 5% slope
Vertical Clearance	<ul style="list-style-type: none"> • 80 inches minimum vertical clearance
Detectable Warning Surface	<ul style="list-style-type: none"> • Detectable warning surface must be present
Ramp Bottom Landing (applicable only to parallel and combination ramps)	<ul style="list-style-type: none"> • 60-inch minimum in width • 2% maximum running slope

The ADA also stipulates that communities make progress on meeting compliance design guides. Agencies with more than 50 personnel are required to assign an ADA coordinator and develop an ADA transition plan (8). A transition plan must include, at a minimum: an inventory and condition assessment, outline of the plan to address compliance issues, the timeline to accomplish improvements, and the person responsible

for overseeing implementation of the plan. The Georgia Tech Sidewalk Lab has assisted communities in creating an ADA transition plan. (13, 14)

2.2 Liability

Sidewalks and public buildings constructed (and not altered) prior to 1992 are not covered by the ADA, meaning they do not need to meet accessibility requirements. However, if facilities adjacent to sidewalks, such as roadways, are altered, they must be improved to meet ADA design requirements. For several years after the ADA design guides were published, the context of “alteration” was disputed by agencies. The precedent set in *Barden v. City of Sacramento* changed alterations to mean any substantial change to the adjacent facility including milling and overlay of adjacent pavement (15). Maintenance activities that do not require ADA improvements for adjacent sidewalks include crack sealing, joint repairs and pavement patching (16).

While many American cities may place responsibility for maintenance of sidewalks on the adjacent property owner, the city may still be liable for personal injuries if the sidewalk is considered public property (17). In fact, cities across the United States have settled civil lawsuits for billions of dollars. In 2015, Los Angeles agreed to a \$1.5 billion dollar settlement that will dictate how a portion of the city’s transportation funds are used for twenty years (18). Lawsuits may arise from “slip and fall”, “trip and fall”, “failure to replace or rebuild”, or “failure to provide facility” claims (15). At this point in time, there is little legal standpoint for not addressing non-compliant pedestrian facilities. To avoid legal action, communities must not only have an ADA transition plan in place but be making reasonable progress toward meeting the timeline laid forth within the plan. Even

if the plan was created under a different governing body, cities must be proactive in the management and implementation of whatever plan they have approved.

2.3 Pedestrian Infrastructure Literature and Research

In addition to avoiding legal action, communities can experience positive externalities from providing quality pedestrian infrastructure. A good walking environment may provide safety, economic and health benefits to communities. The 5,376 pedestrian deaths in 2015 accounted for 15% of all traffic fatalities in the United States (19). A more safe and complete walking environment can significantly reduce the number of fatalities and injuries experienced annually by pedestrians (20). Furthermore, adequate pedestrian infrastructure can return health (3), societal, and economic benefits to community members (2).

Often, infrastructure is not the focus of safety studies. Pedestrian safety research is broken into four sections by the FHWA: problem identification and data collection, managing safety through analysis and decision-making, innovative research and evaluation, and technology transfer (21) with the former three topics considered chief research focus areas. Research has investigated safety implications related to pedestrian distraction (22, 23), vehicle speeds (24), and advanced vehicle assistance features (25).

Another area of research has been in pedestrian level of service. Pedestrian level of service was developed as a potential way to assess infrastructure. Several methodologies have been researched extensively, primarily in countries other than the United States in areas with high levels of pedestrian traffic (26, 27). Pedestrian level of service might not apply to most American communities due to lower walking levels, though certainly may

be an issue in large metropolitan areas. Walkability measures have been researched and discussed as a way to assess pedestrian infrastructure, though a consensus metric has not been reached - unlike vehicle levels of service for roadways and intersections (28). Pedestrian level of service and walkability ratings have not shown the applicability to physical infrastructure assessment that is necessary to manage sidewalks as assets.

2.4 Asset Management Practice

Asset management practices differ across countries, regions, and asset classes. Communities are able to make decisions based on the goals of constituents, with priorities that exist in the short, medium, or long term. Politically-driven organizations may place more emphasis on short term priorities, such as large capital projects worthy of ribbon cuttings, worst-first maintenance, or replacement. On the other end of the spectrum, public private partnerships may have certain level of service agreements built into long-term contracts that mandate preventative and corrective maintenance actions at a timely rate. This section introduces current asset management practices.

Federal funding policies have recently started including asset management goals and planning requirements (6, 29). As a result, federal agencies have published asset management guides to help state agencies develop and implement asset management programs. The Federal Highway Administration (FHWA) partnered with the American Association of State Highway Traffic Officials (AASHTO) to develop an Asset Management guide which lays out three key principles of asset management: 1) recognizing the economic value of the asset, 2) achieving economic efficiency over the lifecycle of the asset, and 3) understanding the role of an agency as “steward” of the asset

(7). These principles challenge agencies to utilize asset management practices to maximize the long-term value of transportation assets. Figure 1 shows how the Federal Transit Agency’s (FTA) Asset Management Guide is constructed using other asset management guides, industry best practices and incorporates a transit application.

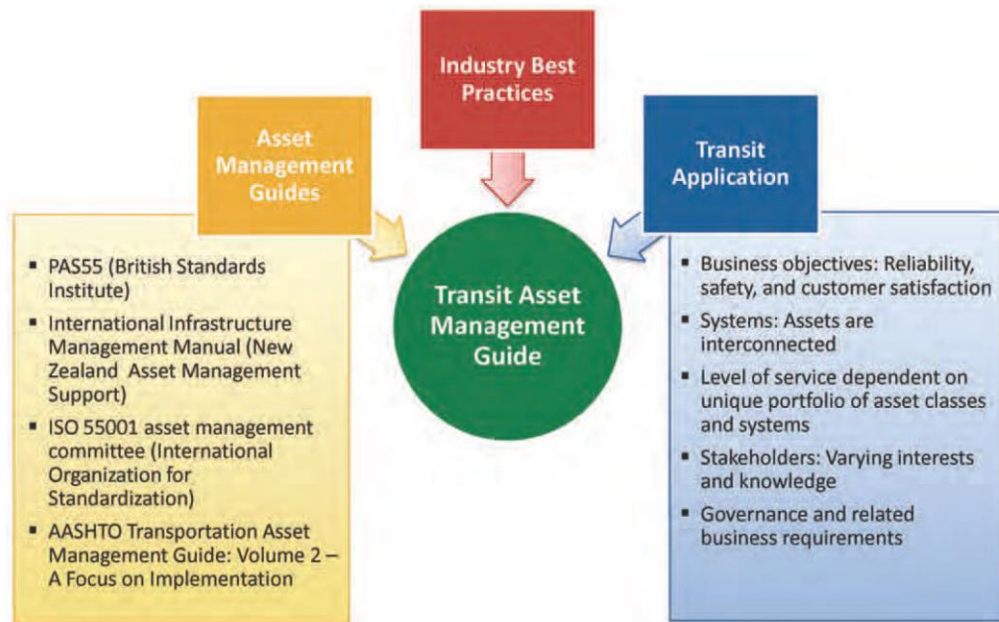


Figure 1. Building Blocks for FTA Transit Asset Management Guide (30)

The FTA guide describes asset management as an ongoing process which involves “evaluating and managing the relationships between costs, risks, and performance over the asset’s lifecycle” (30). The two fundamental concepts at the core of asset management are customer level of service and lifecycle management. Transit agencies tend to understand customer level-of-service better than most other transportation-centric groups because their relationship with the customer is more tangible and personal. Transit users may engage directly with ticketing agents (or machines), use facilities without an intermediary (such as a car interfacing with a road), and interact via some sort of transaction for each use (as if

every road were tolled). Because of the close relationship with customers, transit agencies place a high level of importance on customer service and its direct implications on ridership and community benefit. Safety, security, and risk management concerns are addressed via level of service requirements in an asset management system (30).

Lifecycle management is at the other end of the spectrum. Agencies can achieve long-term benefits from effective lifecycle management practices that reduce total cost of ownership for assets while achieving a required level of performance. At the core of lifecycle management is physical asset management. The Moving Ahead for Progress in the 21st Century Act (MAP-21) required transportation asset management plans to be developed for all National Highway System (NHS) highway pavements and bridges(6). Agencies must inventory assets, conduct condition assessments, monitor performance, and periodically update lifecycle management plans. Additionally, agencies are tasked to complete a risk analysis, develop a financial plan for no less than 10 years, and outline investment strategies. While agencies governing pedestrian infrastructure have not been tasked with these types of requirements, it does not mean they should not be actively seeking ways to incorporate asset management practices into their routines.

Pedestrian infrastructure asset management is predicated on inventory and condition assessment of the walking environment. The Americans with Disabilities Act toolkit provides electronic forms to print out for manual assessments. Georgia Tech's Sidewalk Lab has developed mobile phone applications to expedite inventory and conditional assessment of pedestrian infrastructure (31). Further research has been conducted in project prioritization but has yet to be published. The next several chapters focuses on the financial implications of pedestrian infrastructure asset management.

CHAPTER 3. VALUING PEDESTRIAN INFRASTRUCTURE

Unlike roadway infrastructure where trucks and automobiles cause significant deterioration of the roadway surface, the deterioration of pedestrian infrastructure such as sidewalks and pedestrian ramps is independent of use of the facility. Foot traffic is very unlikely to cause any significant wear and tear to 4” thick concrete slabs. Construction or repair of pedestrian infrastructure often occurs as side-projects, integrated into the construction of a primary assets of interest. Sidewalks and curb ramps are typically built at the same time as adjacent houses, buildings, or streets, and then forgotten. Furthermore, sidewalks generally last 30 to 40 years and do not generate tax revenues. Municipal funding limitations, around infrastructure in general, limit the attention pedestrian infrastructure receives. Hence, it is not surprising that sidewalks and other pedestrian assets are not generally treated as municipal assets, and tracked explicitly in terms of location, condition, and asset management cost.

This chapter discusses a method by which pedestrian infrastructure can be valued. It is helpful for municipalities to use estimated lifecycle costs of owning and operating sidewalks to help improve asset management decisions. The total cost of ownership model assumes the operation of steady-state pedestrian network in perpetuity to estimate the budget required for proper asset management. Initial construction, maintenance, and replacement costs associated with pedestrian infrastructure are discussed in this chapter.

3.1 Initial Construction

Pedestrian infrastructure is typically constructed at the time of construction of complementary assets. Some local ordinances require sidewalks to be built by developers in accordance with land use zoning, while complete streets policies require pedestrian infrastructure features, or lack thereof, to be addressed whenever transportation assets are modified by a project. New construction opportunities are infrequent, but the implications of pedestrian infrastructure construction are long lasting. Once sidewalks are installed they begin supporting pedestrian mobility. Sidewalks are rarely removed; therefore, the decision to construct pedestrian infrastructure means that an acceptable walking environment will be expected at that location in perpetuity.


While understanding the implications of new construction, it is also important to note that greenfield development of pedestrian infrastructure is cheaper than replacing existing pedestrian infrastructure. Unlike new construction costs, replacement costs include removal, transportation, and disposal of physical assets in addition to the installation costs. From analysis of pedestrian infrastructure contracts, the cost advantage new construction may have on replacement cost may be 15-30% due to the aforementioned additional costs incurred (14). The cost of sidewalk replacement can be daunting for communities. The next section discusses common issues in sidewalk elements.




3.2 Common Pedestrian Infrastructure Issues

Depending on the type and location of pedestrian infrastructure, different contributing factors may lead to deterioration. A standard sidewalk section constructed with a well compacted aggregate foundation on soil that experiences relatively little

variation in moisture content (to avoid soil heaving) can last for more than 50 years. Other factors may also cause problems that impact the initially level surface of the sidewalk. The roots of large street trees can begin to uplift concrete panels, causing uneven and disjoint problems (trip hazards) along sidewalk sections. Adjacent construction, such as excavation for utility poles or wastewater structures, may disturb the aggregate foundation, resulting in cracking or potholes from settlement. Uneven sidewalk sections pose trip hazards to walkers and may severely limit the mobility of the elderly, the visually impaired, and those requiring the use of mobility devices. Missing curb ramps are significant barriers to those in wheelchairs, rendering sidewalks with curb ramps unsafe as they require wheelchairs to divert into the roadway, and sidewalks without curb ramps completely impassable. Curb ramps on corners located without proper turning radii may frequently experience vehicle impact loading (large trucks hitting the curb), which leads to premature cracking and crumbling. Table 3 shows examples of common sidewalk and curb ramp ADA issues that can be a substantial impairment to pedestrians with restricted mobility.

Table 3. Common Sidewalk and Curb Ramp ADA Issues

Issue	Description	Example Image
<p>Uneven Sidewalk Surface</p>	<p>Typically refers to sidewalk cracking or pavement uplift. Often caused by adventitious vegetation growth, weathering, heavy equipment damage, or improper installation</p>	

Issue	Description	Example Image
Sidewalk Pothole	A depression in the sidewalk surface often caused by weathering, or damage from heavy equipment	
Curb Ramp Absent	A designated pedestrian crossing where a curb ramp is missing which prevents some pedestrians with restricted mobility from crossing at these locations	
Curb Ramp with Steep Cross Slope	Steep slopes and cross-slopes can cause wheeled mobility devices to tip over, result from improper installation, and often occur where curb ramps are installed on a steeply-sloped road (not brought to level at the crossing)	

Issue	Description	Example Image
Curb Ramp with Missing Detectible Warning Surface	Missing a detectible warning surfaces can be a hazard for blind pedestrians (especially when inconsistently installed) and often occur at locations where curb ramps were installed before detectible warning surfaces were required	
Curb Ramp with Steep Running and/or Flare Slopes	A curb ramp with running slopes or flare slopes that exceed ADAAG standards can hinder or prevent pedestrians with mobility restrictions, especially those with wheeled mobility devices, from using the ramp	

3.3 Replacement Costs

There is a large amount of variability in construction cost estimates for sidewalks, ramps, and curbcuts in the academic literature, as well as within municipality-approved contractor pricing that can be found online (published by various agencies). For example, cost estimates for a “typical” pedestrian ramp can range from \$800 to nearly \$2,000. The variability in published costs is associated with differences in component costs for demolition, concrete placement, traffic control (for concrete placement), and contractor mobilization. The actual costs that a community will ultimately expect to pay for sidewalk,

ramp, and curbcut ramp repair and replacement will be completely dependent upon the terms of the contracts that the community ultimately negotiates with selected contractors in the region or the in-house capabilities available to be used, such as a Department of Public Works.

It is important to note that published contract costs are for typical installations (demolition, concrete pour, traffic control, and contractor mobilization). Typical costs do not apply to installations requiring significant additional work. For example, costs associated with moving utilities, changing sewer inlet locations, and making adjustments to roadway and gutter configurations are very high (and highly variable). Such extraordinary costs are not included in typical or even average costs. Costs for curbcut replacements (which provide access to the private property) are generally borne by private property owners and are not included in the cost estimates reported in this section.

In developing baseline costs for repairing and replacing sidewalks and pedestrian ramps, cost data were collected from a variety of sources (32-38). The following assumptions were made in developing cost estimates for sidewalk and curb ramp repairs:

- Pavement disjoints can be repaired by polymer injection (slurry injection) beneath the slab to raise the surface edge to within ¼” of level (preferred), or leveled by milling when injection will not work. Milling the smooth sidewalk surface sidewalk opens air voids to water penetration, which ultimately degrades the sidewalk surface through the freeze-thaw cycles.
- Obstruction removal (for non-utility issues) requires tree-limbing, clipping, and disposal. Minor obstruction removals assume that two-city staff members or

contractors will drive to the site and perform tree limbing, shrub trimming, and material removal. Removal of major obstructions (e.g., mailboxes, power poles, support cables, etc.) are not currently included in cost estimation.

Construction costs fluctuate across regions and year-over-year. Total costs depend upon project scope and the variable construction costs. Government contract costs may include price premiums for administrative burden or lack of competitive bids from certified contractors. In line item cost selection, a combination of sources and engineering judgement was used to select a reasonable cost estimate for each treatment type. Table 4 and Table 5 present the estimated costs for each sidewalk and ramp repair/replacement activity:

Table 4. Sidewalk Defect Costs

<i>Contractor Activity for Sidewalk Defects</i>	<i>Cost</i>	<i>Problem Addressed</i>
<i>Slurry Injection(37)</i>	\$300.00/event	Disjoint
<i>Mill disjoin (33)</i>	\$225.00/event	Disjoint
<i>Clear debris (labor, sweeping, etc.)</i>	\$ 50.00/event	Debris
<i>Clear obstruction (tree limbs, shrubs, etc.)</i>	\$100.00/event	Obstruction
<i>Patch pothole</i>	\$150.00/event	Pothole
<i>Replace sidewalk[‡](36)</i>	\$110.00/sq-yard	Multiple issues

[‡] Remove sidewalk section, construct forms, and place concrete.

Table 5. Pedestrian Ramp Costs

<i>Contractor Activity for Pedestrian Ramps</i>	<i>Cost</i>	<i>Problem Addressed</i>
<i>Placement of warning surface(32)</i>	\$100.80/pad	Warning pad
<i>Minor Repair(36)</i>	\$110.00/sq-yard	Surface issues
<i>New Ramp(36)</i>	\$160.00/sq-yard	Missing ramp
<i>Replace Ramp[‡] :</i>	\$176.50/sq-yard	Non-compliant ramp
<i>Demolition component(36)</i>	\$ 16.50/sq-yard	
<i>New pour component(36)</i>	\$120.00/sq-yard	
<i>Traffic control component(36)</i>	\$ 19.00/sq-yard	
<i>Mobilization component(36)</i>	\$ 21.00/sq-yard	

[‡] Remove ramp, construct forms, and place concrete.

Based upon field experience, the most complex ramp types, such as combination diagonal parallel, combination perpendicular parallel, and parallel ramps, tend to have a greater number of ADA design standard compliance issues (13, 14). Typically, these ramps are used in less-than-optimal pedestrian facility locations and are more likely to have high cross slopes and transition slopes or inadequate landing space. Because of the rigid compliance metrics and variance in construction in the field, most ramps tend to be non-compliant, especially those built prior to the approval of the ADA. Replacement is often the more cost effective approach rather than attempting to make multiple spot repairs.

Uneven sidewalks typically account for a high percentage of sidewalk section issues identified in the field (13, 14). This type of issue is typically caused by settlement due to drainage issues, soil type, or improper substrate compaction during construction. It is important to note that width issues, though typically rare, can lead to significant cost increases, depending upon the linear feet of insufficient width and desired treatment. The lowest cost alternative to addressing width issues would be to install passing zones, while complete reconstruction for a sidewalk segment would be much more expensive.

As shown in unit cost estimation, the cost of replacement is higher than the cost of new construction due to demotion, removal, and disposal of the existing structure. Costs for certain replacements may be even higher when there is a compelling need to ensure that adjacent high-cost pedestrian infrastructure, roadway infrastructure, or utilities are not damaged. Furthermore, costs are highly variable because of site-specific construction complexity. Utility relocation cost may exceed the cost of replacement several times over, as well as incur administrative expenses associated with permitting and the required level of coordination among stakeholders.

3.4 Theoretical Total Cost of Ownership Model

Understanding the total cost of ownership for pedestrian infrastructure is an important step towards managing sidewalks as assets. While sidewalks are constructed with the intent they will last forever, pedestrian infrastructure has a useful life and will eventually need to be replaced. Many parallels can be seen in both private and public infrastructures. Experienced home buyers understand the useful life of a roof and will build in replacement costs to the property value. Condominium property managers account for the structural life of their property when itemizing depreciation on balance sheets. Smart electric utility companies track and manage the lifecycle of utility poles to avoid preventable outages. Finally, transportation asset managers evaluate pavement and bridge lifecycle costs for the National Highway System to plan for funding repair, maintenance, and eventual replacement.

To conceptualize the total cost of ownership for pedestrian infrastructure into perpetuity, a total cost of ownership model is developed using the net present value (NPV)

of all associated costs or benefits. The model may be useful for valuing the pedestrian infrastructure as an asset but is not intended to be applied to actual infrastructure conditions. Instead, the model should be used to understand the potential value of a pedestrian network when making asset management decisions. The previously-defined pedestrian infrastructure elements are employed in the model structure, and a total cost of ownership (TCO) model is estimated in the following sections.

3.4.1 Assumptions

First, several assumptions must be made to describe the framework of the model. The estimated lifespan of assets varies by type of construction, element classification, and maintenance practices. Even for standard sidewalk sections, expected life can be mostly contingent upon the quality of construction (sub-base compaction) and external environment (presence of street trees and soil moisture content). Lifecycle estimates range from 20 years (39) to 80 years (40). Standardization practices (such as sub-base compaction), adherence to ADA guidelines (will not be replaced due to improper design), and avoidance of unsuitable materials (such as hexagonal pavers) should lead to a longer average lifecycle.

While discount rates vary over time, municipal bonds are typically tied to the U.S. Treasury note yield rates. Several bond programs exist for state and local entities to access tax exempt bonds strategies that enable the bond to be issued to buyers at a lower premium and still be competitive (41). Currently the ten-year treasury yield is around 3%, at nearly a historically low price, but is increasing with federal rate hikes (42). For computing discounted cash flows of public infrastructure projects, lower rates are more conservative

as they increase the present value of future cash outlays relative to the assumption of a higher rate. It is important to conduct sensitivity analyses whenever computing net present values to understand how variation in the discount rate may impact the final value. Sensitivity analysis can help describe the risk associated with NPV calculations and accepted by the agency performing them.

Finally, benefits and liabilities are excluded from the total cost of ownership equation. While cost benefit analysis is an important tool for making construction decisions, this framework is intended to address the costs associated with a facility after construction. It is assumed that the external benefits have justified construction and continued use of pedestrian facilities. As discussed in Chapter 2, communities can face penalties for failing to meet ADA standards. Communities should not necessarily program potential future legal fees into their maintenance budgets because once an ADA transition plan is in place, municipal budget allocations are in place, and ongoing progress is actively demonstrated with respect to ADA compliance issues, the community is meeting the requirements to address ADA concerns and should not be unduly exposed to legal risk (1).

3.4.2 Total Cost of Ownership Equation

The total cost of ownership equation is used to calculate the net present value (NPV) of the expected cost of ownership for any new sidewalk element at the time of construction. The TCO equation is a function of initial construction cost, maintenance cost, removal cost, asset lifespan, inflation, and cost of capital using the following equation:

$$C_T = a \left[C_I + \sum_i \frac{C_{m,i}}{(1+r)^{n_i}} + \frac{C_d}{(1+r)^{n_d}} \right] + \epsilon \quad (1)$$

Where, C_T is the total cost of ownership, a is a factor included to reflect variation in the construction cost index based on region, C_I is the initial cost of construction of the element, C_m is the cost associated with maintenance act i , in year n_i , and r is the discount rate used to calculate net present value. Cost associated with removal and disposal is included in C_d and discounted accordingly to the end of life year. Time periods for maintenance acts can be different, as they may occur at different times of the asset lifecycle, and each maintenance act's NPV is calculated individually to find the total maintenance cost. The final term, ϵ , captures residual error that may occur due to any variation across variables.

Maintenance costs may or may not occur. The summation accounts for maintenance actions of different types in different years. The summation also represents the total cost of maintenance equation. Though not granularly developed here, maintenance activity should include a probabilistic model to account for external factors associated with likelihood of repair necessary. These different factors are difficult to anticipate but could be articulated with precise information regarding the soil type, adjacent foliage, and land use. This probabilistic model is not developed as a part of this research, but in application of the model in Chapter 5, clear assumptions will be made about maintenance costs.

The total cost of ownership is useful for developing a budget for a steady state system. As described in the replacement cost section, removal and disposal of pedestrian

infrastructure adds to the overall cost of ownership. Since pedestrian facilities are rarely removed without replacement, it is assumed that at the end of the asset lifecycle, the cost of ownership resets. It is therefore more appropriate to add the costs of removal and disposal and discount them according to the expected end of life. For this reason, when evaluating alternative asset construction, maintenance and removal costs and lifecycle estimates, NPV must be converted to equivalent annual costs (EAC).

Using EAC, the total cost of ownership equation can be used to articulate the annual burden of properly managing pedestrian infrastructure. When properly applied, a community can build an operating budget that meets the anticipated financial needs for the pedestrian network to remain in a state of good repair. While this may seem to be a logical asset management approach, few communities have such a centralized funding source to properly maintain pedestrian infrastructure. The next chapter will discuss the many decentralized funding solutions currently used by communities in the United States.

CHAPTER 4. PEDESTRIAN INFRASTRUCTURE FUNDING

Pedestrian infrastructure consists of sidewalks, paths, curb ramps, crosswalks, pedestrian signals, and any other relevant elements that comprise the dedicated walking environment. Funding and managing pedestrian infrastructure are complex practices; as such, communities around the world embrace a variety of strategies. Even within the United States, construction costs vary between regions and regional factors, such as snow removal, add extra burden to some communities, while leaving others unscathed. Because of concrete's long useable life, after construction sidewalks are typically forgotten, and the prospect of saving up for asset replacement may be avoided. This chapter discusses different funding sources, funding responsibilities, and cost allocation systems for constructing and managing pedestrian facilities. That is, this chapter addresses the allocation of lifecycle pedestrian asset costs (i.e., the total cost of ownership model outputs from Chapter 3) across stakeholders.

4.1 Funding Sources

Federal, state, and local funding sources are available for pedestrian infrastructure construction and maintenance. Federal gasoline taxes are allocated to states and metropolitan planning organizations (MPOs) from the Highway Trust Fund via criteria in the Fixing America's Surface Transportation (FAST) Act. A variety of general funds have been allocated under other various federal programs (generally associated with health, education, and welfare). State gasoline taxes are allocated to planning regions, and a variety of community grant programs are often available from state sources. Local property taxes and other general funds allocated by a city or municipality are often the

primary public source of funding. As discussed in this section, private funding for sidewalk repair and maintenance is often a primary resource.

4.1.1 Federal Funds

Several federal funding opportunities support the construction and maintenance of pedestrian infrastructure. The U.S. Department of Transportation (USDOT) estimates that states dedicated more than \$7.2 billion to pedestrian and bicycle projects between 1992 and 2012 (43). While this number appears large, annual funding typically amounts to around 1-2% of the total transportation budget (44). Table 6 shows the budget available for transportation funds through FHWA which may be used on pedestrian infrastructure.

Table 6. FHWA Programs with Funds Available for Pedestrian Infrastructure

<i>Program Name</i>	<i>FY18 Budget (thousands) (45)</i>
<i>Highway Safety Improvement Program</i>	\$2,556,260
<i>Surface Transportation Block Grant Program</i>	\$11,667,787
<i>Congestion Mitigation & Air Quality Improvement Program</i>	\$2,405,187
<i>Metropolitan Transportation Planning</i>	\$342,996
<i>Research, Technology & Education Program</i>	\$417,500
<i>Total</i>	\$17,389,730

4.1.1.1 Highway Safety Improvement Program

The Highway Safety Improvement Program (HSIP) allocates funds aimed at reducing fatalities and serious injuries on all public roads for all users including pedestrians (45). The program implements projects through a performance-based approach, funds improved safety data collection, analysis, and use and seeks to improve reporting and compliance with FAST Act requirements. States can use these funds for a Pedestrian Safety

Program (46), such as in Virginia. Georgia used HSIP funds for crossing treatments, crosswalks, pedestrian hybrid beacons, and other infrastructure types (47).

4.1.1.2 Surface Transportation Block Grant Program

The Surface Transportation Block Grant Program (STBG) provides funds for states and localities to spend on roughly 1,000,000 miles of Federal-aid, bridges on any public road and transit capital projects. STBG funds are flexible by design and broadly increases fund use-cases by surpassing the 220,000 miles of the National Highway System (NHS) that the National Highway Performance Program covers (45). The STBG specifically allows spending on eligible pedestrian facilities through the Transportation Alternatives set-aside.

The Transportation Alternatives set-aside is a prescribed amount of funds pulled from each state's STBG appointment. The total is calculated by multiplying 1) ratio of FY 2009 transportation enhancements funding a state received compared to all other states to 2) to an authorization total for the country, which is \$850 million for FY 2018-2020. Additionally, 50% of these funds are sub allocated into buckets intended to serve different regions based on population size, as a percentage of corresponding state demographics. These projects serve a variety of smaller-scale transportation projects that involve active transportation, including safe routes to school projects (48). However, states are able to move some portion of Transportation Alternatives funding away from supporting pedestrian and bicycling facilities. In fact, over \$500 million in funding was transferred to other programs from FY13-FY16 (49).

4.1.1.3 Congestion Mitigation & Air Quality Improvement Program

The Congestion Mitigation & Air Quality (CMAQ) Improvement Program supports projects that reduce emissions from transportation systems and meet three requirements; projects must reduce congestion and emissions, be located in or benefit an EPA-designated nonattainment or maintenance area, and be identified as a transportation project. CMAQ funds can support alternative transportation projects or promote active living which can lead to congestion reduction, air quality improvements and positive health benefits. (48)

4.1.1.4 Metropolitan Transportation Planning

Metropolitan Transportation Planning funds are allocated to Metropolitan Planning Organizations (MPOs) to help carry out the transportation planning process according to guidelines identified in MAP-21 and continued in the FAST Act. These plans include long range (20 years or more) as well as short term prioritized project lists (~4 years) that include pedestrian facility construction and repair. (48)

4.1.1.5 Research, Technology, & Education Program

Through the Research, Technology & Education Program, funds are set aside for a variety of initiatives including highway research, innovative project delivery, intelligent transportation systems, and academic research programs, such as University Transportation Centers. Successful projects include Safe Transportation for Every Pedestrian, which helps promote several pedestrian safety countermeasures, and

Innovative Technologies for Pedestrian Safety, which is helping to develop new technologies for detecting pedestrians at intersections. (48)

4.1.1.6 Federal Transit and DOT Discretionary Funds

While the Federal Transit Administration budget does not explicitly allocate funds for pedestrian facilities, it does provision funds for providing “accessibility” improvements (50). Additional discretionary funds through the Better Utilizing Investments to Leverage Development (BUILD) Grant, for projects that promise to achieve national objectives, and fixed guideway Capital Investment Grants, for projects that add capacity to various transit systems, may include pedestrian infrastructure improvements (51).

4.1.2 *State & Local Funds*

Many communities look to raise funds locally to augment federal funds typically used for larger capital projects. These sources of income can provide some level of consistency in community budgets. Budget consistency helps communities plan improvements, schedule maintenance actions, build dedicated staff, and tackle multi-year projects easier. While only 19 of 50 states have dedicated funding sources for bicycle and pedestrian infrastructure, most have some source of revenue for projects (52). Often, individual communities have better success at funding pedestrian infrastructure projects. This section will describe the variety of mechanisms available for communities to leverage for raising pedestrian funds.

4.1.2.1 State Transportation Related Taxes & Fees

In addition to the federal gas tax that feeds the Highway Trust Fund, states have the ability to levy their own fuel taxes. These taxes range from 14.5 cents per gallon in Alaska to nearly 60 cents per gallon in Pennsylvania. Other funding sources may include vehicle registration fees, vehicle property (ad valorem) taxes, or wheel taxes. However, these funds are rarely used to fund pedestrian infrastructure since most communities identify them as directly related to vehicle traffic (40).

4.1.2.2 Local Funds

General municipal funds are typically raised through property taxes or base sales taxes. These funds can be appropriated for pedestrian infrastructure via municipal budget measures. Property taxes are typically collected through a millage tax applied against some percentage of the assessed value of a property. These taxes may be collected at the state level (typically for vehicle property tax), county level, or city level. Some properties, such as churches, may be considered tax-exempt. Many areas, such as Fulton County, GA, also have some level of exemption depending on level of income, residency, age, or veteran status. For instance, city of Atlanta residents living in their own home receive an exemption of \$30,000; those over 65 can receive an exemption of \$40,000 (53). Effective property tax rates vary across states from as low as 0.27% in Hawaii to 2.40% in New Jersey(54). A large percentage of property taxes are typically spent on schools as well as utility construction and maintenance. For example, about 75% of the property taxes in the City of Atlanta are dedicated to the school system (55).

Sales taxes are used to generate funds from commercial sales revenue within a certain area and of a certain product type. Sales taxes can be set at local and state levels to raise general funds. Some states, such as Delaware, have no state or local sales taxes, where others may have combined levels of over 10% (56). Communities also have the option of taxing the sale of certain product types. Some states, such as Texas, do not tax grocery items. Others have increased sales taxes for tobacco or alcohol.

4.1.2.3 Special Purpose Taxes

Sales taxes can also be used to raise special interest funds. Special purpose funds may come through improvement districts sales taxes (community-, business-, or transportation-improvement districts) and local option sales taxes. Combined, these taxes are called Special Purpose Local Interest Sales Taxes (SPLOST). These taxes are typically voted on by local communities or regions. After receiving approval, community or business improvement districts may levy additional property taxes (on non-exempt commercial or industrial properties) or sales taxes to fund agreed upon improvements. Improvement districts may seek to solve several types of problems in the local area including pedestrian infrastructure. The requirements for forming an improvement district in the state of Georgia are outlined in Figure 2 (57).

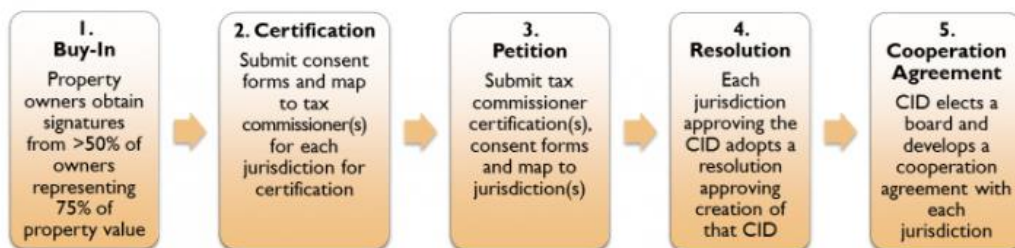


Figure 2. Steps to creating a Community Improvement District in Georgia (57)

4.1.2.4 Other Unique Local Funding Methods

Some communities may find more unique ways to fund pedestrian infrastructure investments. Communities can use enforcement revenue from parking tickets or moving violations, levy utility fees (similar to a periodic fee for water or sewer connections), or raise funds through municipal bond sales (to be repaid via some other funding source). Utility fees, piloted in Corvallis, Oregon, may provide a fair mechanism by charging a flat fee per household (40), though that assumption may be contested by those currently without access to sidewalks (58). Neighborhoods may create homeowner associations with membership dues used for infrastructure improvements, including sidewalk maintenance.

4.1.3 *Private Funding - Adjacent Property Owner Funds*

In many communities in the United States, adjacent property owners are responsible for the sidewalk path along their parcel. Some proponents of this funding model state that property values increase with walking environment quality, but others hint at equity issues regarding the financial burden of paying for sidewalk repair out of pocket (59). In such a funding model, when a sidewalk section is identified by a user (complaint) or city inspector (assessment), the property owner is notified that repair is required and held financially accountable. Communities may have contracts in place for property owners to coordinate repairs (in some cases leading to reduced costs) or property owners may be able to source their own repair independently. Local ordinances may provide for financial assistance when city planted street trees are the source of pedestrian infrastructure failure. Utilities may also be held accountable in similar situations that involve issues related to disturbances.

Communities can also partner with adjacent property owners to share or delay costs. Both the cities of St. Louis and Chicago operated programs that split costs 50/50 with adjacent property owners, though these programs may have only a certain amount of shared funds (60). Cities can sponsor micro loans to residents to cover the cost of sidewalk repair that are payable upon sale of the property (59). In this mechanism, the community receives the benefit of the repaired walking environment and defers actual payment from the property owner. In another alternative, sidewalks in need of repair remain in their current state until the property is sold (59). This practice may relieve some burden on the property owner but does not actively improve the walking environment.

Placing the repair costs on adjacent property owners may come at a cost to the community. Under this model, incentives are not aligned under the goal of creating a better walking environment. Communities that embrace adjacent property owner responsibility for pedestrian infrastructure may be less likely to plan for, allocate funds for or address issues with the walking environment. A discussion on managing pedestrian infrastructure will follow at the end of this chapter.

4.2 Mitigating and Combining Costs

When infrastructure adjacent to sidewalks (streets, curbs, sewer lines, utilities, etc.) are modified, communities can take advantage of the construction disturbance. These activities may disturb existing pedestrian infrastructure and thus responsible entities will be required to replace the assets (15). Roadway construction involving a realignment may displace sidewalk sections and curb ramps at intersections. In some instances, complete streets policies might trigger pedestrian infrastructure improvements, even when the

walking environment is not affected by construction. The number of local and state agencies that have access to complete streets funding is growing (61). Cities should take advantage of these opportunities to decrease construction costs for co-located work (mobilization, traffic control, administrative burden, etc) but may delay repairs in hopes the situation presents itself.

Communities should also monitor utility disturbances to ensure that modifications, such as installing a light pole, do not damage or modify the pedestrian facility such that it becomes non-compliant under ADA design standards. For example, siting a replacement power pole in the middle of a sidewalk section can result in an obstruction that reduces the effective width of the path to less than three-feet. The utility company would need to provide a sidewalk blub-out to maintain compliance with ADA width requirements or place the pole in another location.

Building construction also may provide opportunities for pedestrian infrastructure upgrades. Based on the type of development, local ordinances can require upgrades to the adjacent walking environment that meet ADA standards. These ordinances are common for parcels that have multiple units such as commercial developments, condominiums, and apartment complexes. These types of land use typically require major utility connections and driveway vehicle access construction which may damage existing pedestrian infrastructure in multiple places.

4.3 Pedestrian Infrastructure Ownership and Management

Pedestrian infrastructure faces several obstacles to efficient management. First, sidewalks are generally constructed and forgotten due to their expected longevity. The

Americans with Disability Act and legal precedents associated with facility access affected the expected lifecycle of the asset, compounding the management issue. Two broad models of ownership exist: public and private. Under the public model, indirect (federal and state) funding mechanisms are fragmented and difficult to rely on for maintenance. More direct funding sources, such as property taxes, may have real or perceived fairness issues. The public model will require a dedicated funding source to create a budget and perform effectively. The private ownership model solves the dedicated funding source issue but presents equity concerns as some homeowners may not have the funds available to pay for the required repairs.

The effectiveness of management under the two modes is difficult to quantify, but it is generally understood that public agencies are better at long term maintenance of sidewalks rather than homeowners. First, public agencies can have dedicated staff for forecasting when repairs may be needed and performing periodic assessments. Second, public agencies have economies of scale. Public works departments may have internal capabilities for repairing sidewalks or establish contracts with reduced line item costs (33-36).

Homeowner incentives may be misaligned with creating quality infrastructure. Property owners whose chief concern is to avoid costs will only be reactive in repairing or replacing inadequate pedestrian infrastructure. Even property owners who want to provide a good walking environment may not know the sidewalk on their property is non-compliant. Others may not invest in new pedestrian facilities because the surrounding network is so poor. The privatized model may also cause negative externalities when it comes to dealing with public infrastructure issues. Since local government outsources most

pedestrian asset management in this model, the ability to effectively manage public assets may be diminished, reducing capabilities such as conducting and enforcing assessments, planning and coordinating large-scale projects, and managing in-house repairs.

Though equity issues may arise and management may be less effective, if most homeowners would rather be responsible for only their adjacent sidewalk, it will be difficult for a community to change from this model. They may think this way because of sidewalks' long life (their sidewalk will likely not require replacement, but they would be required to pay taxes each year) or that the tax is unfair (because of their property value the amount of taxes paid over time may be more than the cost of the sidewalk). This behavior is indicative of not treating the pedestrian network as a community asset. The next chapter applies the total cost of ownership model to the city of Atlanta to analyze the tax burden homeowners would experience under the public ownership property tax model.

CHAPTER 5. CASE STUDY: A POTENTIAL BUDGET FOR ATLANTA SIDEWALKS

To apply the concepts discussed in earlier chapters, this chapter presents how the total cost of ownership model might be applied to city of Atlanta, GA. The costs, useful life, and discount rate assumed are meant to serve as a point of departure. As discussed in Chapter 3, the pedestrian infrastructure costs associated with the current built environment may be extremely high and variable based on local situations. This analysis examines the lifecycle costs associated with an adequately sized, steady-state system constructed according to ADA design guidelines. The case study estimates the theoretical pedestrian network (the projected sidewalk facility mileage based on Atlanta road network characteristics), applies the total cost of ownership model to estimate an operating budget, and then calculates the potential tax burden required to meet the anticipated financial needs.

5.1 Estimating Pedestrian Facility Totals for the City of Atlanta

To apply the total cost of ownership (TCO) model developed in Chapter 3 to an area, several inputs must be calculated or estimated. First, the number of sidewalk miles must be calculated. This number can reflect the number of miles that currently exist, or more appropriately, reflect the number of miles that *should* exist. Many communities' pedestrian networks have gaps where sidewalks are prescribed but have either disappeared over time or were never constructed. Conceptually, the suggested number of sidewalk miles in a community can be calculated by analysing road functional classes and applying design guidance to the results. Divided highways and rural residential areas (<1 unit per

acre) may not require sidewalks. Suburban residential areas may only need sidewalks on one side of the road. Figure 3 shows the Institute of Traffic Engineers' recommendations for installing sidewalks (62). For this analysis, the preferred recommendations for suggested sidewalk presence are used. Only areas classified as rural residential will be assumed to have sidewalk on one side of the road, all other non-divided roadways are assumed to have sidewalks on both sides.

Land-Use/Roadway Functional Classification/ and Dwelling Unit	New Urban and Suburban Streets	Existing Urban and Suburban Streets
Commercial and Industrial (All Streets)	Both sides.	Both sides. Every effort should be made to add sidewalks where they do not exist and complete missing links.
Residential (Major Arterials)	Both sides.	Both sides.
Residential (Collectors)	Both sides.	Multifamily—both sides.
		Single family dwellings—prefer both sides; require at least one side.
Residential (Local Streets) More than 4 Units Per Acre	Both sides.	Prefer both sides; require at least one side.
1 to 4 Units per Acre	Prefer both sides; require at least one side.	At least 4-foot shoulder on both sides required.
Less than 1 Unit per Acre	One side preferred; shoulder on both sides required.	One side preferred, at least 4-foot shoulder on both sides required.
<p>NOTES:</p> <p>1) Any local street within two blocks of a school site that would be on a walking route to school—sidewalk and curb and gutter required.</p> <p>2) Sidewalks may be omitted on one side of a new street where that side clearly cannot be developed and where there are no existing or anticipated uses that would generate pedestrian trips on that side.</p> <p>3) Where there are service roads, the sidewalk adjacent to the main road may be eliminated and replaced by a sidewalk adjacent to the service road on the side away from the main road.</p> <p>4) For rural roads not likely to serve development, a shoulder at least 4 feet in width, preferably 8 feet on primary highways, should be provided. Surface material should provide a stable, mud-free walking surface.</p>		

Figure 3. Guidelines for Installing Sidewalks (62)

From analysis of the GDOT Road Inventory in ArcGIS, approximately 1,714 total roadway centerline miles are present within the city of Atlanta, with 74.2 miles designated as divided highway miles (63). The rural residential parcels (those > than 1 acre) accounting for 18.1% of the land area are assumed to have sidewalk on one side. This percentage is multiplied by the 1,640 non-divided roadway miles to yield 297 roadway miles with sidewalk on one side. The remaining 1,343 miles are assumed to have sidewalks on two sides. Since sidewalks transition to the roadway surface at intersections, the expected length of intersection crossings should be removed from the total sidewalk miles. The average number of vehicle lanes (2.37) was calculated from GDOT Road Inventory data and multiplied by a standard roadway width (11 feet) to calculate an average roadway width (26.1 feet) (63). The number of intersections (11,137), also calculated using ArcGIS, is then used to calculate the expected length of sidewalk intersection crossings that should be excluded from analysis. The final calculation shows that Atlanta should have approximately 2,774 miles of sidewalk. The assumptions, calculations, and results are presented in Table 7 and Table 8.

Table 7. Residential Parcels in City of Atlanta by Acreage

<i>Type</i>	<i>Number</i>	<i>Acreage</i>	<i>% of Total</i>
<i>Residential Parcels</i>	132,885	37,575	55.9%
<i>Residential Parcels >1 Acre</i>	5,212	12,167	18.1%
<i>Commercial, Industrial and Other</i>	13,826	17,529	26.0%
<i>All Parcels</i>	151,923	67,271	100%

Table 8. Sidewalk Mileage Estimation for Atlanta

<i>Facility</i>	<i>Metric</i>
<i>Total Road-miles</i>	1714.1
<i>Divided Highway-miles</i>	74.2
<i>Non-divided road-miles*</i>	1639.9
<i>Road-miles with two sidewalks*</i>	1343.3
<i>Road-miles with one sidewalk*</i>	296.6
<i>Sidewalk-miles incl. Intersection Width*</i>	2983.2
<i>Average Vehicle Lanes*</i>	2.37
<i>Average Width of Roadway (ft)*</i>	26.1
<i>Intersections</i>	11137
<i>Sidewalk-miles excl. Intersection Width*</i>	2774.2

* Designates a calculated field

Next, the number of curb ramps is calculated. Every roadway section that has a curb and gutter will require curb ramps at intersections where sidewalks are expected. Each intersection corner should have zero, one, two, or more curb ramps, depending on the number of sidewalk and roadway crossing sections intersecting the corner node and the style of curb ramp used. In this application, if there are two sidewalk sections intersecting at a corner, two standard curb ramps are assumed to be needed. Thus, eight curb ramps are assumed to be located at each four-way intersection of roadways with sidewalks on both sides, and four curb ramps are assumed for intersections of roadways with sidewalks on each side. The same percentages for roadways with sidewalks on one and both sides is applied to the number of intersections. Based on these assumptions, 75,470 curb ramps should exist at the 11,137 intersections in the anticipated sidewalk network.

The scope of case study only includes sidewalk sections and curb ramps. Midblock crossings could be accounted for but are likely to represent a very small number of curb ramps that can be factored into the expected number of curb ramps at corners. Curb cuts

(vehicle access ramps within parcels) are not included in the analysis since even under the property tax model, they would likely be considered the property owner's responsibility. Additionally, pedestrian crossing infrastructure (crosswalks, pedestrian signs, and push buttons) is excluded since those assets' installation and management is typically included under pavement marking and traffic signal operation purviews. The next section will discuss how to use the calculated number of pedestrian assets in the cost of ownership model.

5.2 Calculating the Total Cost of Ownership

To apply the total cost of ownership model, the costs associated with construction, maintenance and removal must be calculated. Construction costs, described in Chapter 3, can easily be applied to the estimated facility totals calculated in the previous section. Assuming that sidewalk sections are five feet wide (meeting the city of Atlanta ordinance) the total sidewalk area is estimated to be 8,137,067 square-yards, which is about 2.6 square miles, or just under 2% of the total land areas occupied by the city of Atlanta. Typically, sidewalks are 4" thick, which corresponds to 904,119 cubic yards of concrete, or roughly the size of a super tanker of approximately 243,000 gross tons. At a construction cost of \$60 per square-yard, the total cost of construction of Atlanta sidewalks is estimated to be \$488,224,000. For curb ramps, the estimated cost of construction is conservatively priced at \$1,200. With an estimated 75,470 curb ramps, cost of curb ramp construction is \$90,564,000. Hence, total costs for sidewalks and curb ramps are \$578,788,000. Costs are summarized in Table 9.

Table 9. Estimated Cost of Construction for Atlanta Sidewalks and Curb Ramps

<i>Cost of Construction</i>	
<i>Sidewalk-Miles</i>	2774
<i>Width in feet</i>	5
<i>Sidewalk Area in Square Yards</i>	8,137,067
<i>Cost per square yard</i>	\$ 60.00
<i>Sidewalk Cost</i>	\$ 488,224,000
<i>Ramps</i>	75470
<i>Ramp Cost per Unit</i>	\$ 1,200.00
<i>Ramp Cost</i>	\$ 90,564,000
<i>Total Cost of Construction</i>	\$ 578,788,000

To estimate the cost of maintenance, several assumptions must be made about the type and frequency of maintenance actions. Based on sidewalk analysis conducted by the Georgia Tech Sidewalk Lab, sidewalk incidents requiring maintenance occur around 45 times per mile, or once every 117 feet (14). The sidewalks in this analysis were likely 30-40 years old and had not received very much maintenance (if any at all) over the course of their lifecycle. To take a conservative approach, 53 times per mile, or once every 100 feet will be used.

The most common repair is typically a disjoint, so an estimated cost of \$300 per repair is used as developed in Chapter 3. Since costs associated for repairing potholes or removing obstructions are less than for repairing a disjoint, the median cost of repair is used for a conservative estimate. Maintenance is assumed to take place at year 20 as it is exactly half of the lifecycle (40 years). The net present value of maintenance is calculated with a discount rate of 3.5%. As indicated in Table 10, the estimated net present worth the cost of maintenance is \$22,166,472. In reality, some sidewalks may require more maintenance than others, but at a certain point those sidewalk sections will be replaced altogether. This assumption is built into the estimation for lifespan of the sidewalk.

Table 10. Estimated Cost of Maintenance for Atlanta Sidewalks and Curb Ramps

Cost of Maintenance

<i>Sidewalk Defects per mile</i>	53
<i>Total Defects</i>	147022
<i>Cost per Defect</i>	\$ 300
<i>Average Year</i>	20
<i>Discount Rate (%)</i>	3.5
<i>Total Cost of Maintenance</i>	\$ 22,166,472

The final cost developed in the total cost of ownership is the cost of removal. As discussed in Chapter 3, the average usable life is estimated to be 40 years, but there is a high degree of variability with many external factors. Using the same discount rate as before (3.5%), the NPV cost of removal after 40 years is \$109,908,067. Finally, the sum of NPV costs is \$710,862,540. This translates to approximately \$255,000 per sidewalk mile. Once the costs are converted to NPV they can be represented as an annual equivalent cost over the lifecycle of the asset. This corresponds to an equivalent annual cost (EAC) of \$33,287,761. The EAC is necessary to create an annual budget for the asset that considers construction and maintenance cycles extending into perpetuity. The next section will discuss sensitivity around the financial and lifecycle assumptions.

5.2.1 Sensitivity Analysis

The time-value of money can significantly affect the costs calculated in the previous section. Future costs must be converted to net present value (NPV) before an equivalent annual cost (EAC) is calculated as a starting point for budget building. The EAC is a function of NPV, the discount rate and the number of payment periods (which corresponds to the asset lifecycle) The discount rate affects out-year costs and must be selected according to current market trends, inflation rates, and borrow credibility, but the

most crucial factor in evaluating the total cost of ownership’s annual cost is the expected lifecycle.

Four sets of analysis were conducted by holding all assumptions equal other than changing the asset life and the discount rate. The proper metric for analysis is the EAC, since it is an annual cost that expected to continue after the life of the asset, since it is expected the pedestrian asset lifecycle will reset (the sidewalk infrastructure will be reinstalled and not simply removed). The most significant difference in EAC is between asset life assumptions. Decreasing the useful life of the asset from 40 years to 30 years increases the annual tax burden of the asset 23% from \$33,287,761 to \$41,104,219. Increasing the discount rate also correlates to a higher EAC, but of a smaller magnitude. Table 11 shows how increases in interest rate and decreases in asset life raise the equivalent annual cost. The values (discount rate of 3.5%, asset life of 40 years) used in the previous section and discussed in chapter 3 will be applied in the next section to analyse the tax burden placed on homeowners.

Table 11. Estimated Total Cost of Ownership for Atlanta Sidewalks and Curb Ramps

<i>Total Cost of Ownership Sensitivity Analysis</i>				
<i>Asset Life</i>	30	30	40	40
<i>Discount Rate (%)</i>	3.5	3	3.5	4
<i>NPV</i>	\$ 755,990,656	\$ 780,232,399	\$ 710,862,540	\$ 691,592,405
<i>EAC</i>	\$ 41,104,219	\$ 39,806,879	\$ 33,287,761	\$ 34,941,661

The variation in cost from changing removal year highlights the importance of building infrastructure that maximizes useable lifecycle. Conversely, communities that overestimate the lifecycle of their assets risk underfunding assets significantly. Pedestrian infrastructure has fallen prey to this overestimation for two reasons. First, their useable life

is always assumed to be toward the right tail of the timeline (or never considered at all). Second, the design standard changes through ADA immediately shrunk the expected usable life of many sidewalk sections. These confounding factors lead to much higher than expected costs due to less than expected usable life of sidewalks.

5.3 Cost of Ownership and Property Taxes

Once the 40-year lifespan cost and annualized costs (which account for discount rates) are calculated, decisions regarding funding sources can be made, as discussed in Chapter 4. Given the experience in Atlanta over the past 50 years and the existing condition of Atlanta sidewalks, a more centralized approach to sidewalk funding may be desirable. If communities wished to fund their sidewalks with an annual budget that allows for continual construction and maintenance on a rolling investment basis for construction, repair, and replacement, property tax might be the most appropriate source of funding. To understand the potential burden on property owners, the EAC computed in the previous section will be applied to the city of Atlanta operating budget property tax formula.

Currently, the city of Atlanta raises around \$190.3 million annually in property tax revenue. The dollar value of one “mill” (i.e., one-thousandth) or “point” in the millage rate fluctuates year to year as the city approves budget measures. Over the last several years, the value of one mill has increased because property tax assessment values across the city have risen since the recession of 2009. The city government has elected to decrease the millage rate to keep tax burdens from increasing too fast as property values appreciate. In the past five years, the assessed home value has increased 24% (nearly \$5 billion) (55). Recent historical millage rate and total assessed property values are presented in Figure 4.

THE DOLLAR VALUE OF ONE MILL				
	Assessed Value	Mill Rate	CY Property Tax Revenue	Dollar Value of One Mill
FY18	\$26.2 Billion Est.	8.87	\$190.3 Million (Proposed) ¹	\$21.5 Million
FY17	\$25.8 Billion	8.88	\$184.9 Million (Actual)	\$20.8 Million
FY16	\$25.0 Billion	8.89	\$180.9 Million (Audited)	\$20.4 Million
FY15	\$22.5 Billion	9.75	\$179.4 Million (Audited)	\$18.4 Million
FY14	\$21.7 Billion	10.05	\$174.8 Million (Audited)	\$17.4 Million
FY13	\$21.4 Billion	10.24	\$171.7 Million (Audited)	\$16.7 Million

Figure 4. Dollar Value of One Mill in the City of Atlanta Property Tax Rate (55)

For the purposes of this analysis, the millage rate calculation was recreated to study the impact of raising property taxes on individual households. The millage rate formula applies exemptions to certain households based on the Homestead Act (53). In the city of Atlanta, the exemption rate is \$30,000 for residents under 65 and \$40,000 for those over 65 and meeting certain income requirement (64). The property tax model was calibrated using parameters for Homestead exemptions and tax assessment data to replicate the data for FY18 in Figure 4. For example, a household qualifying for the homestead act assessed at \$100,000 would receive a \$30,000 exemption reducing the assessed value to \$70,000. Multiplying the current millage rate of 8.87 returns an annual property tax bill of \$620.90. Without the exemption, the property taxes due would be 43% higher (\$887.00). The magnitude of exemption benefits is decreased as assessed property values increase, since the exemption dollar amount is static.

Next, the equivalent annual costs associated with sidewalk ownership can be used to calculate a subsequent millage rate increase to meet the tax burden. The EAC of \$33,287,761 (calculated in the previous section) is divided by the cost of one mill (~\$21,500,000) to calculate a millage rate increase of 1.55. After applying a 1.55 mill increase, the average and median additional tax burden per residential property were

\$188.01 and \$103.23, respectively. The difference in mean and median is due to the higher proportional benefit from tax exemptions that properties with lower assessed values receive. Table 12 shows the estimated millage rate and property tax increases associated with the total cost of ownership of sidewalks and curb ramps in Atlanta.

Table 12. Property Tax Increases for Estimated Total Cost of Ownership of Atlanta Sidewalks and Curb Ramps

<i>Property Tax Assessment</i>	
<i>Removal Year</i>	40
<i>Interest Rate</i>	3.5
<i>NPV</i>	\$ 710,862,540
<i>EAC</i>	\$ 33,287,761
<i>Millage Rate Increase</i>	1.55
<i>Average</i>	\$ 188.01
<i>Median</i>	\$ 103.23
<i>1st Quartile</i>	\$ 43.90
<i>3rd Quartile</i>	\$ 245.83

5.4 Discussion

The case study presented above focuses purely on pedestrian infrastructure financial considerations and offers a potential funding solution. Because the sidewalk networks provide local benefits, property tax assessments may be an appropriate funding solution. This approach follows the same system used to fund other municipal activities (schools, parks, etc.), pooling community resources to provide a public community benefit. However, there are potential incentive misalignments and negative externalities to funding pedestrian infrastructure through this mechanism.

One of the key assumptions for developing this funding model was to consider what the sidewalk network *should* be, rather than its current state. This means property owners who lack sidewalks will be assessed taxes to construct and maintain sidewalks that they do

not currently have. Even if they pay into the program, it may take several years before a sidewalk is constructed. Other property owners may live in less dense areas which only require a sidewalk on one side of the road. These property owners may feel their assessment should be halved. Such misaligned incentives may cause issues for agencies looking to build a centralized funding solution to pedestrian infrastructure.

Finally, the model does not address prioritization and equity concerns. Further analysis is needed to answer questions regarding whether maintenance of existing facilities or new construction for increased access should be prioritized. Equity should be considered when making location prioritization decisions. Perhaps pedestrian infrastructure issues in low-income areas less likely to have vehicle access should be addressed first. Additionally, areas around schools, bus stops, or senior citizens could deserve attention before other locations. These types of prioritization and equity concerns can create barriers to approval for centralized funding programs, even though centralized funding programs might be better able to the problems. Constituents have varying levels of willingness to pay for other people's issues. In some regions, this willingness is higher than others, so the barriers to implementing this type of program would be reduced, but the converse may also be true. Agencies looking to take this approach should conduct public outreach and fund communications programs to show the overall benefits such a program can yield before attempting to implement the program. The final chapter will provide concluding remarks on pedestrian asset ownership and management as well as indicate future research opportunities.

CHAPTER 6. CONCLUSIONS AND FUTURE RESEARCH

6.1 Conclusions

Because pedestrian infrastructure is involved in almost every trip taken in a metropolitan area, it is difficult to argue that these facilities do not constitute transportation assets. The financial value of the physical pedestrian infrastructure constitutes \$700 million in a city the size of Atlanta, and sidewalks provide substantial economic and equity benefits in terms of mobility. When communities do not practice pedestrian infrastructure asset management, sidewalks tend to fall into disrepair, communities lose the benefits of a quality walking environment, and eventually communities are forced to deal with increased collective costs. Hence, it makes sense that pedestrian infrastructure would be proactively managed in a similar fashion to roadway assets. The research presented in this thesis examined pedestrian infrastructure costs, funding and management practices, and finally constructed a potential operating budget to meet the estimated financial needs of an adequate pedestrian asset management system for the city of Atlanta.

Establishing a pedestrian infrastructure asset management program first requires development of an asset inventory (locations, design, and composition of the infrastructure) and the performance of a condition assessment. After considering the lifecycle costs for these assets, communities can begin to build a plan for addressing pedestrian infrastructure issues systematically. It is difficult to anticipate and plan for future repair and maintenance costs, but it is essential to develop a model to predict these costs, and to calibrate the model over time, in implementing a truly steady-state asset management program.

To better understand the lifecycle costs associated with pedestrian infrastructure, the net step in the research effort was to develop a Total Cost of Ownership (TCO) model. The TCO model calculates the net present value (NPV) of the construction, ongoing maintenance, and removal costs associated with pedestrian infrastructure asset lifecycle. Converting NPV to equivalent annual cost (EAC) allows to a community to begin planning for potential bond measures and an annual budget dedicated to pedestrian asset management. Developing an annual budget gives a community the ability to centrally fund the construction, maintenance, and rehabilitation of pedestrian infrastructure, which is a key element of public asset ownership.

In the United States, the majority of communities currently place the responsibility of sidewalk ownership onto adjacent property owners (59). However, a private ownership model can lead to misaligned incentives. Property owners may care little for the walking environment and may only choose to pay for improvements when they are left with no other choice, requiring the municipality to actively manage the enforcement of sidewalk improvements. A public ownership model benefits from a dedicated staff to manage operations (condition assessment, project planning, and construction management) as well as significant economies of scale associated with implementing large projects and bundling construction contracts. A public ownership model with a centralized funding source, such as property taxes, seems more likely to provide a better quality walking environment at a lower total cost, though more research needs to be conducted on quantifying the trade-offs between investment and pedestrian infrastructure quality.

Finally, the Atlanta case study presents the high asset value of pedestrian infrastructure, totalling over \$700 million. This level of investment calls for more strategic

oversight through centralized funding and proper lifecycle management. Sidewalks take up between 1-2% of the entire city land and can cost as much as \$250,000 per sidewalk-mile. Significant improvements can be made to the walking environment by adequately funding pedestrian infrastructure and implementing asset management practices.

Cities with privatized sidewalk ownership models, including Atlanta, should carefully investigate their pedestrian infrastructure practices. Equitable transportation, improved health, socio-economic benefits, and reduced total ownership cost (including tort claims) are important drivers for shifting to a public or shared cost model. Physical inventory and condition assessment are an important part of establishing an asset management program but recognizing the value of pedestrian infrastructure is essential for communities to fight for more appropriate funding and better management.

6.2 Future Research

This research has brought to light many opportunities for research to further investigate pedestrian asset management methods, as well as pedestrian infrastructure funding mechanisms. A natural continuation of this research will be to explore a variety of projects in three key areas: 1) sidewalk asset lifecycle assessment, 2) project prioritization, and 3) financing methods.

This research focused primarily on the financial aspects of pedestrian asset management. Sidewalk asset lifecycle assumptions rely heavily on engineering judgement and analysis of regional field data collection. Lifecycle modelling could be significantly improved by undertaking additional research into how sidewalk concrete responds to: 1) periodic vehicle loading (typically when construction vehicles drive onto sidewalks); 2)

adjacent tree presence (by tree type) and tree root growth over time; and 3) impacts of soil composition, water content, weather, and soil heaving. Research results in these areas could help with classifying the expected life of pedestrian infrastructure as a function of environmental variables. Because the estimate of asset lifespan drives the equivalent annual cost of ownership, communities will be better equipped to make funding decisions if the accuracy of lifespan assessments can be improved.

Project prioritization is a critical next step in pedestrian infrastructure asset management that has yet to be fully addressed. Project prioritization methodologies seek to assess how funding should be spent in response to community accessibility, mobility, and safety concerns (13). However, bundling of repair and construction projects can significantly impact the total costs of ongoing asset management. Municipalities need a system logic that allows decision makers to combine new construction, repairs, and replacement activities based on spatial proximity or type of work. Given the structure of the cost model developed in this thesis, it should be possible to apply the model to sidewalk links within a GIS framework and implement a repair optimization system once contractor cost savings associated with bundling are quantified and introduced into the tracking system. It should also be possible to apply different project costs and prioritization weights across communities, where such costs or community interests may differ.

Finally, pedestrian infrastructure funding and financing alternatives should be holistically investigated in terms of practicality, results, and equity. Complex institutions cannot expect to be fixed with a one-size-fits-all approach. The variable nature of pedestrian infrastructure in terms of ADA compliance, system size, and expected life may lead to different funding and financing models for different agencies. The funding

alternatives introduced in this research should each be critically analysed under the premise that pedestrian infrastructure should be funded appropriately. It should be possible to perform these financial analyses using the total cost of ownership methodology as an input for adequate pedestrian infrastructure performance.

For both project prioritization and funding alternatives, research should include an equity analysis for individual households and neighborhoods under different the various models. Prioritization models can yield project lists that could be considered inclusive or exclusive, but more research needs to be conducted to determine an equitable mix based on engineering and social responsibility. The tax burden of funding alternatives will affect households and neighborhoods differently. Spatial analysis could be used to show the share of taxes each homeowner and neighborhood must pay based on different funding models. Research addressing the variation in the weight of the tax burden upon different social-economic demographics will help make equitable decisions and inform policy makers.

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