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Economic Sustainability of Sidewalk Networks and Funding Scenario Cost Distributions in Atlanta, GA

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Economic Sustainability of Sidewalk Networks and Funding Scenario Cost Distributions in Atlanta, GA

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A Research Report from the National Center for Sustainable Transportation

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16. Abstract

Sidewalk infrastructure presence is a key indicator of pedestrian safety and walkability for neighborhoods in cities throughout the United States. The existence and condition of sidewalk infrastructure, however, is not prioritized as much as motor vehicle infrastructure. Many cities lack sustained maintenance and operations programs for sidewalk infrastructure and comprehensive datasets covering the locations and distributions of sidewalk infrastructure, limiting the ability to develop such programs. This work refines prior sidewalk infrastructure network generation techniques, contributing new methods to identify sidewalk infrastructure presence. QA/QC efforts were conducted for Atlanta's sidewalk network by correcting errors identified in input data. Error identification and correction times were comprehensively tracked and used to estimate future labor costs. A custom application with online access to Bing Maps Streetside and aerial imagery was developed to allow technicians to verify sidewalk presence data, which were joined to the structural sidewalk network and associated with adjacent parcels. Cost of ownership of Atlanta's sidewalk infrastructure over an 80-year management period is then broken down by asset type and allocated in part to property owners directly adjacent to the applicable infrastructure, while remaining costs are recovered through a proportional increase in property tax millage rates. Sidewalk network estimates developed in previous Atlanta research efforts decreased sidewalk network mileage by 12% (386 miles), post-QA/QC. Regression analysis of error correction activity and labor data indicates gaps between tax parcels and misplacement of intersection centroids significantly increased QA/QC labor costs. Overall, 46% of Atlanta's potential sidewalk links were present (i.e., along property superblock boundaries), with significant clustering in the city's oldest neighborhoods. Hence, sidewalk repair and maintenance costs accrue disproportionately to these areas. Sidewalk infrastructure costs across neighborhoods also differ considerably, depending on whether estimates account for existing sidewalk infrastructure. The annual cost burden on property owners to implement a program to fund sustainable sidewalks (lifecycle assessment) by increasing property tax millage rates varies significantly across household income and ethnicity. The research suggests that sustainable sidewalk infrastructure assessments should consider spatial and demographic disparities in cost allocation (i.e., equity) for any proposed pedestrian infrastructure asset management program.

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Disclaimer

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TABLE OF CONTENTS

List of Tables

List of Figures

Economic Sustainability of Sidewalk Networks and Funding Scenario Cost Distributions in Atlanta, GA

EXECUTIVE SUMMARY

Sidewalk infrastructure presence is an indicator of pedestrian safety and neighborhood walkability throughout the United States. The existence and condition of sidewalk infrastructure, however, is not prioritized for repair and maintenance to the same extent as vehicle infrastructure. The poor condition of sidewalk assets arise from the lack of sustained municipal maintenance activity, disparate policies at the local level, and lack of dedicated funding. Most cities do not even have comprehensive datasets covering the location and distribution of sidewalk infrastructure, limiting their ability to develop pedestrian infrastructure asset management programs. This work refines sidewalk infrastructure network generation techniques previously developed by the Georgia Tech Sidewalk Lab, develops new methods to identify sidewalk infrastructure presence, and assesses the cost distributions of potential funding strategies.

Outputs from previous efforts to generate sidewalk network data in the City of Atlanta involved only limited QA/QC of the resultant data (Patel, 2019). This work expanded QA/QC efforts to the entire City of Atlanta sidewalk network and corrected errors caused by errors in input parcel boundaries and public roadways datasets. Error identification and correction times were comprehensively tracked for every neighborhood in the City of Atlanta and used to estimate labor costs to generate the initial structural sidewalk network.

This work shows that comprehensive QA/QC of semi-automatically generated sidewalk network data greatly improves the accuracy of the network’s extent. The City of Atlanta's sidewalk network mileage decreased 12% (386 miles), post-QA/QC. Network generation techniques may limit the accuracy of the post-QA/QC network, suggesting that further improvements to the network generation procedure would be beneficial. Regression analysis of error correction data indicates the presence of gaps between tax parcels and the misplacement of intersection centroids significantly extend QA/QC labor costs; regression analysis further suggests the labor costs for QA/QC of network input files may vary significantly between technicians.

Previous cost of ownership estimates for the of the City of Atlanta’s sidewalk network did not discount estimated costs by factoring the existence of previously constructed infrastructure (Patel, 2019). The research reported herein implemented a methodology to collect sidewalk infrastructure presence/absence data using the Bing Maps API. A custom HTML file with online access to Bing Maps Streetside and aerial imagery allowed technicians to record whether sidewalks were observed in the images. Sidewalk presence data collected from this custom application were joined to the structural sidewalk network to associate sidewalk presence with the post-QA/QC sidewalk network data. Percentages of sidewalk links actually present were tabulated for every neighborhood in the City of Atlanta and tested for spatial autocorrelation.

This work shows that sidewalk infrastructure data collection and management are aided significantly by the development and use of online data collection tools. Using Bing Maps Streetside imagery, made available through the Bing Maps API, sidewalk presence data collection was made possible without the need for field surveys to indicate the presence of sidewalk surface. However, it remains unclear whether cities can implement these techniques given the current use restrictions of imagery (cities may need to collect new imagery). Overall, 46% of Atlanta's sidewalk links were identified as present, with significant clustering occurring in the city's oldest neighborhoods close to Downtown and Midtown. Many of the available Streetside images have not been updated since 2014, suggesting that the use of more recent aerial imagery would also improve Streetside-based observations.

The research team then assessed the cost of ownership of the City of Atlanta's sidewalk infrastructure over an 80-year management period across four scenarios. Costs are broken down by asset type: sidewalk surface, pedestrian ramp, and driveway curb cut. The four scenarios assume varying approaches to the management of the sidewalk network by the City of Atlanta: 1) maintaining existing sidewalk infrastructure only; 2) maintaining existing sidewalk infrastructure and building out all missing assets; 3) maintaining a set percentage of existing sidewalk infrastructure and replacing the remaining percentage simultaneously with construction of missing assets; and 4) complete reconstruction of the entire network.

Equivalent annual cost estimates for the cost of sidewalk ownership of the City of Atlanta's sidewalk infrastructure (construction and maintenance over an 80-year lifecycle) are allocated in whole or in part to the property owners directly adjacent to the applicable infrastructure. Current City of Atlanta ordinances stipulate that sidewalk maintenance is the responsibility of adjacent property owner, which is an unpopular policy (Boyer, et al., 2017). In example cost allocation scenarios, sidewalk infrastructure lifecycle costs are first allocated completely through property taxes, via a proposed increase in property tax millage rates (i.e., sidewalk costs are shared across properties just as the costs of maintaining curbs, gutters, drainage structures, and other city assets). In subsequent scenarios, some to all of the costs for sidewalks, ramps, and curb cuts are shifted to the adjacent property owners (toward the current policy structure). To assess the distributional impacts of these policies, the costs allocated to property owners in each scenario are converted to annual equivalent costs and averaged across each household income group and ethnic group using licensed Epsilon household-level demographic data.

The analytical work shows that sidewalk infrastructure costs differ considerably, depending on whether the estimates account for the presence of existing sidewalk infrastructure. Repairing existing infrastructure is considerably cheaper than reconstructing the entire network in the baseline year. Cost estimation could also benefit from updated asset construction and repair cost estimates. The analyses show that the increased annual property tax burden per parcel (a function of assessed property value and millage rate) to support sustainable sidewalk infrastructure varies considerably across household income and ethnicity. The results suggests that sustainable infrastructure management strategies requires serious considerations of cost allocation equity due to disparities in geographic distribution of assets and how the costs to support sustainable infrastructure maintenance programs (increased annual property tax burden) accrue to income and ethnicity groups based upon assessed property value.

1. Introduction

Sidewalks are one of the most influential transportation infrastructure assets, supporting pedestrian travel as well as healthy pedestrian activity for several millennia (Ehrenfeucht and Loukaitou-Sideris, 2011). Almost every trip by every mode begins and ends with access via the sidewalk. The presence and condition of sidewalk infrastructure are important indicators of perceived safety and quality of walkable neighborhoods (Landis, et al., 2001). Many cities, however, have gaps between the connectivity (and quality) of pedestrian infrastructure compared to that for motorized vehicles (Li, et al., 2018; Shoup, 2010).

Many communities suffer from discontinuous pedestrian infrastructure and poor sidewalk maintenance (Shoup, 2010), making sidewalks inaccessible to those with physical disabilities (NACTO, 2003). Sidewalk users are diverse in age, gender, and physical condition; hence, sidewalk design needs to serve an entire spectrum of the population (Patel, 2019). Regulations under the Americans with Disabilities Act (ADA) have been enacted to ensure that pedestrian infrastructure is accessible to members to the disability community (NACTO, 2003). It is also important to ensure that sidewalk infrastructure accommodates all individuals, regardless of socioeconomic status, to facilitate equitable accessibility and mobility for all pedestrians.

There are numerous reasons for poor quality pedestrian infrastructure within different neighborhoods; however, one of the main reasons is the lack of structured assessment and maintenance programs in local government agencies. This results in part from a lack of adequate, sustainable, and equitable sources of funding for sidewalk infrastructure maintenance (Raybaut and Cordoba, 2021). Nearly all city and county governments budget for the construction, repair, and maintenance of local roads and highways, but few allocate funding and labor for similar treatment of sidewalks. Instead, these cities expect the adjacent property owner to pay for and maintain the sidewalks adjacent to their property (Shoup, 2010). This is the case in the City of Atlanta.

The research presented in this report is motivated by the significant role sidewalks play in encouraging active transportation and recreation and the observed lack of sustainable maintenance programs in most cities to support the use of sidewalks.

1.1 Overview of work conducted

This work applies the methodology for semi-automated sidewalk network generation developed by Li et al. (2018) in previous sidewalk infrastructure analyses. Generating a spatially accurate structural sidewalk network is crucial to subsequent steps for lifecycle cost estimation and cost allocation. This work expands previous QA/QC efforts to ensure the spatial accuracy of sidewalk network data. In addition to performing additional network verification, this work modified lifecycle cost estimations by Patel (2019) in his M.S. thesis using the sidewalk presence data to eliminate costs associated with replacing existing sidewalk infrastructure.

This work is organized along the lines traditional asset management and cost estimation reporting. Chapter 2 describes the sidewalk network generation process and associated QA/QC procedures. Chapter 3 reports the results for image-based sidewalk presence and absence identification. Chapter 4 details the procedures for association of sidewalk links with their adjacent tax parcels. Chapter 5 assesses the cost of ownership of the City of Atlanta’s sidewalk infrastructure. Chapter 6 analyzes the annual cost burden on households in the City of Atlanta under four cost allocation scenarios, with varying percentages of direct cost allocation to adjacent property owners vs. property taxes, and discusses the differences in cost burden across households. Concluding remarks and recommendations are presented in Chapter 7.

2. Sidewalk Network Generation and QA/QC

Sidewalk network generation is carried out in a manner consistent with the semi-automated method to generate GIS-based sidewalk networks conceived by Li, et al. (2018) and illustrated in Figure 1. The original methodology used automated models in a GIS environment to generate the preliminary sidewalk network and its features, followed by a subsequent manual editing of the network to correct for inaccuracies in the input data sources. While this process produced a fully connected sidewalk network, the QA/QC effort in the original study was only conducted for six out of Atlanta's 266 neighborhoods and subareas (Li, et al., 2018).

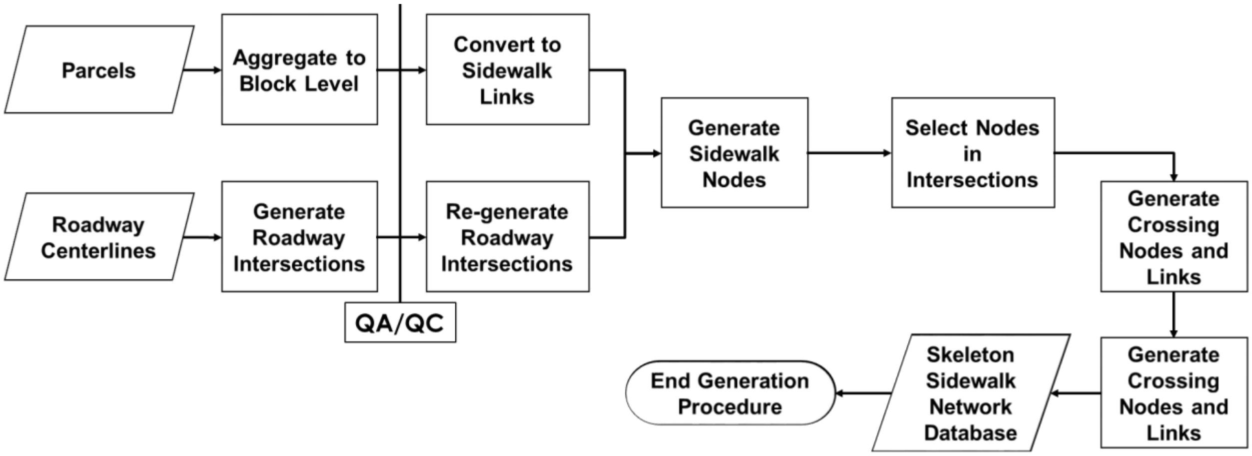


Figure 1. Sidewalk network generation flowchart

2.1 Methodology

In this research effort, sidewalk network QA/QC procedures were conducted for all 266 City of Atlanta neighborhoods. Although parcel aggregation and intersection centroid generation are automated processes, their input files can contain various errors that may distort the resulting sidewalk network. Some of these errors, such as gaps between parcels, result in the erroneous generation of sidewalk links and nodes in places where sidewalks would not logically be found. QA/QC of the aggregated parcels and intersection centroids therefore improves the spatial accuracy of the prototype sidewalk network and its extent.

The sidewalk network QA/QC process was carried out from early May 2020 through October 2020, followed a multi-phase procedure outlined in Figure 2. Aggregate parcels and roadway intersection centroids were split into 266 neighborhood geodatabases and assigned to QA/QC technicians. In each neighborhood data set, a QA/QC technician would correct the various errors observed in the aggregate parcel data and intersection centroids. After individual neighborhoods were analyzed, neighborhood geodatabases were aggregated into batches, wherein additional corrections were made to join neighborhood parcel databases together and remove seams along neighborhood boundaries. Batches were then aggregated and corrected to form the citywide network. Labor hours were tracked for each QA/QC technician throughout the multi-phase process for updated estimation of QA/QC labor hour costs and comparison to those originally estimated by Li et al. QA/QC processes were originally estimated to take between 1.0 hour and 2.4 hours per neighborhood (Li, et al., 2018). Given the variability, researchers are advised to exercise caution in estimating labor. A comparison of aggregate parcel data for the English Avenue neighborhood can be seen in Figure 3.

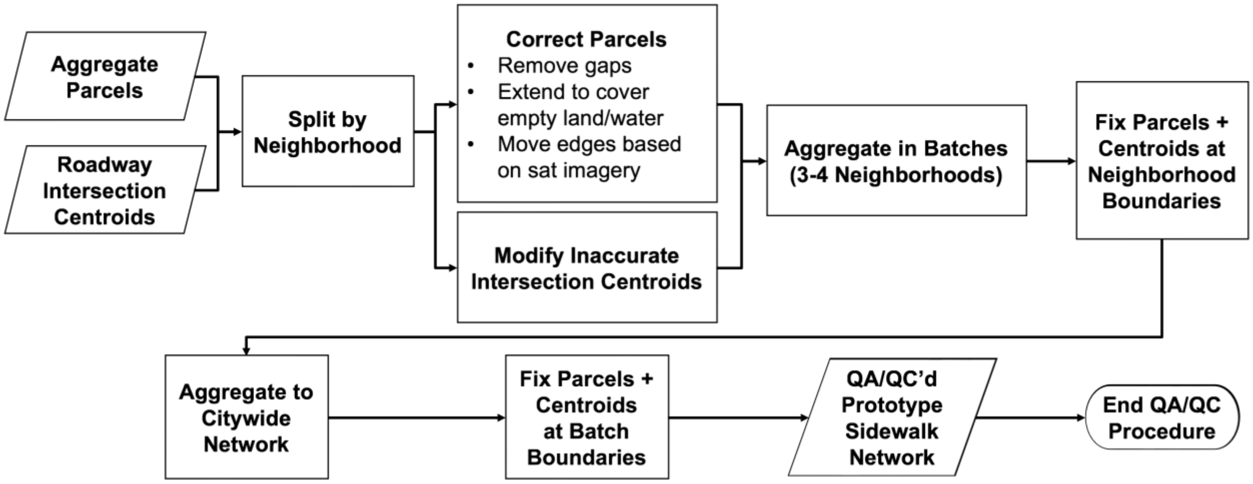
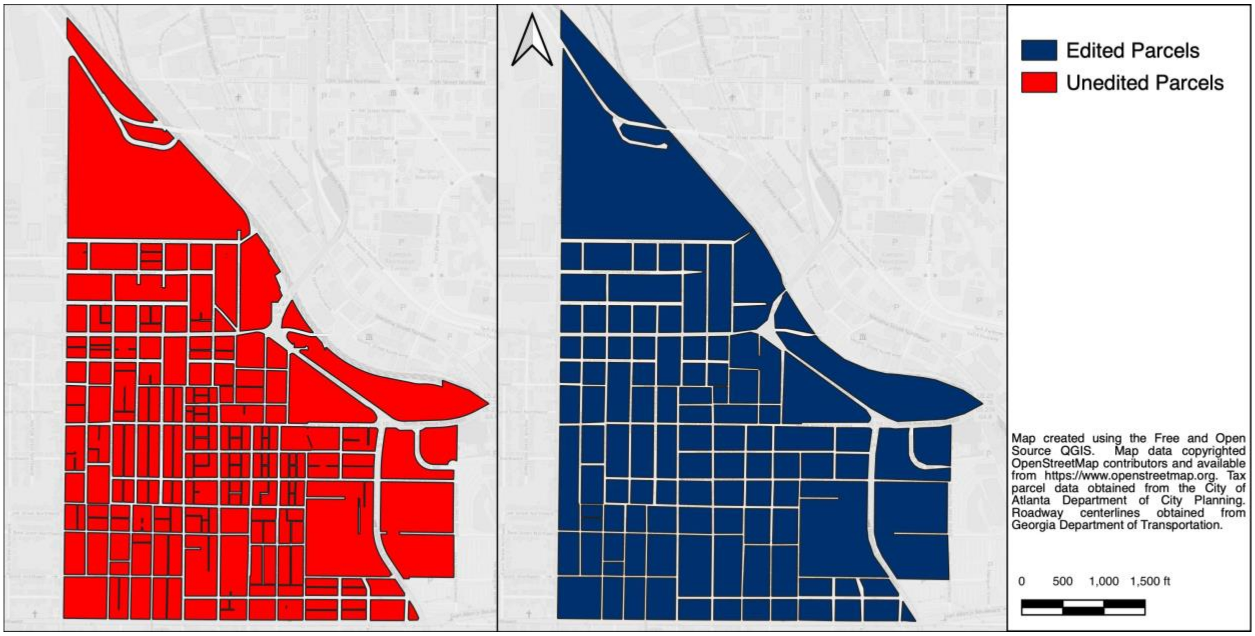


Figure 2. Sidewalk network QA/QC flowchart



Map created using the Free and Open Source QGIS. Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org. Tax parcel data obtained from the City of Atlanta Department of City Planning. Roadway centerlines obtained from Georgia Department of Transportation.

Figure 3. English Avenue aggregate parcel data before (left) and after QA/QC (right)

2.1.1 Tracking input file error identification and correction

To assess the causes of QA/QC labor, comprehensive error tracking was performed throughout the QA/QC process to identify the most common error sources in the aggregate parcel and intersection centroid databases. The various error sources were categorized by their geometric characteristics and coded for simplified reporting during the QA/QC process. The coded errors for the QA/QC process are summarized in Table 1.

The first element of the error code identifies the specific feature in which the error originates: P for the parcel feature class and I for the intersection centroid feature class. The second element identifies the specific network feature that is impacted by the error. In the parcel error codes, the second element subsets to either the sidewalk links and nodes (SW), the crossing links and nodes (CR), or discontinuities in the aggregate parcels (G). Because the intersection centroids are the only features derived from the intersections database, the second element for these error codes is always the centroid (C).

The third element of the error code identifies the specific nature of the error. R identifies the error as caused by redundancy in features. A redundant sidewalk vertex (P-SW-R), for example, indicates that the parcel's geometry creates redundant vertices that may cause errors with the automated network generation. MP identifies the error as caused by a misplaced or misaligned vertex. This error is frequently observed when parcels are drawn with concave or convex sections on their frontages, resulting in jagged edges that do not represent the typical alignment of a sidewalk. MIA identifies the error as resulting from a missing vertex, centroid, or link. This error is frequently observed in areas where larger parcels have yet to be partitioned to reflect the construction of new residential properties and their accompanying provision of roadway access. Because these features are hidden underneath the undivided parcel, no network features are generated for that roadway. This error w only observed with major significance in one instance (Atlantic Station).

The last four categories for the third element (GEN, RR, RVR, HWY) cover the causes for unintended gaps between parcels and their accompanying neighborhood boundaries. Gaps between the aggregate parcels and their corresponding neighborhood boundary result in the erroneous generation of sidewalk links and nodes along the edges of the parcel facing the gap. These additional sidewalk miles result in an overestimation of overall sidewalk mileage in the city. GEN identifies gaps in the parcel and neighborhood boundary without a discernible justification for the gap. RR identifies the cause of the gap as due to railroad rights-of-way splitting aggregate parcels along the edges of neighborhoods. RVR identifies the cause of the gap in parcels and boundaries as due to the presence of a river at the boundary of the neighborhood; this cause of error was observed only in neighborhoods bordering the Chattahoochee River in Atlanta's northwestern neighborhoods. Lastly, HWY identifies the cause of the gap in parcels and boundaries as due to the presence of a highway along the neighborhood's boundary. Like other roadways, tax parcels are not drawn on a highway's lane footprint. Because highways form portions of many neighborhood boundaries in the City of Atlanta, these gaps in the parcel database were frequently observed in neighborhoods along the Connector, I-20, I-85, I-75, I-285 and even some non-Interstate arterials, such as Langford Parkway and GA-400. Filling these gaps greatly improves the accuracy of the network by reducing the total inaccurate sidewalk link mileage generated by the automated process.

Table 1. QA/QC error codes and descriptions

Error Code	Error Description
P-SW-R	Redundant sidewalk vertex on the parcel
P-CR-R	Redundant crosswalk vertex on the parcel
I-C-R	Redundant intersection centroid
I-C-MP	Misplaced/misaligned intersection centroid
P-CR-MP	Misplaced/misaligned crosswalk vertex on the parcel
P-SW-MP	Misplaced/misaligned sidewalk vertex with roadway
I-C-MIA	Missing intersection centroid
P-CR-MIA	Missing crosswalk node/vertex
P-R-MIA	Roadways/sidewalks missing in the parcel data (no gap b/w parcels to reflect the roadway's existence)
P-G-GEN	Gap between parcels or between parcel and boundary for unspecified reason
P-G-RR	Gap between parcels or between parcel and boundary b/c of railroad
P-G-RVR	Gap between parcels or between parcel and boundary b/c of river
P-G-HWY	Gap between parcels or between parcel and boundary b/c of limited access highway (i.e., I-85 and I-75)

The QA/QC technicians tracked the number of each error type that they observed and the time they spent correcting the errors (parcels and intersection centroids), as well as the time spent stitching batches together. Error tracking data were aggregated by neighborhood and citywide to estimate the total labor hours spent in QA/QC for the sidewalk network database.

2.2 Results

QA/QC was conducted on the aggregate parcels and intersection centroids used to generate the skeleton sidewalk network to ensure spatial accuracy before re-generation of the network database. Final quality controls and analysis were implemented on the network features to correct any errors not previously identified in the QA/QC procedures depicted in Figure 1. Final sidewalk mileage estimates were calculated and compared to original estimates by Patel (2019) in Table 2. The original pre-QA/QC sidewalk network contained approximately 3,145 miles of sidewalk links; the post-QA/QC sidewalk network contained approximately 2,759 miles of sidewalk links. With a difference of 386 miles, the post-QA/QC reduction in sidewalk mileage is approximately 12% of the original network extent.

Table 2. Sidewalk network mileage pre- and post-QA/QC

Column 1	Column 2
Pre-QA/QC	3145
Post-QA/QC	2759
Difference	-386 (12%)

Maps of the pre-QA/QC and post-QA/QC sidewalk networks are depicted in Figure 4. The most notable change between the sidewalk networks was the removal of the sidewalk links automatically generated along the edges of the City of Atlanta. The City of Atlanta's official boundary is approximately 114 miles, constituting nearly one-third of the change in sidewalk link network mileage calculated pre-QA/QC and post-QA/QC.

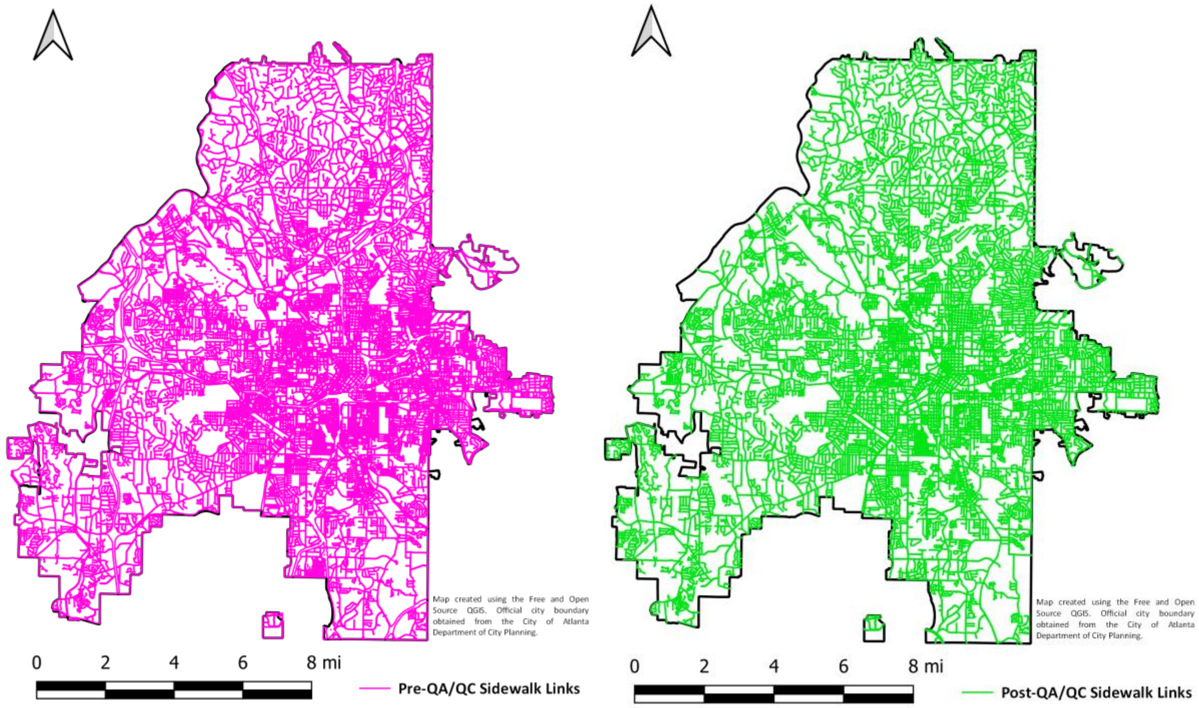


Figure 4. Comparison of pre- (left) and post-QA/QC (right) sidewalk network extent

2.2.1 Error correction analysis

Error correction times were aggregated across all neighborhoods and analyzed to quantify the average minimum and maximum error correction times. Average minimum and maximum correction times address variation across QA/QC technicians. The error code with the highest average maximum correction time was P-SW-R, for redundant sidewalk parcel vertices (458.5). The error code with the highest average minimum time was P-G-HWY (283 seconds). The error code with the lowest average minimum time was I-C-MP (7 seconds).

Correction times were aggregated for each feature class and averaged across all neighborhoods for which QA/QC data were available. As seen in Table 4, the average time to correct the aggregate parcels in a neighborhood was approximately 18.2 min, about five times the average correction time for intersection centroids (3.3 min). The standard deviation for aggregate parcel correction times was 16.8 min. The standard deviation for intersection centroid correction times was 6.5 min.

Table 3. Error code correction time minima and maxima

Error Code	Average Minimum Time (seconds)	Average Maximum Time (seconds)
P-G-HWY	283	454
P-G-RR	174	309.5
P-G-RVR	166	279
P-G-GEN	74.5	330
P-SW-MP	74	182
P-R-MIA	62.5	193
P-CR-R	14	145
P-CR-MP	13	263
P-SW-R	12	458.5
P-CR-MIA	12	95
I-C-R	8	100
I-C-MIA	8	87
I-C-MP	7	63

Table 4. Correction times by feature class

Aggregate Parcel, Average (minutes)	Aggregate Parcel, Standard Deviation (minutes)	Intersection Centroid, Average (minutes)	Intersection Centroid, Standard Deviation (minutes)
18.2	16.8	3.3	6.5

Total Phase I QA/QC time was calculated using timestamps from each QA/QC technician's timesheet and aggregated by neighborhood. Of 256 neighborhoods tracked and corrected through QA/QC, Phase I QA/QC took 401 hours, with a neighborhood average time of 1.6 hours. Seven neighborhoods were not recorded through the QA/QC error tracking process due to technician turnover at the end of Phase I. Bankhead and Ansley Park were excluded from the analysis of correction times, due to their use as training neighborhoods for QA/QC technicians. Hadlock was also excluded due to abnormally high centroid correction time, suggesting inaccurate time reporting for the neighborhood. Neighborhood correction times and total QA/QC times were aggregated and reported in Appendix A.

To quantify the extent to which each error coded in the Phase I QA/QC process impacts neighborhood QA/QC time, multivariate regression was performed, with dummy variables to represent the QA/QC technicians that performed the procedures. The regression outputs are tabulated in Table 5. Of the error codes included, two showed reasonable significance with a p-value of 0.01: gaps in parcels due to roadways and misplaced intersection centroids. The overall number of aggregated parcels was also found to be significant, with a p-value well below 0.01. Of the technicians included in the regression analysis, Technicians A and Z were appear to have influenced overall neighborhood QA/QC correction time in Phase I (neighborhood correction times can take considerably longer for certain technicians).

Table 5. Multivariate regression of QA/QC time

Variable	Estimate	Standard Error	t value	Pr(>|t|)
(Intercept)	2371.594	371.411	6.385	9.48E-10
Centroids	-2.042	12.652	-0.161	0.87195
Parcels	70.224	12.299	5.71	**3.51E-08**
I_C_MIA	2.378	49.681	0.048	0.961858
I_C_R	376.509	163.57	2.302	0.022247
P_G_HWY	503.151	295.211	1.704	0.089673
P_G_RR	1455.556	404.524	3.598	**0.000393**
P_SW_R	43.862	80.04	0.548	0.584229
I_C_MP	258.497	91.776	2.817	**0.005279**
P_CR_R	3.2	51.588	0.062	0.950595
P_SW_MP	41.626	133	0.313	0.754585
P_CR_MIA	142.849	100.848	1.416	0.158001
P_G_GEN	-6.071	54.2	-0.112	0.910906
P_CR_MP	158.42	298.77	0.53	0.596461
P_G_RVR	-135.104	985.351	-0.137	0.891063
Technician A	4642.67	627.43	7.4	**2.60E-12**
Technician F	986.294	1109.033	0.889	0.374764
Technician Z	-2684.783	522.21	-5.141	**5.87E-07**

2.3 Discussion

While average maximum times are useful to understand the relative range of correction time needed for certain errors, average maximum times across technicians are subject to externalities (such as Internet speed or interruptions). Thus, average minimum time is a more reliable estimate of the time needed to address each error code. Additionally, average minimum time serves as a useful estimate of the best-case scenario, wherein externalities were minimized and a technician demonstrates QA/QC skills sufficient to minimize the error correction time. Thus, average minimum times can help generate minimum expected QA/QC times for neighborhood aggregate parcels and intersection centroids.

Conducting QA/QC efforts in the early stages of the COVID-19 pandemic may have led to some distorted labor estimates. QA/QC was conducted entirely remotely; hence, technicians used non-standardized computers with varying quality in processors, CPUs, and GPUs. QA/QC was performed on files stored in a secure Dropbox cloud server, resulting in QA/QC processes being subject to the quality of Internet service available to the individual technicians. The COVID-19 pandemic also complicated training, making it harder to gauge technician comprehension of instructions until the process was underway. This created potential errors in error tracking and timekeeping due to misunderstanding the relevant spreadsheets. The inability to be in person with technicians may also have made the error correction process itself take longer, because it was more difficult to explain confusing situations to the technicians.

Because technicians provided their own equipment for QA/QC work, commonly used and licensed GIS software under the Esri suite of products could not be used by all technicians. Instead, QA/QC methodologies and documented procedures were drafted and adapted to both the ArcMap environment and QGIS environment. Although ArcMap and QGIS share many features in common, the two software applications vary considerably in compatible file formats and terminology, presenting additional difficulties during the early stages of QA/QC. Although this application-agnostic methodological approach enabled greater adaptability for QA/QC technicians, selecting a single software program is recommended for future QA/QC efforts to minimize conflicts across files edited in separate GIS environments.

In addition to external factors affecting the QA/QC of the Atlanta sidewalk network, internal factors inherent to variation in QA/QC technician experience and skills also complicate the interpretability of the Phase I QA/QC times. Multivariate regression on neighborhood Phase I QA/QC correction times indicated Technician A had a significant impact on neighborhood correction times, increasing the overall time for the neighborhood by an estimated 77 minutes. Technician Z, on the other hand, had a smaller but opposite estimated impact on neighborhood Phase I QA/QC correction times, decreasing the overall time for the neighborhood by approximately 45 minutes.

It is not possible to isolate technical factors (e.g., Internet speeds) from individual capabilities, making Technician dummy variables difficult to interpret. Technician A may be more efficient than Technician Z, but technical difficulties may not have been equal across technicians. Because these two factors are measured by the same variable, any attempt to isolate these characteristics of the QA/QC process and technicians could be misleading.

3. Sidewalk Identification

Coding of sidewalk presence is crucial to the analysis of Atlanta's sidewalk network for multiple reasons. Chief among these reasons is the need to compare the mileage of sidewalks in Atlanta that are missing and those that are currently constructed. Coding sidewalk links for presence and absence allows for parcel-by-parcel evaluation of the percentage of sidewalk buildout, the costs to construct the missing sidewalk mileage, and the cost to maintain existing sidewalk mileage. Parcel-by-parcel estimation of sidewalk presence also facilitates sociodemographic analysis of the cost burden associated with property owner-based funding scenarios explored later in the Assessment of Funding Options section of this report.

The prototype sidewalk network generation and QA/QC processes outlined in Figure 1 and Figure 2 rely heavily on the knowledge and use of GIS software by all participants in the process, including the QA/QC technicians. While familiarity with GIS methods is generally necessary to perform these processes, due to their complexity, collecting sidewalk presence data does not require GIS skills. Furthermore, sidewalk identification can prove time-consuming, requiring local assessment of infrastructure that may significantly extend data collection duration. In recognition of these factors, a separate, scaled-down process was developed to identify sidewalk presence data with the help of multiple technicians.

3.1 Methodology

Figure 5 outlines the general procedure for sidewalk identification used in this study. An HTML5 and JavaScript-based application was developed to provide an interface between data collection users and geospatial data and tools provided by the Bing Maps V8 Web Control Application Programming Interface (API). Once sidewalk data has been collected from this application, geocoded point data are assembled into polylines representing the presence and absence of sidewalk mileage. This data then undergo a brief QA/QC process to resolve geometric issues with the sidewalk presence polylines. The polylines are subsequently joined spatially to the prototype sidewalk network to identify and split network links based on where sidewalks are identified as absent or present.

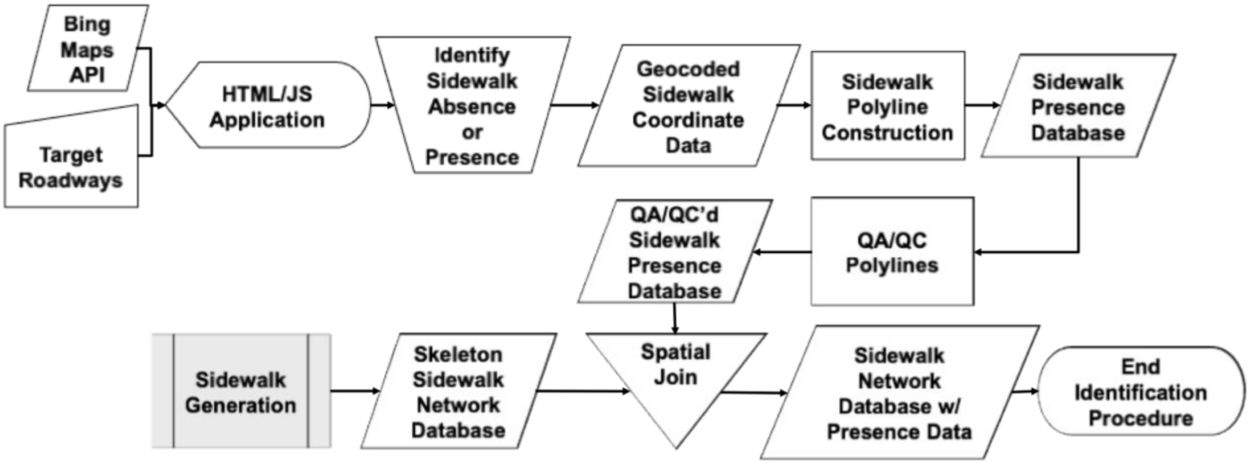


Figure 5. Sidewalk identification flowchart

The procedure for sidewalk identification data collection, simply put, sought to replicate the feature class creation process in GIS applications, without the added complexity of a GIS program's other features. The sidewalk identification platform, or Sidewalk Flythrough as it would become known, can provide the necessary controls for data collection technicians without requiring extensive familiarity with GIS principles and software required in the sidewalk network QA/QC process.

3.1.1 Bing Maps API and Services

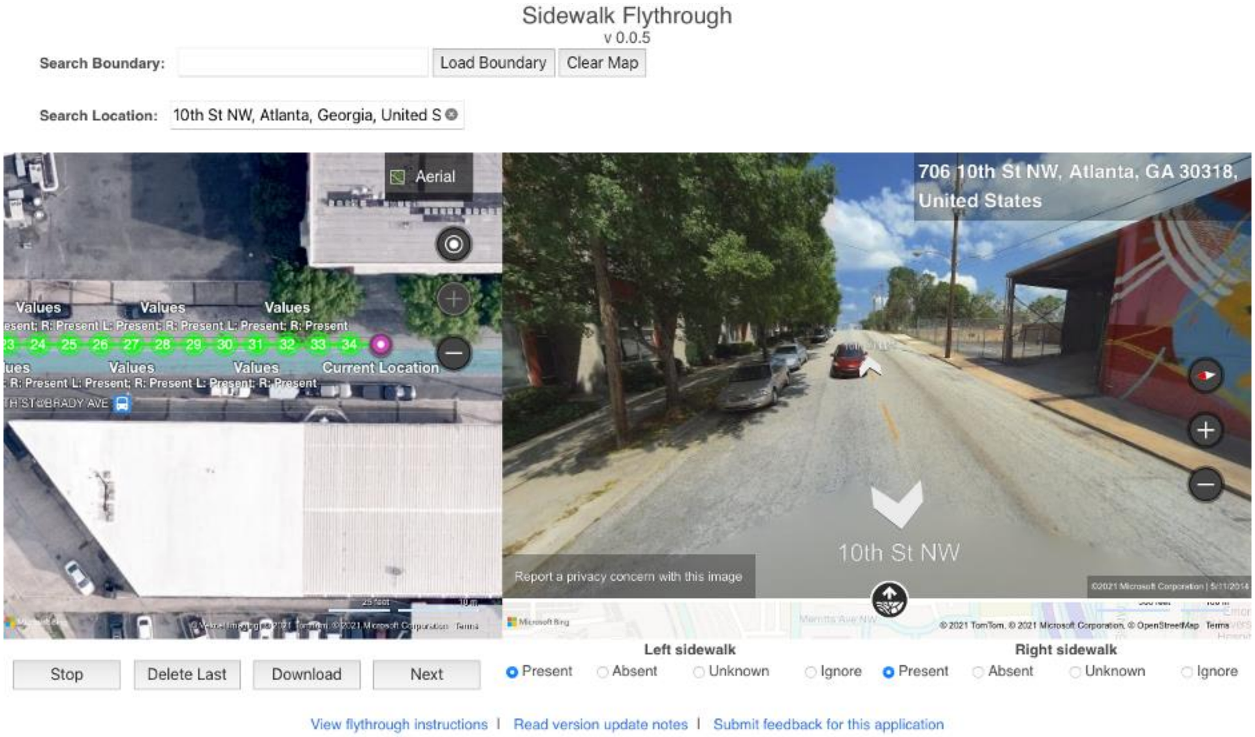
The Bing Maps API formed the backbone of the sidewalk identification data collection application. The Bing Maps API offers a suite of spatial analytics modules that allow for the customization of programs with wide applications, including the identification of sidewalk infrastructure assets. The Bing Maps API provides access to satellite aerial imagery, as well as Streetside imagery collected by Microsoft that depicts the state of sidewalk infrastructure along public roadways. Panoramic Streetside imagery is a necessary supplement to the aerial imagery of sidewalks in Atlanta due to the city's ubiquitous tree canopy that obstructs sidewalks in aerial imagery.

3.1.2 Autosuggest and Search Modules

Critical to the Sidewalk Flythrough's function is the implementation of Bing Maps' Autosuggest and Search modules. The Autosuggest module, as described in the Bing Maps V8 Web Control API Reference, takes text strings and provides suggestions for locations stored in the Bing Maps repository. The Search module plays a similar role in that it takes a string of location information and geocodes the best matching address. Together, these tools add flexibility to the Sidewalk Flythrough by allowing the user to customize their data collection to any desired location with street side data available through Bing Maps. A user could collect sidewalk data for any study area without pre-loading data into the application.

3.1.3 Sidewalk Flythrough Layout

A Sidewalk Flythrough application was used to facilitate quick and simultaneous reference to both aerial imagery and its corresponding Streetside images. Figure 6 depicts the layout of the sidewalk identification data collection application. The Sidewalk Flythrough functions use the Microsoft Pushpin class object and record data at its location. The application uses the arrow buttons built into Microsoft's Streetside imagery to advance the pushpin linearly along a series of panoramic public street images.



Search Location: 10th St NW, Atlanta, Georgia, United S

Left sidewalk: ● Present ○ Absent ○ Unknown ○ Ignore

Right sidewalk: ● Present ○ Absent ○ Unknown ○ Ignore

Figure 6. Sidewalk flythrough application layout

At each new panoramic image, the Sidewalk Flythrough Application user toggles the buttons at the bottom-right of the interface to reflect the state of the sidewalks along the current street section as either present, absent, or unknown. Unknown was included as a category for sidewalk identification data due to the potential for debris and foliage to obstruct the sidewalk in Streetside imagery. A full description of each sidewalk identification category used in data collection is presented in Table 6.

Table 6. Sidewalk identification categories

Sidewalk Status	Description
Absent	Sidewalk is not detectable within the next 5 feet in the street side or aerial imagery
Present	Sidewalk is clearly visible within next 5 feet in the street side or aerial imagery
Unknown	Absence or presence of sidewalk within next 5 feet cannot be assessed due to debris or poor imagery

Each time the pushpin is moved, the application retrieves the geographic coordinates of its last location and the state of the sidewalk toggles as a row in a data frame of results collected during the active session. Once the user has completed data collection for a street, the user downloads their results as a comma-separated values (CSV) file containing the geocoded sidewalk identification data collected during the session.

3.1.4 Sidewalk Polyline Construction

Once sidewalk identification data has been exported from the Sidewalk Flythrough Application, the geocoded data are reconstructed as a series of polylines. Polyline construction was performed using Python scripts developed with the GeoPandas package, an open source project that enables geo-processing in Python by combining the database datatypes of Pandas and the geometric operation of Shapely (Jordahl, et al., 2020). The virtual environment for polyline construction was managed using Spyder IDE through Anaconda (Raybaut and Cordoba, 2021; Anaconda, 2016). Each polyline is constructed using sequential rows of geocoded sidewalk identification data with the same identification status. Thus, in areas where sidewalks are mostly built (e.g., Downtown Atlanta), most sidewalk mileage may be depicted using one or very few polylines, whereas areas with fragmented sidewalk networks may have substantially higher number of polylines depicting the status of sidewalk links. In instances where only one sequential row contains the same sidewalk identification status, the previous row is used as the starting node for the polyline.

3.1.5 QA/QC

After sidewalk identification polylines are constructed, the individual polylines are aggregated into a singular shapefile. Subsequent QA/QC of the sidewalk identification polylines for spatial accuracy is essential for several reasons. While Streetside panoramic imagery is generally collected in a linear manner as a Microsoft vehicle drives down the target street, the geocoding of each panoramic image is subject to GPS drift, wherein some data points may have drifted perpendicularly away from the centerline of the roadway. Furthermore, duplicates of the same data point collected by the user or accidental jumps in location backward and forward may result in data points that are no longer spatially sequential, resulting in abnormal polyline geometry that may distort or reduce the accuracy of spatial joining to the prototype network.

3.1.6 Spatial join with prototype network

Once all sidewalk identification polylines have been edited for spatial accuracy, the polylines are joined to the prototype sidewalk network (the network of potential sidewalk links developed using the automated tools developed in Li, et al., (2018)). This spatial join process requires its own separate QA/QC, as the geometric mismatch between the prototype network's source data and the sidewalk identification data's source produces segments where no sidewalk identification data is joined to the prototype network. This manual process also allows for resolution of sidewalk segments classified as “Unknown” status. Manual correction of prototype network links missing sidewalk identification data was performed in GIS by referencing Bing Maps Aerial Imagery Services and Streetside imagery on Bing Maps. Sidewalk identification QA/QC labor will likely vary. For Atlanta, this QA/QC took about 30 hours.

3.2 Results

3.2.1 Sidewalk identification data

Sidewalk surface identification was conducted for all public roadways in the City of Atlanta and joined spatially to the original prototype sidewalk network. Sidewalk surface mileage was aggregated by identification category and reported in Table 7. Approximately 1,277 of 2,759 miles of sidewalk links were identified as present/existing (46%), and 1,469 miles of potential sidewalk links were identified as absent/missing (54%). The spatial distribution of sidewalk links by identification category is depicted in Figure 7. Notably, sidewalk links identified as present or existing are more heavily clustered in Downtown, Midtown, and adjacent neighborhoods.

Table 7. Sidewalk network link mileage by identification category

Sidewalk Status	Miles
Present	1277
Absent	1469

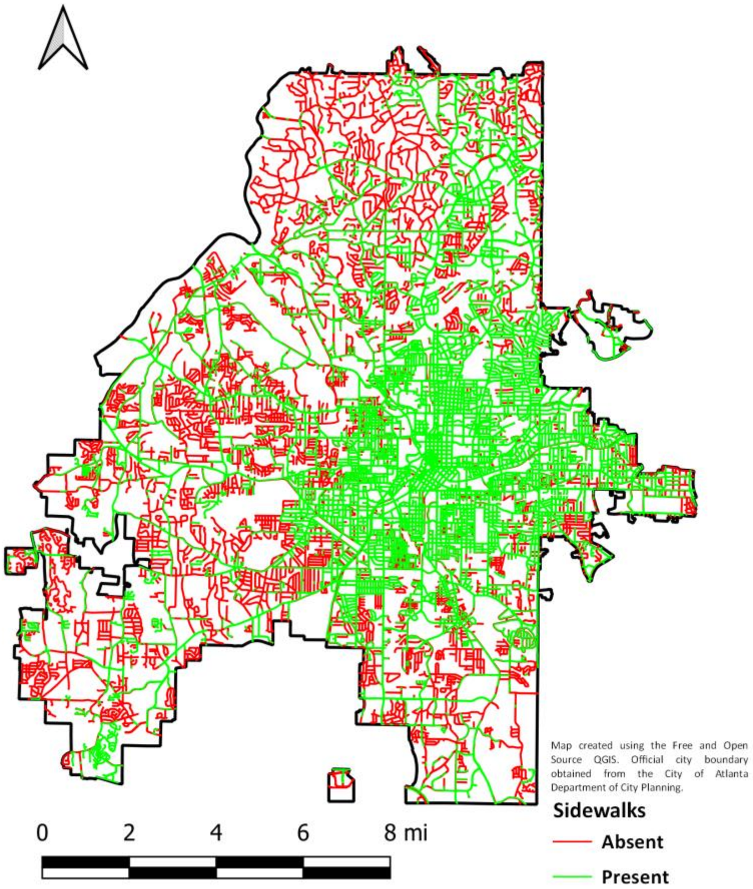

Map created using the Free and Open Source QGIS. Official city boundary obtained from the City of Atlanta Department of City Planning.

Figure 7. Map of sidewalk mileage identified as absent or present

3.2.1 Testing for spatial autocorrelation

To assess whether existing sidewalk surface mileage is distributed randomly or is spatially clustered, a Global Moran's I was calculated. Sidewalk surface mileage was normalized for each neighborhood by measuring the percentage of overall sidewalk network surface mileage in the neighborhood that was identified as built or existing. Normalizing by percentage eliminates skews in the measure of sidewalk surface miles built due to the varying sizes of neighborhoods. Neighborhood percentage of sidewalk surface mileage present is illustrated in Figure 8.

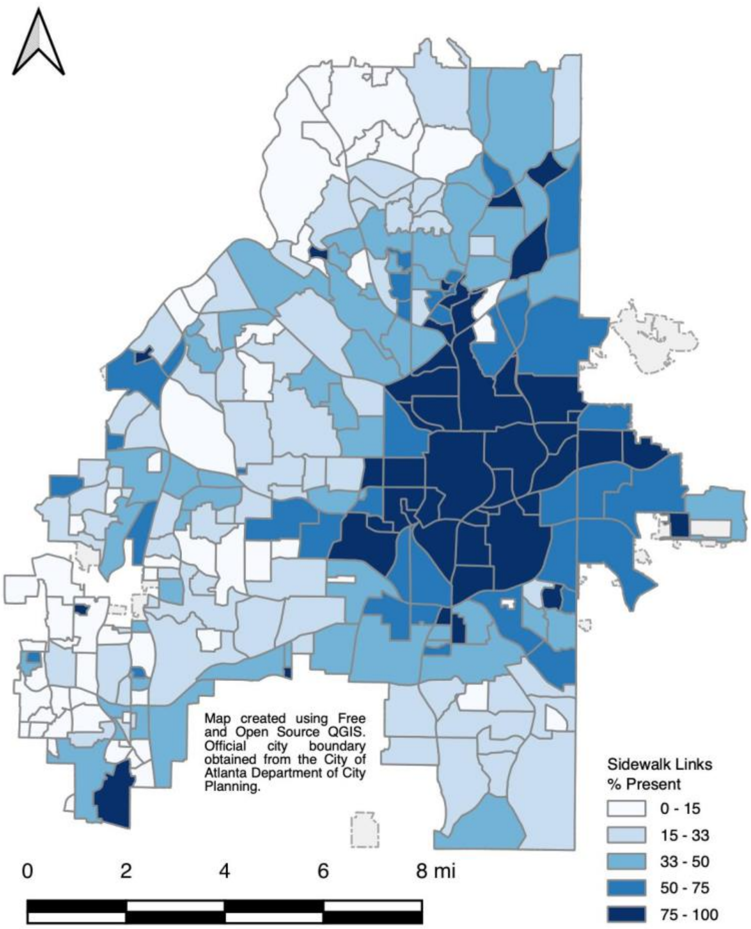


Figure 8. Percent of potential sidewalk network surface present by neighborhood

Moran's I was calculated for the percentage of sidewalk mileage present in a neighborhood using the ape package for R Statistical Software after cleaning the data with dplyr (R Core Team, 2021; Paradis and Schliep, 2019; Wickham, et al., 2019). The observed Moran's I for the City of Atlanta neighborhoods was 0.169462, with an expected value of -0.003788. The standard deviation was 0.005930 (Table 8). With a p-value of effectively zero, there is sufficient evidence to reject the null hypothesis that sidewalk links have no spatial autocorrelation. This interpretation of the Moran's I results is further supported by the visualization of percentage sidewalk mileage built or existing (Figure 8 above). These results were anticipated.

Neighborhoods around the urban core of the City of Atlanta have significantly higher percentages of sidewalk mileage built than neighborhoods outside the core, particularly neighborhoods on the western side of the city.

Table 8. Summary of test for spatial autocorrelation of neighborhood sidewalk mileage

Observed Statistic	Expected Statistic	Standard Deviation	P-value
0.169462	-0.003788	0.005930	0

3.3 Discussion

Although the Sidewalk Flythrough Application offers a unique platform through which to collect sidewalk identification data remotely and easily, the platform has several limitations. Bing Maps imagery, while generally recent, may be outdated. In some instances, identification data collection at the beginning of 2021 employed Bing Maps images taken in 2019. Effectively, the temporal accuracy of most sidewalk links in the network is limited to the age of the aerial imagery hosted. Further complications in collecting sidewalk presence data arise when aerial views of sidewalks are obstructed by trees, a common occurrence in the City of Atlanta due to the ubiquitous tree canopy. Obstructed satellite imagery forces the data collection technician to rely on Streetside imagery hosted by Bing Maps, which may be several years older than satellite imagery. In many residential areas of the City of Atlanta, Streetside images were collected in 2014, representing a seven-year gap in potential photographic accuracy.

3.3.1 Improving Spatial Accuracy with Drawing Tools Module

Matching the Sidewalk Flythrough results to the prototype sidewalk network posed significant challenges due to the differing geometries of the two datasets. The prototype sidewalk network is created through the aggregation of parcel level data, whereas the Sidewalk Flythrough data is generated by aggregating point data collected via a web interface into polylines. The polylines constructed through the flythrough are subject to various geometric errors due to the unpredictable directions the next street side imagery, resulting in jagged lines. GPS inaccuracies during the Streetside imagery data collection process can also result in abnormal geometries in the Sidewalk Flythrough data, necessitating a manual review of data collected. Furthermore, neither data collection process satisfactorily accounts for refuge islands, mid-block crossings, and other elements of the pedestrian infrastructure that cannot be identified/predicted in the current network generation processes.

A solution to this challenge has been proposed and tested preliminarily in the form of integration of the Bing Maps' Drawing Tools Module. The Drawing Tools Module enables full geometric control on the part of the user, providing tools for polygon, polyline, and pushpin creation. The Drawing Tools could enable a modified approach to sidewalk network construction in which all presence data is collected in concert with the geometry of the associated pedestrian infrastructure.

The Drawing Tools Module has been integrated into additional pedestrian infrastructure data collection tools developed for a similar project in Clayton County, GA. These related tools implement the Drawing Tools Module by allowing the user to manually draw polygons and pushpins to represent curb cuts and driveways. When a drawing (e.g., a polygon) is complete, the Drawing Tools Module can detect its completion, allowing the application to prompt the user to describe what the drawing is. An advanced and refined version of the Sidewalk Flythrough application could implement the Drawing Tools module and allow the user to collect present sidewalk polylines, absent sidewalk polylines, crosswalk polylines, ramp pushpins, and curb cut polygons/pushpins all on a single platform. The input roadway centerlines are invaluable in structuring a coordinated multi-user data collection process, as data collection assignments can be based upon roadway names and mileage. These roadway names are easy to match in the Sidewalk Flythrough application using the Autosuggest and Search modules, allowing a user with modest training to navigate the platform to find their spatial assignment. Although the use of Bing Maps systems to identify the presence and absence of sidewalk infrastructure is very promising, it remains unclear whether cities can implement these techniques given current use restrictions of imagery under Bing Maps license agreements. If use of host service images in these processes is ultimately disallowed, cities will need to collect their own flythrough video (or similar series of still images) for use with such tools.

4. Sidewalk-Parcel Association

To apply demographic information to Atlanta's sidewalk network, sidewalk links must be associated with Atlanta's parcel-level database. Demographic data licensed from Epsilon is broken down at the household level, meaning most of the income and demographic data can be applied at parcel-level scale. It was not possible to differentiate between renters and homeowners for rental houses. Most credit reporting is expected to be for the renters (and we anticipate that sidewalk costs will be passed along to renters via rents).

4.1 Methodology

In the original study performed on Atlanta's sidewalk network (Patel, 2019), sidewalk lengths were associated with each residential parcel in the City of Atlanta using geo-processing tools. Figure 9 illustrates the process for sidewalk-parcel association in the City of Atlanta. Roadway centerlines carrying through lane widths are used to identify the edges of tax parcels that parallel the public right-of-way. These edges are then associated with their corresponding parcels and measured to estimate the length of frontage for each parcel. These parcel edge length estimates are joined to the sidewalk network database containing identification data by matching parcel IDs across both datasets.

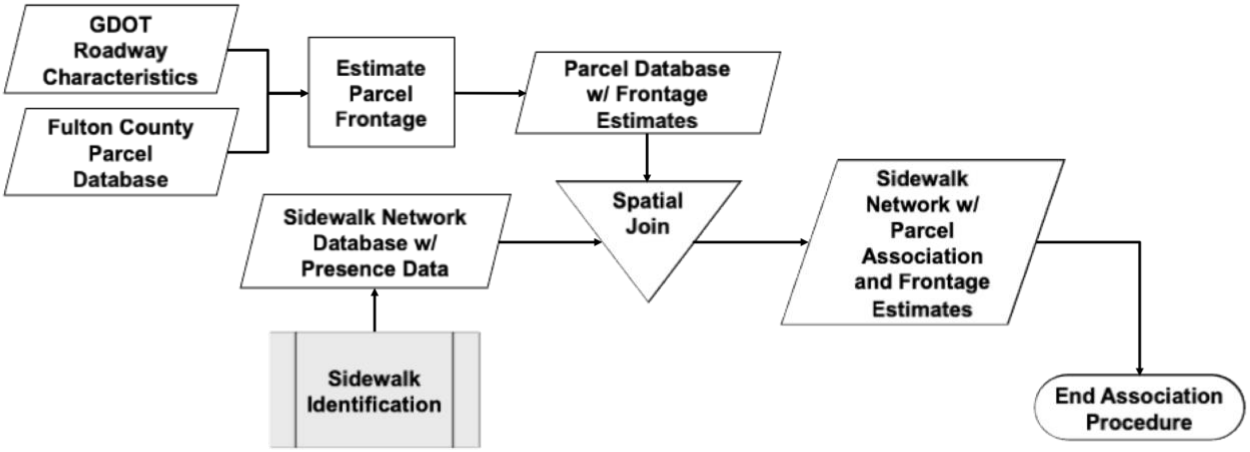


Figure 9. Sidewalk-parcel association flowchart

To extract the parcel frontage from each tax parcel in the City of Atlanta, geo-processing tools were used to select and extract all complete parcel edges falling within a variable buffer distance from the corresponding roadway. This extraction method relies on the near-universal practice of partitioning land such that one or more parcel edges has access to a public roadway. The GDOT Roadway Characteristics geodatabase's "THROUGH LANES" feature class used Equation 1 to calculate the variable buffer radius.

$$\text{Buffer Radius (ft)} = \left[15 \cdot \frac{\text{Number of Through Lanes}}{2}\right] + 30$$

Equation 1. Variable centerline buffer radius equation

Multiplying the number of through lanes by 15 feet accounts for a general lane geometry of 12 feet plus three feet for gutters, curbs, planters, and other features adjacent to the road. Dividing by two accounts for the number of through lanes in each direction on the centerline. Adding 30 feet accounts for variation in buffer zones across various roadway classes.

Once centerline buffers have been generated, parcel frontage is extracted by selecting and exporting only the edges of a parcel falling completely within the buffer zone. To collect parcel edges within the buffer zone, parcel polygons are converted to polylines and exploded to separate individual linestrings. This explosion of parcels into their constituent linestring elements allows for the extraction of only the linestrings falling within the roadway centerline buffer. This extraction method is superior to using the intersection of the parcel polylines and roadway buffers, as it does not overestimate a parcel's frontage by capturing parcel edges that are not parallel to the roadway centerline.

Once extracted, parcel edges are then used to extend the footprint of the parcel and capture associated sidewalk links, as seen in Figure 10. Note that parcel edges not parallel to road centerlines are not buffered. Because the original Parcel ID for each edge is retained in each step of geo-processing, frontage edges can be buffered and dissolved with their corresponding tax parcels to extend the range of the parcel into the public road right-of-way. Extending the parcel's range to the right-of-way is necessary to overlap the parcel with adjacent sidewalk links, especially in cases where QA/QC resulted in the shifting of sidewalk links away from and out of the original range of the tax parcel. Once the tax parcel and its corresponding buffer are merged, the combined parcel-buffer polygon is overlaid on the sidewalk network to subdivide sidewalk links wherever they overlap with a parcel-buffer polygon. The intersection method allows for the transfer of Parcel IDs through the overlaid parcel-buffer polygons, thus associating sidewalk links with adjacent tax parcels.

Figure 10. Example frontage buffer output

4.2 Results

4.2.1 Sidewalk-Parcel Association

Sidewalk mileage from the City of Atlanta sidewalk network was associated with adjacent tax parcels to estimate the length of adjacent sidewalk linkage for parcels facing public roadways in the City of Atlanta. The distribution of sidewalk mileage associated with adjacent parcels is illustrated in Figure 11. The median sidewalk length associated with a tax parcel was 70 feet. Of the 111,553 parcels associated with sidewalk links in the network, 110,743 parcels have sidewalk lengths less than 1000 feet.

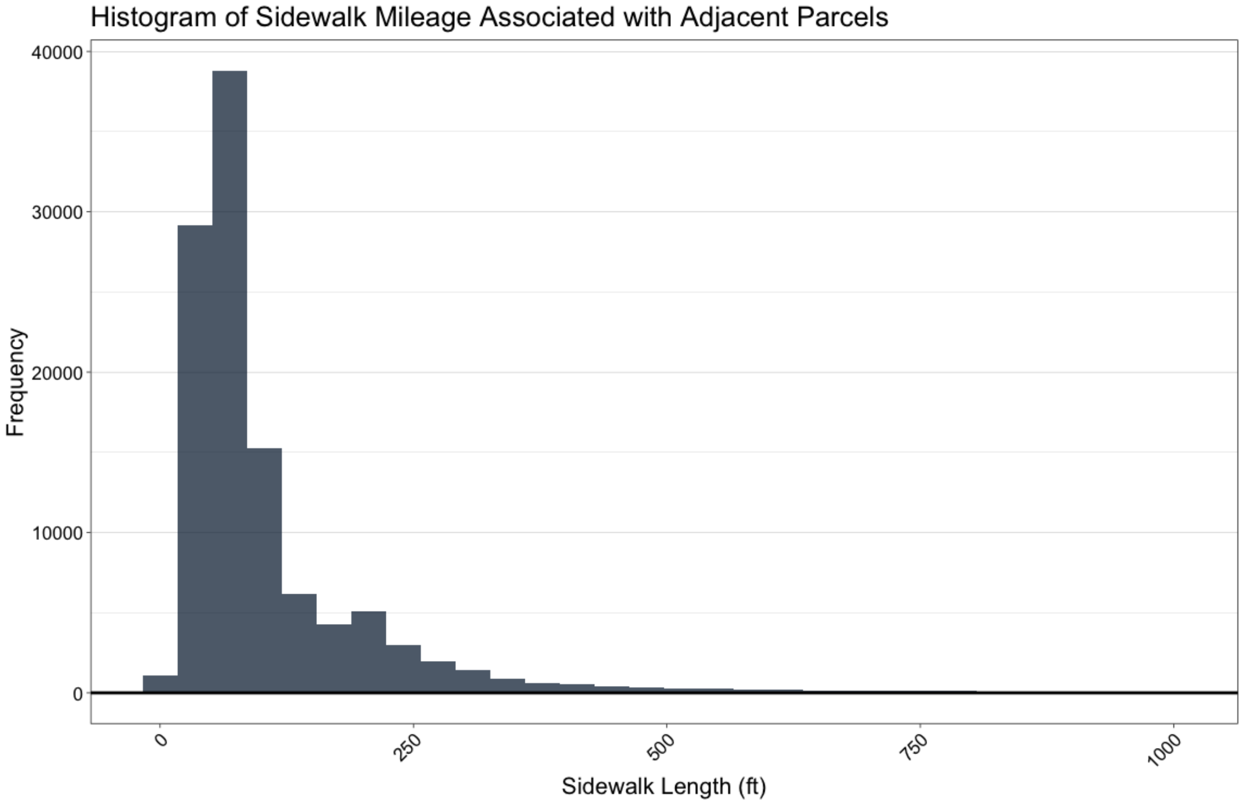


Figure 11. Histogram of parcel sidewalk lengths in the City of Atlanta

Sidewalk lengths associated with each parcel have a significant right skew, reaching values as high as 20,000 linear feet. This range of differences is higher than anticipated for any singular value within the dataset and reflects edge cases seen within the tax parcel database, specifically tax parcels drawn over private roadways and large tax parcels for amenities surrounded by public rights-of-way, such as Chastain Memorial Park and the East Lake Golf Course.

4.2.2 Assessing Accuracy of Sidewalk-Parcel Associations in the City of Atlanta

To evaluate the accuracy and precision of parcel sidewalk length estimations for parcels in the City of Atlanta, the difference between the estimated parcel sidewalk length and the associated parcel's frontage length was estimated using Equation 2. A negative difference in lengths indicates an underestimation of parcel sidewalk length compared to its corresponding parcel frontage, whereas a positive difference in lengths indicates an overestimation.

$$\text{Parcel Difference} = \text{Parcel Sidewalk Length} - \text{Parcel Frontage Length}$$

Equation 2. Parcel sidewalk length vs. frontage length

The differences in a parcel's associated sidewalk lengths and frontage length estimates were calculated for every parcel in the City of Atlanta. Statistical measures for central tendency and spread were calculated for the parcel sidewalk-frontage differences. The differences in parcel sidewalk-frontage lengths were also subjected to tests for statistical significance. Values falling outside of the interquartile range (very large parcels or those not facing public roadways) were removed from the analytical dataset to avoid skewing the summary statistics. The mean difference between parcel sidewalk length and parcel frontage length was -2.2 feet, while the median difference was 0.0 feet. The standard deviation of differences was 8.5 feet. The mean and median suggest a slightly negative skew of the differences in lengths with a clustering of data around a difference of 0 feet. This clustering can be seen in Figure 12. Although the mean and median differences and histogram of differences would suggest that the sidewalk-parcel association process accurately identified the length of sidewalk for most parcels, the standard deviation suggests a significant amount of variation in the differences.

A one-sample t-test was performed on the differences in a parcel's associated sidewalk length and frontage length. The null hypothesis was the difference between these two measures was zero, while the alternate hypothesis was the difference between these two measures was non-zero. With a t-statistic of -80.986 and 98,803 degrees of freedom, the results of the test suggest that the mean difference between parcel sidewalk length and parcel frontage length is non-zero and skews negatively, indicating an underestimation of sidewalk lengths compared to parcel frontages.

A small subset of potential outliers was observed when comparing tax parcel frontage estimates and associated sidewalk lengths. Most of these edge cases are the result of tax parcels being drawn over roadways used to access private properties, an example of which can be seen in Figure 13. Two special cases, Atlantic Station and Hartsfield-Jackson Atlanta International Airport, have large differences between their frontage estimates and sidewalk lengths, because many of their sidewalk lengths fall within the tax parcel as opposed to along the frontage edges. These two cases are privately owned developments that are accessed by a significant number of travelers; hence, they were included in the analysis. The one outlier not following this pattern was the result of aggregating several parcels with no designated Parcel ID. These parcels range in size and location, with the largest corresponding to sections of Freedom Park and the smallest appearing as small narrow stretches of land between parcels.

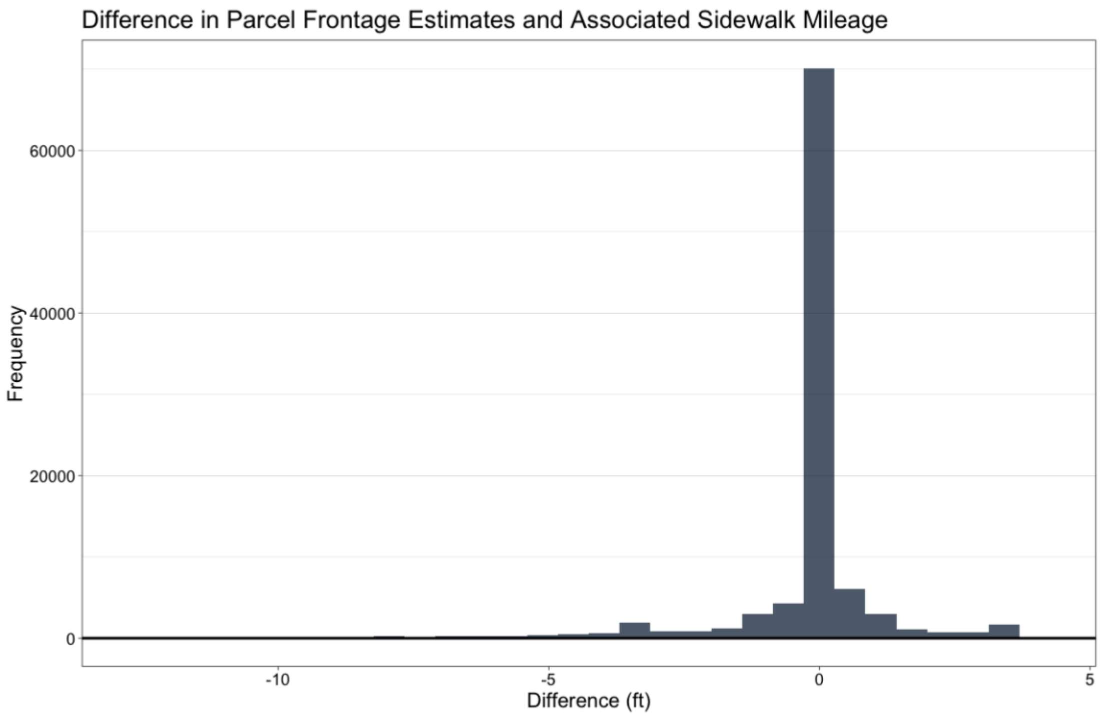
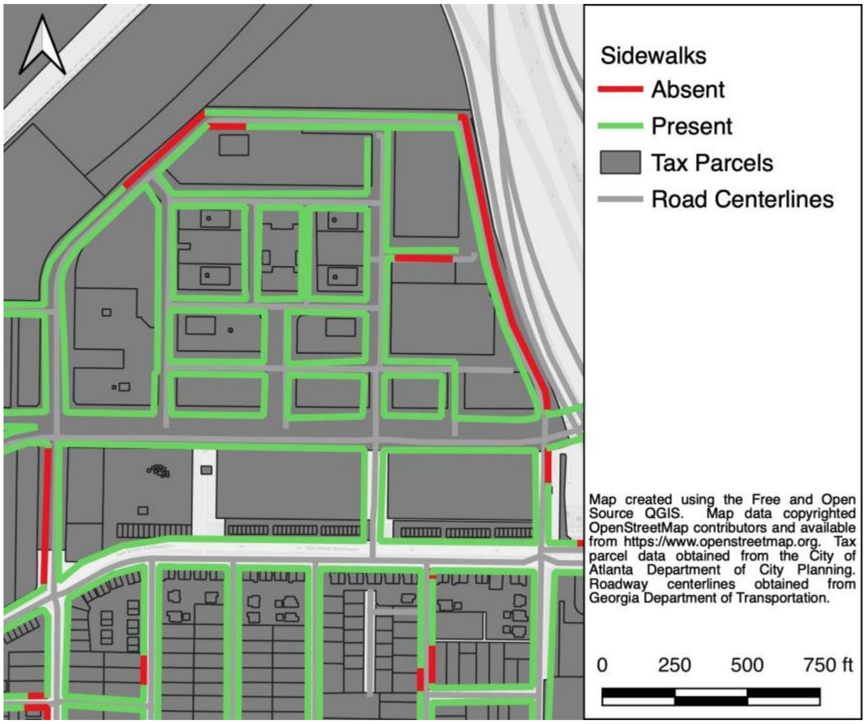


Figure 12. Parcel sidewalk length and parcel frontage differences



Map created using the Free and Open Source QGIS. Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org. Tax parcel data obtained from the City of Atlanta Department of City Planning. Roadway centerlines obtained from Georgia Department of Transportation.

Figure 13. Tax parcel covering roadway causing large difference in lengths

4.2.3 Residential Sidewalk-Parcel Association

Tax parcels with associated sidewalk links were filtered to analyze only residential tax parcels for which socioeconomic data were available for subsequent cost burden analysis. Of these 110,254 parcels, the mean difference was -3.8 feet; the median difference was 0.0 feet; and the range of values was -21,226.2 feet to 7,063.0 feet. Because the minimum and maximum values have been observed previously as outliers, the dataset was subsequently filtered for values between the 5th and 95th percentiles. This filtered residential parcel dataset, containing 99,228 parcels, had a mean length difference of -0.3 feet, a median of 0.0 feet, and a range of -12.7 feet to 3.7 feet. The distribution of these values is depicted in Figure 14.

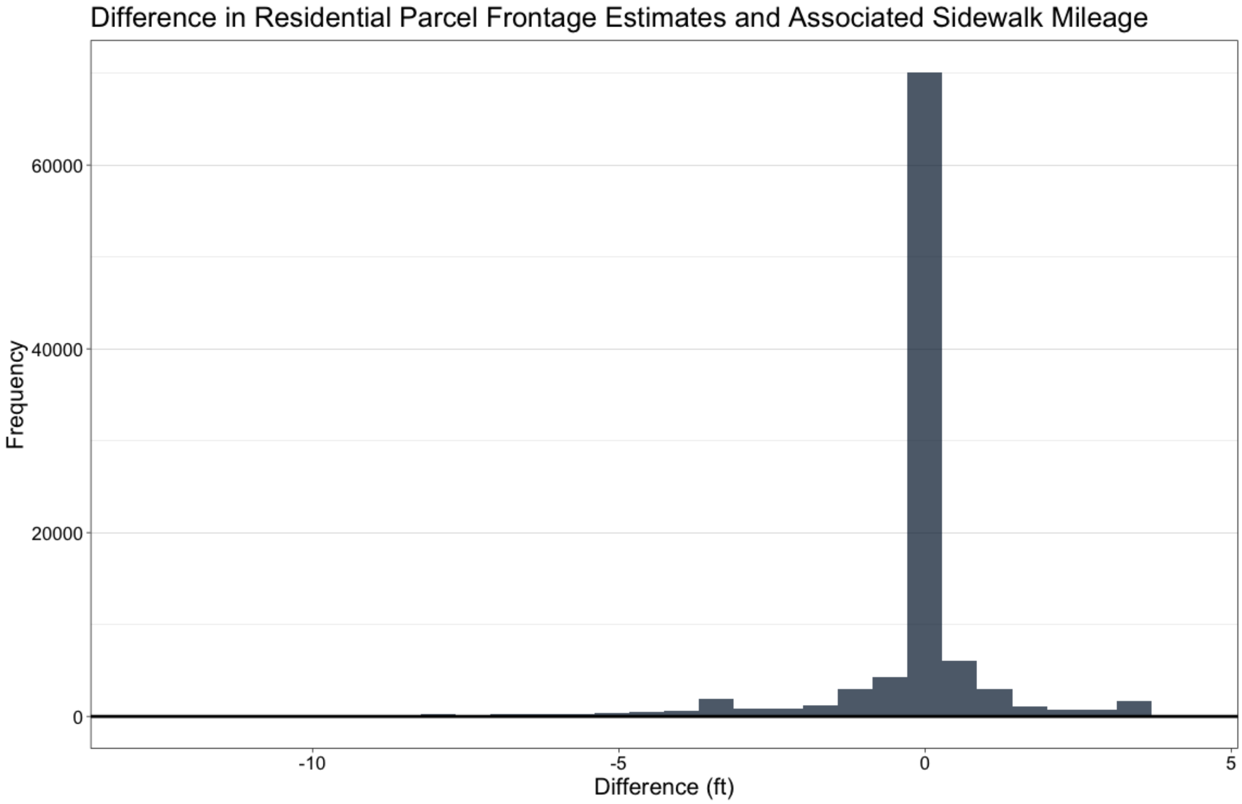


Figure 14. Difference in estimated residential parcel frontage and sidewalk mileage

4.2.4 Demographic Analysis

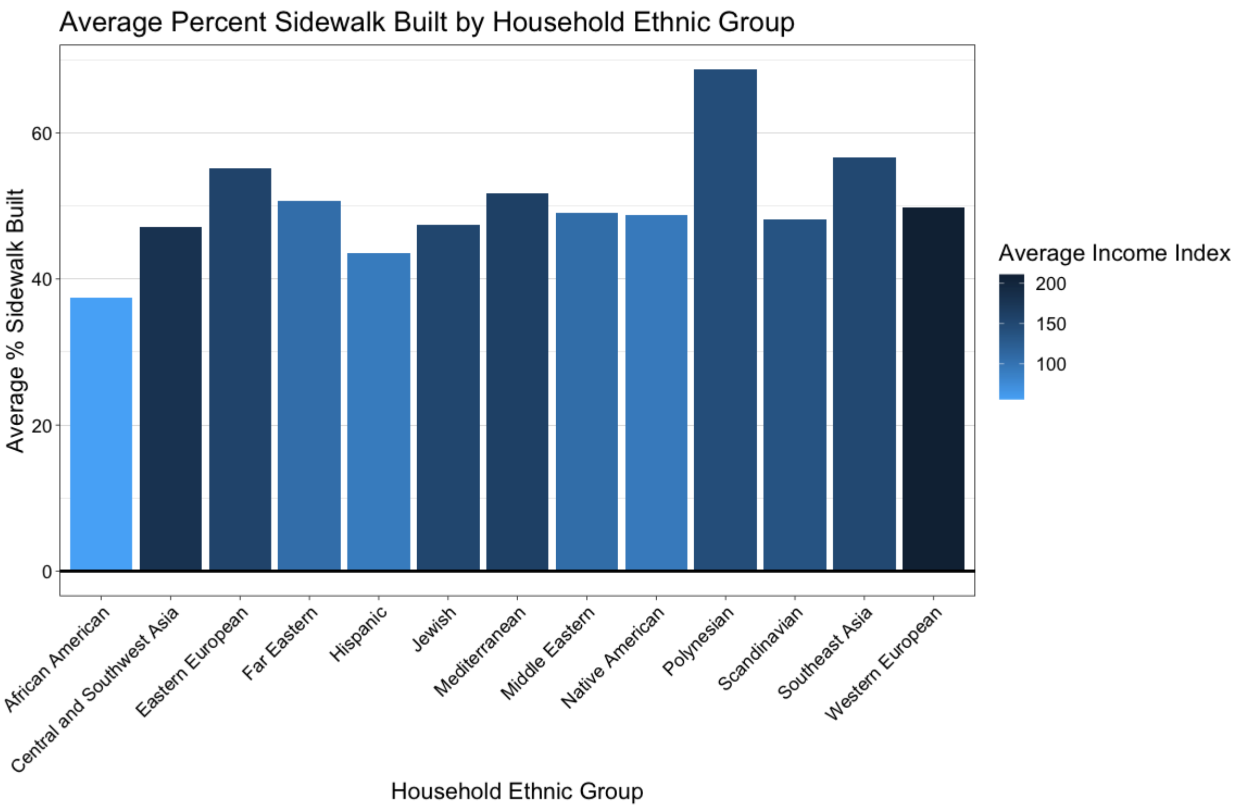
With sidewalk lengths associated with their adjacent parcels, demographic data were incorporated to understand the distribution of sidewalk infrastructure in various demographic groups throughout the City of Atlanta. Epsilon demographic data licensed for this study were used to identify the ethnic group of the first person listed in a residential parcel's owners in 2019. The Epsilon data also includes an average income index to compare the household's income to the average income for Fulton County. An average income index value of 100 indicates the household earns income equal to the county's average; index values lower and higher than 100 indicate household incomes and above the county average, respectively. For example, an income index value of 125 indicates that the household earns 125% of the average household income. Average income index by neighborhood is summarized in Appendix B.

To estimate the percentage of sidewalk built out for a specific parcel, the percentage was calculated by dividing the length of sidewalk intersected with the parcel overlay layer by the total frontage associated with the parcel (Equation 3).

$$\%\ \text{Sidewalk Built} = 100 \cdot \frac{\text{Parcel Built Sidewalk Length}}{\text{Total Parcel Frontage}}$$

Equation 3. Estimation of percent sidewalk built associated with parcel

The percentages of sidewalk built were then grouped by household ethnic group and averaged across all parcels within the ethnic group. Figure 15 depicts each ethnic group's average percentage present of total sidewalk length associated with a parcel using Sidewalk Flythrough data. The full ethnic group averages are reported in Table 9. The highest percentages of sidewalk built out on a parcel corresponded to Polynesian, Eastern European, and Far Eastern ethnic groups, while the lowest percentage corresponded to the African American ethnic group, with only 38.7% of potential sidewalk constructed. African Americans also have the lowest average income index in the City of Atlanta (where an average income index of 100 indicates that the household earns income equal to the county's average). These trends suggest that most of the cost burden to construct Atlanta's missing sidewalks would fall upon households with the least means to finance them.



Demographic data licensed from Epsilon.

Figure 15. Average percent sidewalk built by household demographic

Table 9. Average % sidewalk built by household ethnic group

Ethnic Group	Average Percent Sidewalk Present	Number of Households	% of Households
African American	38.7%	62,486	63%
Central and Southwest Asian	47.1%	51	0%
Eastern European	67.8%	1,929	1%
Far Eastern	67.8%	1,918	1%
Hispanic	45.9%	2,621	3%
Jewish	56.4%	3,476	3%
Mediterranean	59.2%	2,129	2%
Middle Eastern	50.6%	796	1%
Native American	48.8%	48	0%
Polynesian	58.7%	80	0%
Scandinavian	60.8%	1,514	1%
Southeast Asian	56.9%	617	1%
Western European	53.3%	27,791	24%

4.3 Discussion

4.3.1 Sidewalk-Parcel Association

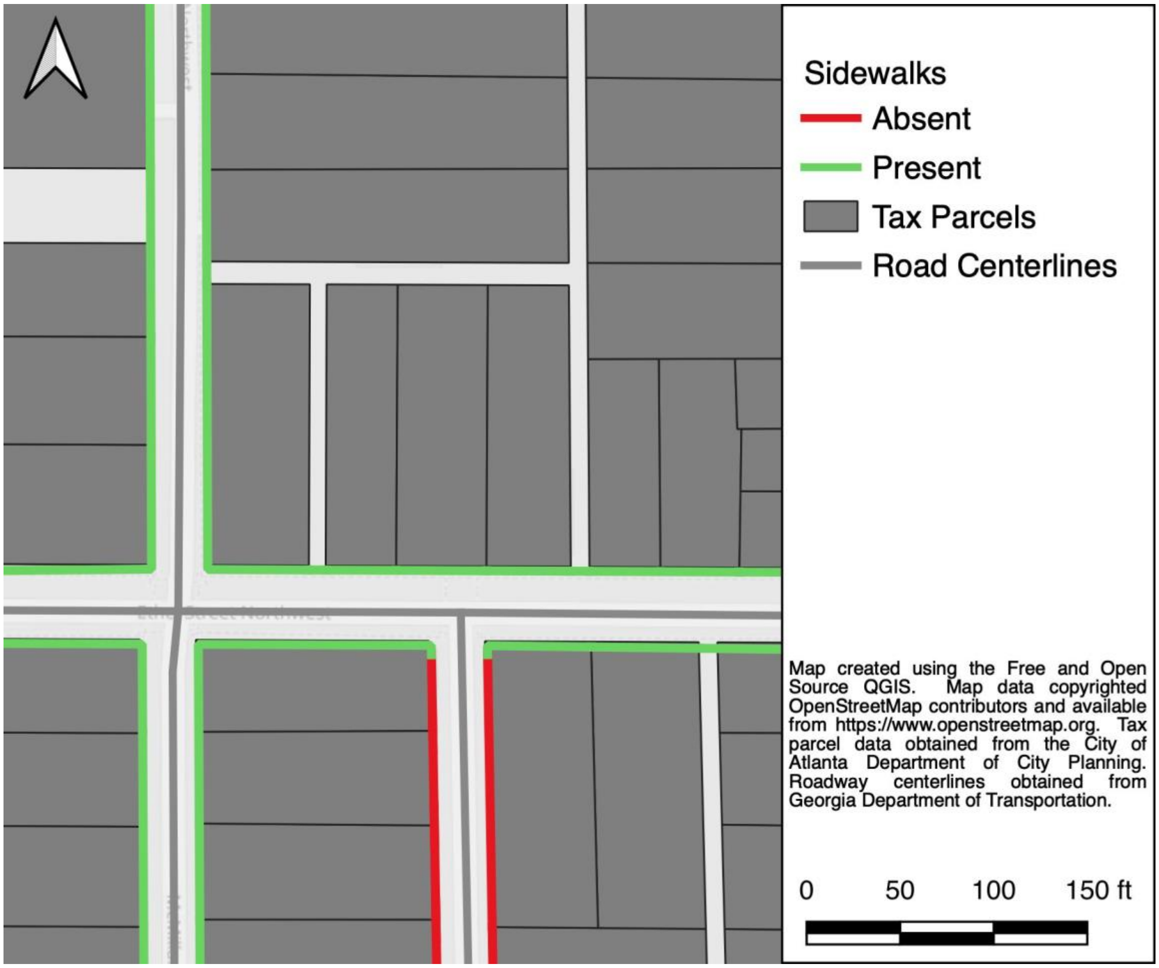
A total of approximately 2,500 miles of sidewalk links were associated with 111,553 parcels in the City of Atlanta. While this leaves approximately 200 miles of sidewalk links (~8%) unassociated with tax parcels, the outcome is not surprising. The QA/QC process required significant transformations of aggregate parcel input data to generate sidewalk links in locations that are not adjacent to the original tax parcels. A prime example of locations where such sidewalk links are found is an overpass for a limited access highway, such as the case seen in Figure 16. Limited access highways are not typically incorporated in the tax parcel cadastral mapping process and would therefore not be found anywhere close to a tax parcel.

Map created using the Free and Open Source QGIS. Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org. Tax parcel data obtained from the City of Atlanta Department of City Planning. Roadway centerlines obtained from Georgia Department of Transportation.

Figure 16. Example of sidewalk links not associated with tax parcels

While examples such those in Figure 16 are known and expected within the sidewalk network, there is evidence to suggest that a small portion of sidewalk links not associated with an adjacent tax parcel should have been associated with their adjacent tax parcel. These parcels fall into two categories: parcels with gaps between them, creating unassociated sidewalk links between them; and parcels that are set too far back from the public right-of-way for their frontage edges to be automatically identified.

The parcel gaps, as observed in Figure 17, were the root cause of many errors observed and corrected in the initial QA/QC process. The parcel gaps result in frontage buffer gaps and therefore result in short stretches of sidewalk that are not associated with any adjacent tax parcel. This phenomenon is most often observed in older neighborhoods where cadastral surveys left gaps between property owners for provision of public utilities or natural resources. While these sidewalk gaps are considered publicly owned for the sake of this analysis, an argument could be made to treat these segments as owned by the nearest property owners.



Map created using the Free and Open Source QGIS. Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org. Tax parcel data obtained from the City of Atlanta Department of City Planning. Roadway centerlines obtained from Georgia Department of Transportation.

Figure 17. Example of gaps between tax parcels

The second category of parcel geometries that result in gaps between parcels is those that are set too far back from the public right-of-way to have their frontage edges identified. These parcels range in land use classification from commercial to residential. Because these parcels fall outside the buffer range, their adjacent sidewalk links are erroneously un-associated with their respective parcels and inflate the estimate of un-associated sidewalk mileage. An example of these setback parcels can be seen in Figure 18.

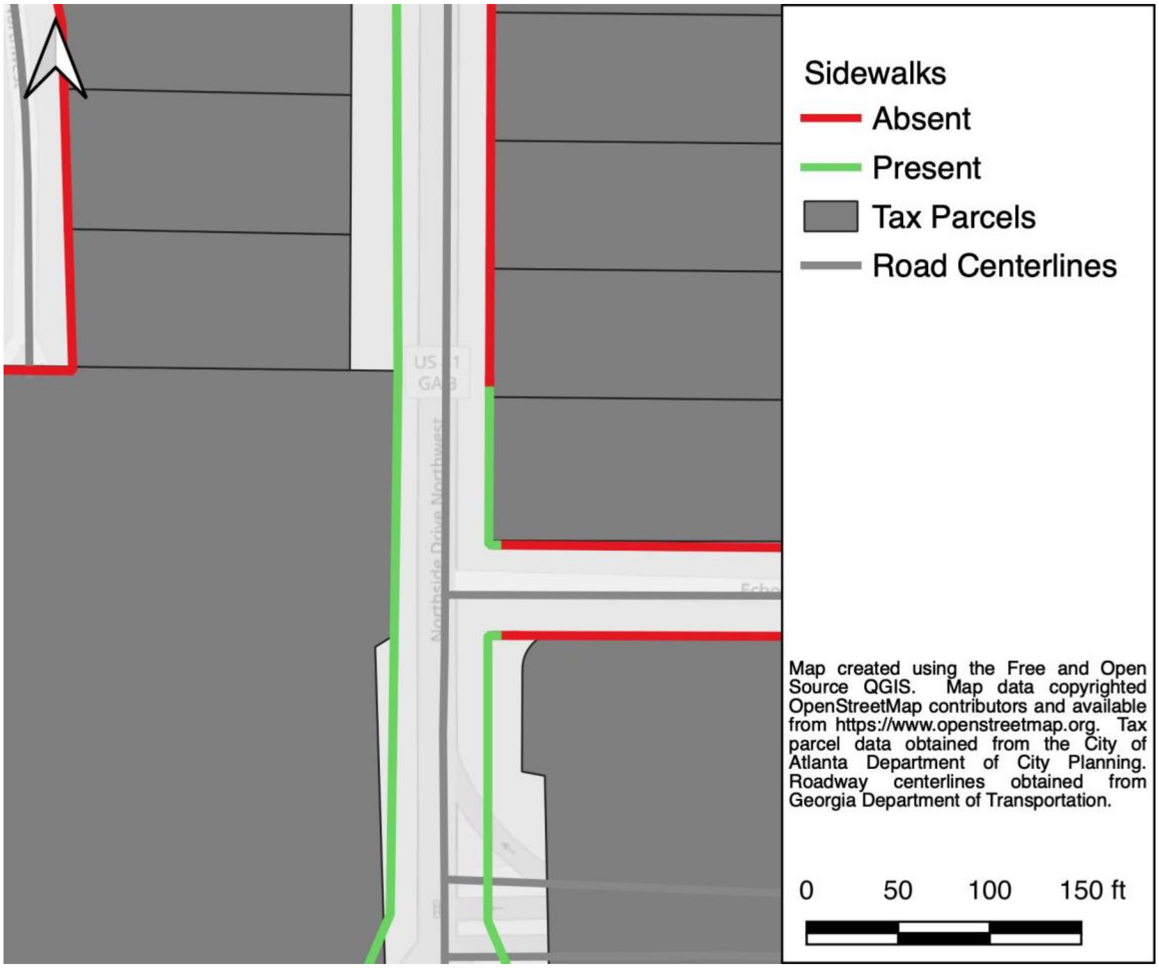
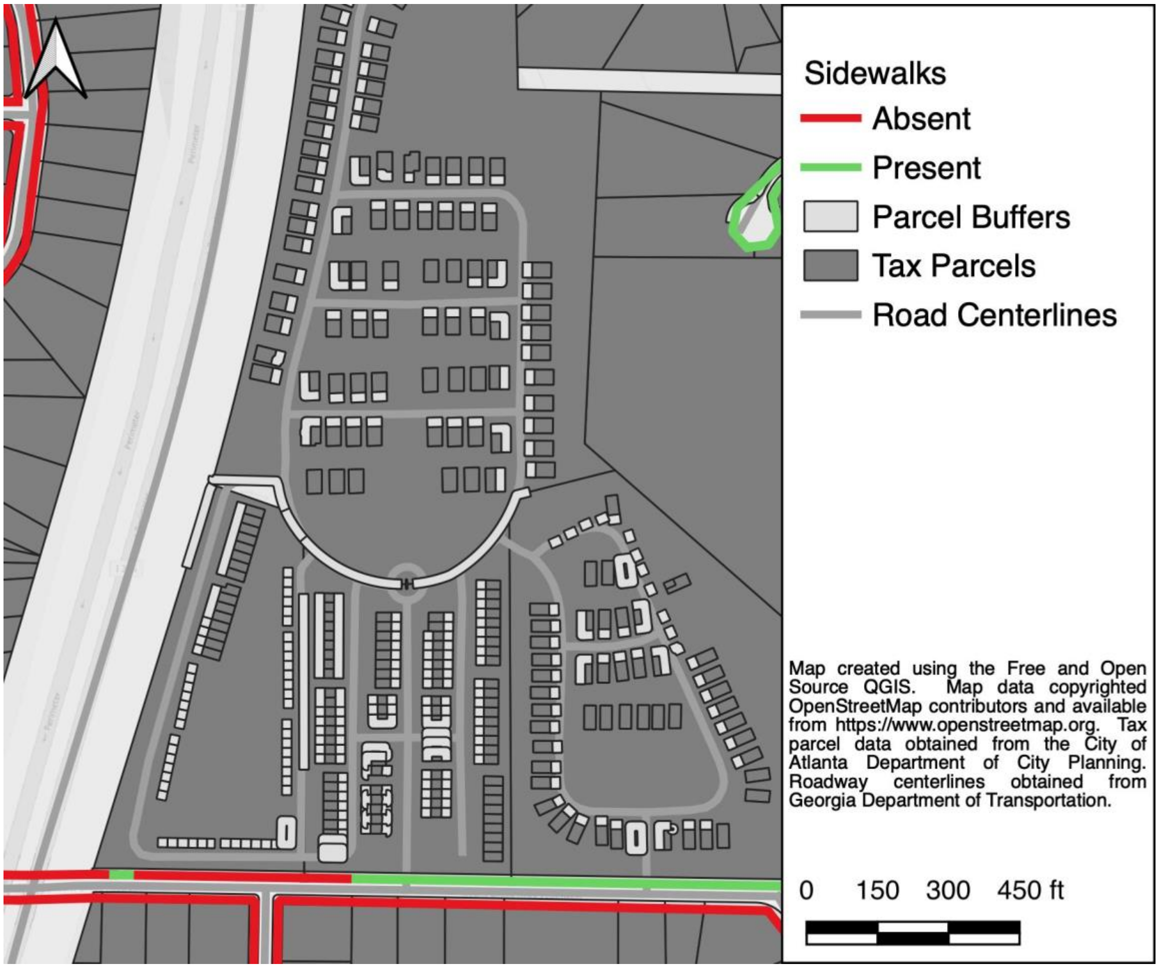


Figure 18. Examples of parcel setbacks on Northside Drive

4.3.2 Sidewalk Length and Frontage Length

The difference between sidewalk mileage and frontage length for 90% of all parcels with both estimates fall within a range of -12.7 to 3.7 feet, as seen in Figure 12. More than 80% of parcels are within plus or minus one foot. This range suggests sufficient accuracy for further analysis at the individual property level, but there are several edge cases throughout the network that require consideration.

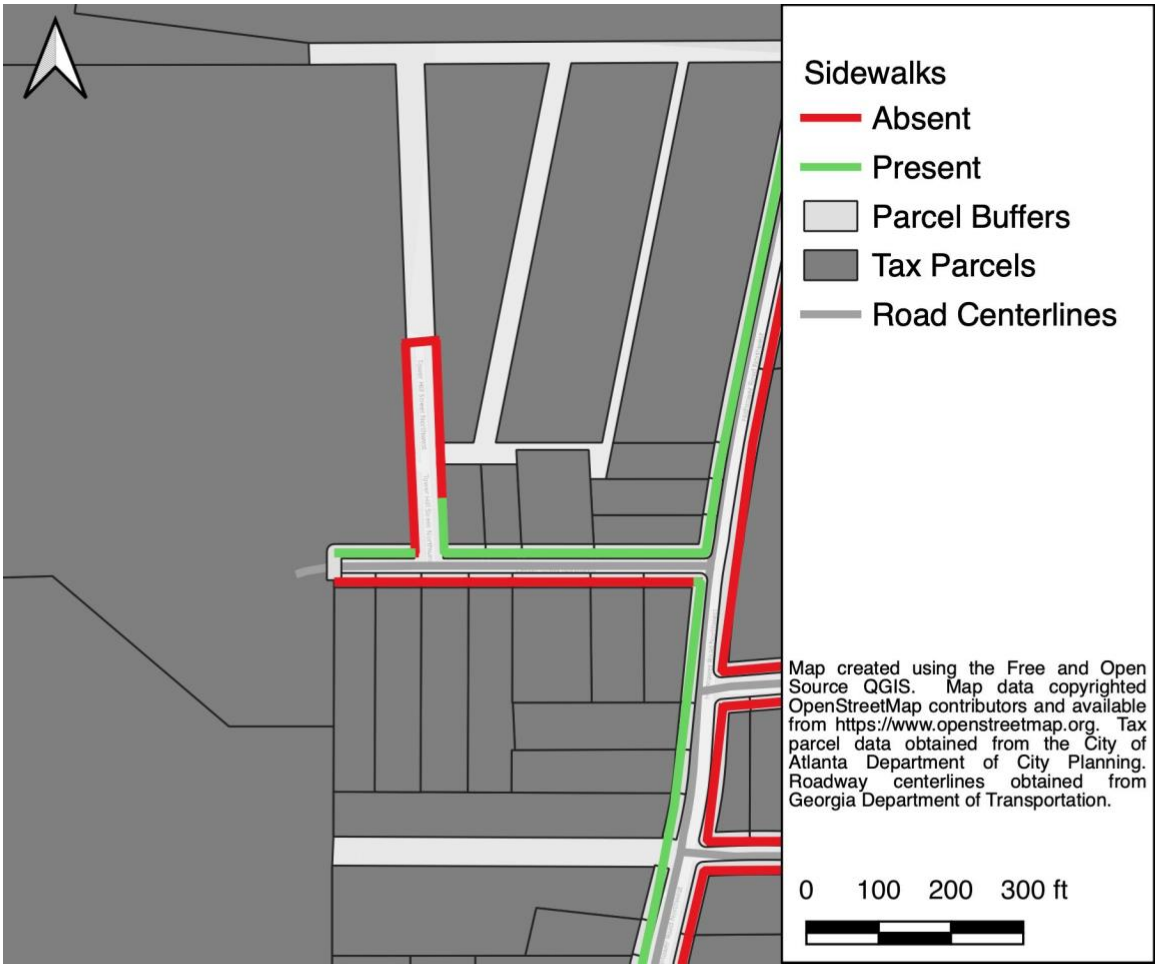
One such edge case is observed when public rights-of-way pass through private developments, such as subdivisions or larger-scale commercial centers. Although these roadways appeared private during network generation, and did not have Streetside imagery for sidewalk surface identification data collection, these roadways appear in the GDOT roadway database, resulting in frontage estimates with no sidewalk links to associate. An example of this is seen in Figure 19. While this edge case does not affect the accuracy of sidewalk-parcel association, the potential to miss roadways due to their concealment by the tax parcel database suggests that some parcels with frontages on public rights-of-way may be missed in this analysis.



Map created using the Free and Open Source QGIS. Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org. Tax parcel data obtained from the City of Atlanta Department of City Planning. Roadway centerlines obtained from Georgia Department of Transportation.

Figure 19. Example of private parcel frontages captured

An edge case that does have some significant impact on parcel frontage estimations occurs when GDOT road data do not extend to cover certain road segments for which sidewalk link data are present. An example of this phenomenon is seen in Figure 20. In this example, the sidewalk link segment following a dead-end road does not have corresponding data in the GDOT Roadway Characteristics dataset, resulting in underestimation of the frontage for adjacent parcels. This underestimation of parcel frontage leads to larger differences in parcel frontage length estimations and adjacent sidewalk length estimations.



Map created using the Free and Open Source QGIS. Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org. Tax parcel data obtained from the City of Atlanta Department of City Planning. Roadway centerlines obtained from Georgia Department of Transportation.

Figure 20. Roadway missing where sidewalk links present

A final edge case was observed in limited areas of the city where tax parcels and public roadway data were not spatially matched in their datasets. This geometric mismatch only appears to occur in relatively newer subdivisions in which the cadastral mapping was not updated to reflect the pattern of development. An example of this case can be seen in Figure 21. While this particular edge case could have been addressed in sidewalk network generation QA/QC, significant editing of the aggregate parcels to match the roadways would have resulted in highly inaccurate sidewalk-parcel associations when using the original tax parcel database to associate sidewalk links with adjacent parcels.

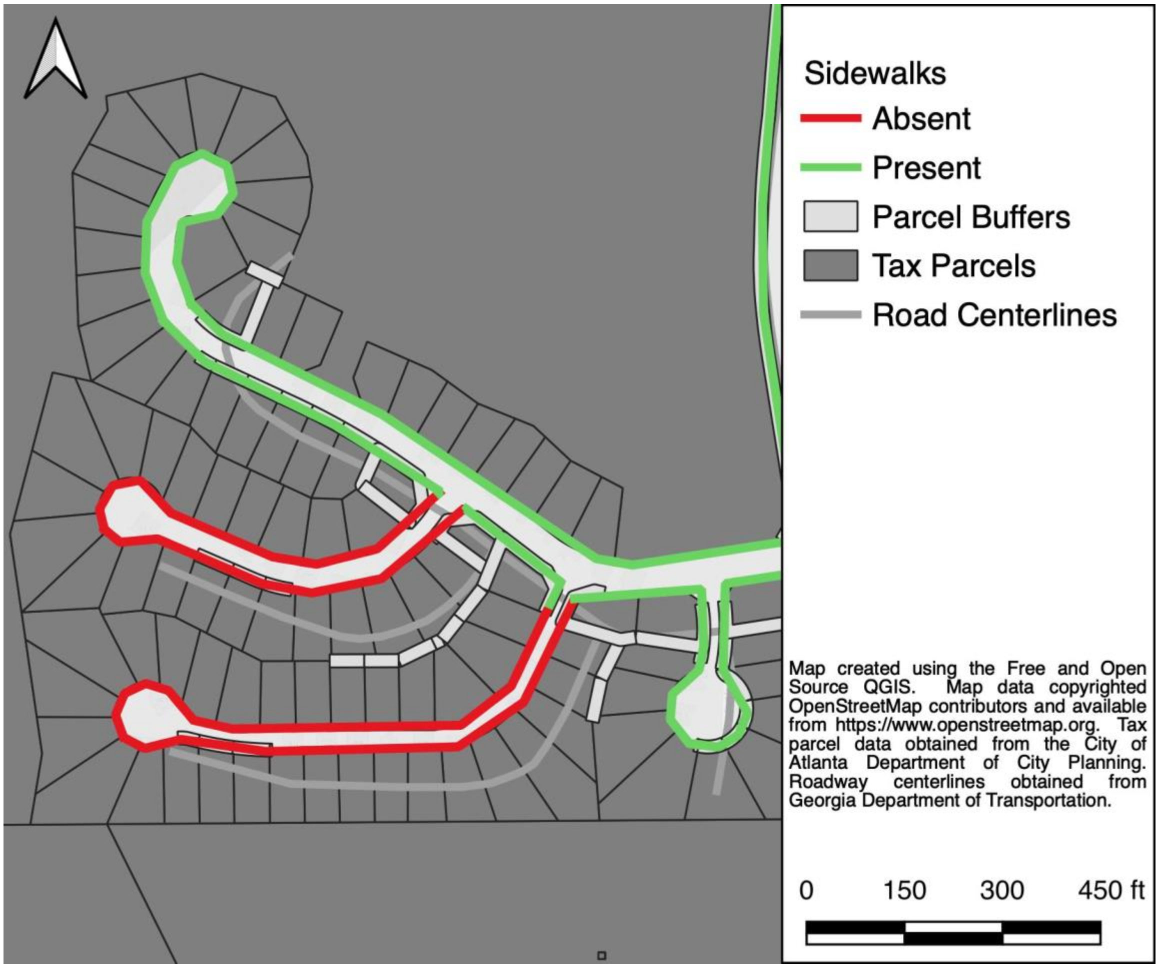


Figure 21. Cadastral mapping and roadway alignment mismatch

While these error cases may raise some concerns about the accuracy of the sidewalk-parcel association method, the vast majority of the parcel and sidewalk associations appear to have sufficient accuracy for subsequent life cycle cost estimations for infrastructure associated with residential properties and estimations of cost burdens performed later on in this report. The errors seen in this analysis largely affect commercial and industrial properties (although some residential properties are affected to a lesser extent). Parcels without estimated frontages do not skew subsequent cost burden analyses. Further expansion of this work should seek methods to address edge cases to mitigate their impact on sidewalk network cost analysis.

5. Asset Management Cost Estimation

As described in Chapter 4, the sidewalk network in prior studies was updated and confirmed during network QA/QC. Curb cuts and curb ramps were not revisited by the research team in preparing this report, so estimates from previous studies are used in the cost calculations for those assets. The sidewalk assets associated with residential properties (sidewalks and cur cuts) and the ramps associated with residential areas were quantified for use in asset cost analysis for residential sidewalk network construction and ongoing repair. This chapter first outlines the construction and repair cost assumptions used to quantify the current value of the existing assets, unconstructed assets, and major maintenance cycle costs for the study area. Then, economic analysis tools are applied to quantify the equivalent annual cost to maintain current assets and to construct and maintain missing assets over an 80-year analysis period.

5.1 Sidewalk infrastructure asset construction and repair cost assumptions

Each roadway crossing is assumed to require two pedestrian ramps. During QA/QC, curb ramp nodes were removed from the network or added to the network here appropriate, yielding minor changes in the number of curb ramp locations previously identified in the network. The number of constructed curb ramps is estimated by multiplying the percentage of the sidewalk network identified as constructed or existing by the total number of potential curb ramp assets estimated in previous studies. That is, if 50% of the sidewalks are constructed in a neighborhood, the team assumes that 50% of the pedestrian ramps are constructed.

Curb cut cost estimation is slightly more complicated than ramp asset calculations. To estimate the curb cut quantity in the City of Atlanta, differences in curb cut construction patterns between parcels of various land use types must be considered. A random sample of City of Atlanta parcels was used to identify the average number of curb cuts and average curb cut length across major land use categories (summarized in Table 10). Using the results from the sample of parcels in the previous study, average curb cut quantity and length are assigned to each parcel based on the land use category.

Table 10. Average curb cut quantity and length by parcel land use

Land Use	Average Curb Cuts per Parcel	Average Curb Cut Length (feet)
Commercial	1.3	28
Industrial	1.3	60
Utility	1.3	35
Residential	1	16
Other	1	10

Source: (Patel, 2019; Boyer, 2018)

Sidewalk mileage valuation and lifecycle cost estimation in this study is similar to previous studies by the GT Sidewalk Lab (Patel, 2019; Boyer, 2018). Effective sidewalk mileage (total sidewalk length in the analysis, less curb cut mileage) is used to estimate the total value of the

City of Atlanta's sidewalk assets. The average costs to construct sidewalk network assets (sidewalk mileage, ramps, and curb cuts) has been estimated in previous studies conducted by the Sidewalk Lab and are summarized in Table 11.

Table 11. Sidewalk network asset construction cost breakdown

Sidewalk Asset	Estimated Construction Cost
Pedestrian ramp	$1,200 each
Curb cut	$140/square yard
Sidewalk link	$60/square yard

Source: (Boyer 2018)

Previous sidewalk network asset inventories and assessments in the City of Atlanta estimated the percentages of network assets requiring repair and the associated costs by surveying sidewalk infrastructure along four major corridors in the city (Patel, 2019; Boyer, et al., 2019a, 2019b, 2019c, 2019d). The percentages of network assets that were identified as being in need of repair are used to estimate the quantity of curb ramps, curb cuts, and sidewalk surface defects in need of repair network-wide. Repair percentages and costs for curb ramps, curb cuts, and sidewalk surfaces are summarized in Table 12. For the purposes of the analyses that follow, the team will assume that major repairs need to be performed for this share of the assets every 20 years, starting in year 0 and ending before assets are demolished and rebuilt.

Table 12. Sidewalk network asset major repair cost breakdown

Pedestrian Ramps	
Percentage of Ramps Requiring Repair	21%
Repair Cost Per Defective Ramp	$686
Curb Cuts	
Percentage of Curb Cuts Requiring Repair	13%
Repair Cost Per Defective Curb Cut	$1,196
Sidewalks	
Sidewalk Surface Defects/Mile Requiring Repair	57
Cost Per Sidewalk Surface Defect	$242

Source: (Patel, 2019; Boyer, 2018)

Sidewalk surface defects per mile were used to estimate the cost of repairing sidewalk surfaces per mile using Equation 4.

$$\text{Sidewalk Repair Cost per Mile} = \text{Sidewalk Surface}\frac{\text{Defects}}{\text{Mile}} \times \text{Repair Cost per Defect}$$

Equation 4. Sidewalk surface defect repair cost formula

Because curb cut number and length are estimated by land use classification, curb cut estimates are generated by applying the average number of curb cuts and average length in Table 11 to frontage estimates for parcels matching the tabulated land use classifications. Because total curb cut length and effective sidewalk length can be calculated for each parcel from frontage estimates, the costs for curb cuts and sidewalk links are first calculated at the individual parcel-level before aggregating to the city-level. Total sidewalk length not associated with individual parcels is used to calculate the additional value in sidewalk links not associated with property owners.

Finally, to estimate replacement costs, several estimates from previous studies were used to calculate the replacement costs in Year 80. Table 13 shows the replacement cost per square yard for pedestrian ramps, curb cuts, and sidewalks to be used in this analysis. Replacement costs constitute both the cost to demolish the previous asset and construct the new asset. Sidewalk replacement costs are taken from Boyer (2019). Ramp construction costs range from $800 to $2,000 (average new construction is $1,200 per ramp. A conservative estimate of $1,200 per ramp is used for replacement to account for demolition and debris removal. Curb cut replacement costs were not available in Boyer (2019), so the $140/square yard was increased to $180/square yard to account for demolition and debris removal.

Table 13. Sidewalk asset demolition and reconstruction cost by element

Sidewalk replacement cost	$110.00/square yard
Pedestrian ramp replacement cost	$1,600/replacement
Curb cut replacement cost	$180.00/square yard

Source: Boyer, 2018

5.2 Study area sidewalk infrastructure asset construction and repair costs

The lifecycle cost estimation presented in this report is limited to the subset of the Atlanta sidewalk network associated with residential parcels for which information on assessed property values, income, and household ethnicity are available. The assumptions outlined in Section 5.1 were used to quantify sidewalk asset construction costs periodic major maintenance costs for a lifecycle analysis. In the analyses that follow, the residential subset of the City of Atlanta potential sidewalk network is approximately 2,536 effective miles (curb cut mileage is tracked separately). Of the prototype network, 1,183 miles of sidewalk are currently present and 1,354 miles need to be constructed to complete the network. The existing inventory of residential sidewalk assets and the inventory that needs to be constructed to complete the network is described in Table 14. The current economic value of existing assets and the cost to construct new assets are based upon the cost per square yard for sidewalks and curb cuts, and the cost per unit for ramps. Sidewalks are assumed to be 5' feet wide and 4" inches thick and curb cuts are assumed to be 8' deep and 4" thick (Patel, 2019).

Table 14. Summary of current and missing residential sidewalk assets

Asset	Inventory	Cost/Value
Existing residential sidewalk assets	1,183 miles	$208,208,000.00
Missing residential sidewalk assets*	1,354 miles	$238,304,000.00
Existing pedestrian ramp assets	25,156 ramps	$30,187,200.00
Missing pedestrian ramp assets*	28,856 ramps	$34,627,200.00
Existing curb cut assets	102.4 miles	$67,283,626.67
Missing curb cut assets*	120.2 miles	$78,979,413.33
Subtotal of current asset value		$305,678,826.67
Subtotal of missing asset cost		$351,910,613.33
Total value (current + missing assets)		$657,589,440.00

* Requires new construction

5.3 Equivalent Annual Cost Methodology

The total cost of ownership (TCO) for the City of Atlanta's sidewalk network was calculated in previous studies without factoring existing assets into the valuation (Patel, 2019), as if all infrastructure was constructed or re-constructed in Year 0. With sidewalk identification data available for the entire sidewalk network of the City of Atlanta, cost estimates in this analysis now account for the existence of previously constructed assets. Only new sidewalks require initial construction costs in Year 0. However, current sidewalks network assets do require major repairs and all assets will require ongoing major repair investment. Although sidewalk asset repairs actually take place throughout the lifespan of the asset, the analyses will assume a major repair infusion every 20 years (starting in Year 0, considering the degraded condition of current assets). Final demolition and replacement of all assets is assumed to occur at the end of an 80-year lifespan (i.e., all assets are demolished and reconstructed in Year 80). The timeline for asset management costs is summarized in Figure 22 for missing assets that must be constructed and for existing assets that only require major maintenance and final reconstruction in Year 80. The notable difference between existing and missing assets is the absence of new construction costs in Year 0 for existing assets and no maintenance in Year 0 for new construction of missing assets.

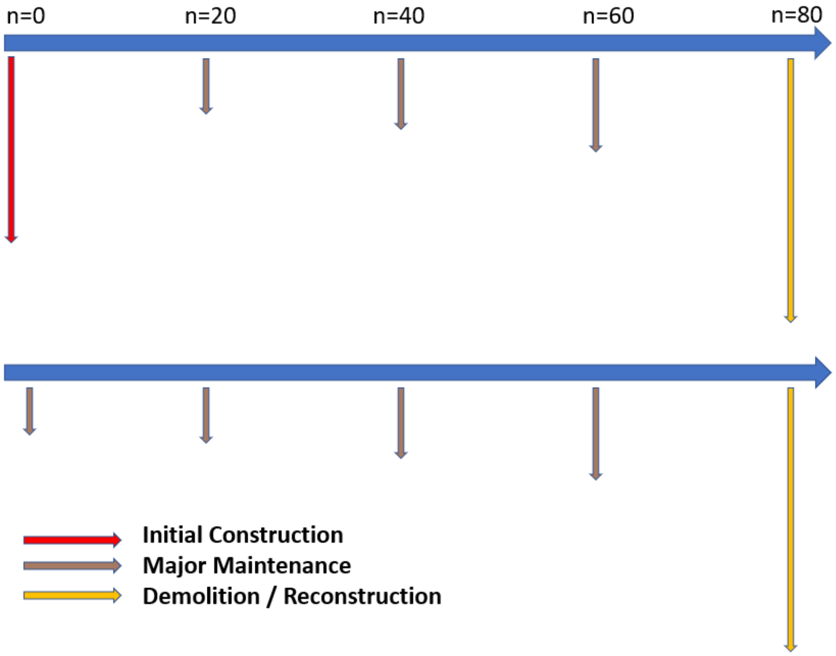


Figure 22. Investment infusions over time for new and existing network assets

Three sidewalk asset investment scenarios are explored in this Chapter, where sidewalk assets are assumed to have an 80-year lifespan before complete replacement is warranted:

1. Investment Scenario 1 - Lifecycle cost estimates derive from ongoing maintenance of existing sidewalk network assets. This scenario does not include construction of missing sidewalk mileage or other assets. Maintenance activities for existing assets follow the cost schedule for existing assets in Figure 22, with major repairs conducted in Years 20, 40, and 60. In Year 80, all network assets are demolished and reconstructed.
2. Investment Scenario 2 - Lifecycle cost estimates include the same costs outlined in Scenario 1 for existing assets, plus the construction of missing network assets in Year 0. Maintenance activities for all assets now follow the cost schedule for existing assets in Figure 22, with major repairs conducted in Years 20, 40, and 60. In Year 80, all network assets are demolished and reconstructed.
3. Investment Scenario 3 - Lifecycle cost estimates replicate the activities in Scenario 2 but limit replacement activities in Year 80 to 40% of the network's assets. This assumes that periodic major repairs extend the useful life of most assets beyond 80-years.

Standard engineering economics equations are employed to convert future cost estimates to Net Present Values (NPVs) using a discount rate of 3.5% (Bernhard, 1992). The total NPV in each investment scenario is then converted to an Equivalent Annual Cost (EAC) to estimate the annualized cost over the 80-year management period. An EAC is necessary to see how annualized sidewalk network management costs fit within municipal annual budgets and to assess the viability of several funding options.

5.4 Equivalent Annual Cost Input Data

Each of the three investment scenarios involve different assumptions related to new sidewalk asset construction (sidewalks, ramps, and curb cuts) and different assumptions related to major repair and maintenance activity and percent of the infrastructure that will be demolished and replaced in Year 80 (as outlined in the previous section). Table 15 summarizes the capital construction costs in Year 0, major maintenance infusion costs (every 20 years), and the demolition and reconstruction costs for the entire system in Year 80. The table shows individual rows for existing assets, newly constructed assets, by asset type (sidewalk, ramp, and curb cut). Table 15 incorporates the investment values defined in Table 14, calculated maintenance infusions from earlier maintenance replacement assumptions presented in Section 5.1 (sidewalk miles, curb cuts, and ramps with defects multiplied by cost of repair), and uses higher rates for demolition/reconstruction (Table 13). The values in Table 15 are then used to summarize the net present value of each infrastructure investment scenario, which can then be converted to a uniform annual cost for funding scenario analyses where property tax millage rate increases might be proposed to cover some or all of these annual costs.

Table 15. Cost assumptions employed in economic analyses

Capital Construction	Cost/Value
Existing residential sidewalks*	$208,208,000.00
Existing pedestrian ramps*	$30,187,200.00
Existing curb cut*	$67,283,626.67
New residential sidewalks	$238,304,000.00
New pedestrian ramps	$34,627,200.00
New curb cuts	$78,979,413.33
20-year Major Repair Costs	
Existing residential sidewalks	$16,318,302.00
Existing pedestrian ramps	$3,623,973.36
Existing curb ramps	$5,253,980.16
New residential sidewalks	$18,677,076.00
New pedestrian ramps	$4,156,995.36
New curb cuts	$6,167,269.68
80-Year 100% Demolition/Replacement Costs	
Existing residential sidewalks	$381,714,666.67
Existing pedestrian ramps	$40,249,600.00
Existing curb ramps	$86,507,520.00
New residential sidewalks	$436,890,666.67
New pedestrian ramps	$46,169,600.00
New curb cuts	$101,544,960.00

* Analyses will assume that these assets are already in place (but require major repair)

5.5 Investment Scenario Results

The total cost of ownership for the residential subset of 2,536 effective sidewalk miles (1,183 existing miles and 1,354 new miles) of the City of Atlanta sidewalk network over an 80-year management period was calculated using post-QA/QC sidewalk network data with sidewalk identification information obtained from the Sidewalk Flythrough application. Lifecycle costs were calculated assuming an 80-year lifespan of sidewalk infrastructure with major repairs and maintenances costs allocated in 20-year tranches as outlined in Figure 22. All future cost components were subjected to a 3.5% discount rate. Three asset investment scenarios were pursued for sidewalk network construction and maintenance (Table 16).

Table 16. Summary of equivalent annual costs to own and maintain sidewalk network

Investment Scenario	Description	Net Present Value	Equivalent Annual Cost
1	Maintain existing assets Major maintenance every 20 years Reconstruct every 80 years	$534 million	$7,489,034.56
2	Maintain assets, add missing assets Major maintenance every 20 years Reconstruct every 80 years	$1,633 million	$22,912,972.03
3	Maintain assets, add missing assets Major maintenance every 20 years Reconstruct 40% every 80 years	$843 million	$11,834,688.48

5.6 Discussion

Investment Scenario 3 is probably the most realistic for Atlanta. b. The public continues to express a desire to build out sidewalk networks in underserved areas, and proper inspection and maintenance will ensure that most of the system does not need to be completely reconstructed every 80 years. All cities should implement an inventory and inspection program. For the purposes of this report, program funding implementation in Chapter 6 will assume that Investment Scenario 3 is implemented.

The investment cost analyses rely on a number of assumptions that can be reasonably debated. The 80-year lifespan and the 40% replacement assumption in Year 80 are the most influential variables. The percentage of assets requiring major maintenance and replacement every 20 years (Table 12) were estimated from the analysis of four major corridors in the City of Atlanta. The asset conditions along those corridors may not accurately represent the condition of sidewalk infrastructure assets in other contexts, such as along minor residential streets or along more heavily trafficked freight corridors (or other roadway and land use contexts). Improved demolition/reconstruction costs are also needed. Nevertheless, if the City were to establish a sidewalk asset trust fund, revenue collection could be adjusted over time so that the correct amount of funding is collected over time (based upon annual inspection and maintenance program engineering analyses).

6. Assessment of Funding Options

One traditional method of public funding sidewalk construction and repairs is through the collection of property taxes. In this manner, revenue collection for sidewalk network construction and repair is distributed throughout the city, in proportion to each property's assessed value (akin to how many other public services are funded). The second traditional method of public funding sidewalk construction and repairs is by assigning responsibility for the expenses to each adjacent property owner, as is currently the policy in Atlanta, GA. In this funding system, the owner is responsible for inspecting, maintaining, and repairing the assets. Some cities take a hybrid approach to funding, where sidewalk repairs are split 50/50 or 70/30 between the property owner and the city.

The distribution of costs to each individual property owner therefore depend on the annual cost associated with each asset for Investment Scenario 3 (described in Chapter 5) and the amount of that asset cost that is assigned directly to the property owner and the amount of that cost is recovered city-wide through an increase in the property tax millage rate. The resulting shares of the cost (percentage directly assigned and percent paid via property taxes) at each individual property depends upon the amount of assets present, the asset costs that are directly assigned, and the property value to which the millage rate will be applied. Hence, assessing the allocation of sidewalk infrastructure costs property-by-property is complicated and requires quantification of assets adjacent to each property and individual assessed property values. Neither of these factors is uniformly distributed throughout the City (and as we will see later, the distributions across incomes and ethnicity groups is highly variable).

The following sections explore the estimation of life-cycle costs for the sidewalk network of the City of Atlanta and assess funding options, including exploration of cost-share scenarios between the City of Atlanta and residential property owners. The analyses in this report are restricted to the subset of sidewalk assets adjacent to residential properties; however, a similar approach could be taken for commercial and other land uses.

6.1 Methodology

A traditional funding source for most annual municipality expenditures is property tax collected from property owners. Increasing annual property tax rates would allow for continuous construction, repair, and life cycle replacement of sidewalk infrastructure. These public costs are distributed among all the properties in the City of Atlanta, based on the assessed value of the property. However, not all costs associated with sidewalk network infrastructure necessarily benefit the public. For example, driveway curb cuts are a private asset that allow vehicles to access a property and therefore primarily benefit the property owner. Because this is a contested matter of public policy, a portion of this analysis will reflect the unsettled dispute over who should bear the costs of certain assets in the sidewalk network.

6.1.1 Funding Scenarios

Several funding scenarios are formulated to explore how the total costs of annual pedestrian infrastructure asset management accrue to each individual property depending upon what costs are collected via property taxes and what costs are assigned directly to the property owner. In each scenario, annual sidewalk infrastructure asset costs calculated in the previous chapter are allocated in part to the City of Atlanta (and then to property owners via property tax collection), and in part directly to the adjacent property owner. Four scenarios are assessed.

Scenario 1 assumes that all annualized costs of owning and maintaining the City of Atlanta's sidewalk network are borne by the city and paid via property tax increase. Scenario 2 assumes that the City of Atlanta will shoulder the costs of owning and maintaining the sidewalk mileage and curb ramps; property owners, however, will pay the direct annual costs to own and maintain their curb cuts. Scenario 3 assumes the same cost allocations for curb ramps and curb cuts as Scenario 2. However, Scenario 3 then assumes that 50% of the costs to own and maintain sidewalk mileage are allocated to the adjacent property owner. Finally, Scenario 4 assumes that 100% of the annual costs to own and maintain the sidewalks within the network are allocated directly to the adjacent property owner (only pedestrian ramps would be publicly funded). The scenarios are summarized in Table 17 and explored in the analyses that follow.

Table 17. Sidewalk infrastructure funding scenario comparisons

Cost Item	Percent Allocation to City	Percent Allocation to Property Owner
Sidewalk Construction and Maintenance		
Scenario 1	100%	0%
Scenario 2	100%	0%
Scenario 3	50%	50%
Scenario 4	0%	100%
Ramp Construction and Maintenance		
Scenario 1	100%	0%
Scenario 2	100%	0%
Scenario 3	100%	0%
Scenario 4	100%	0%
Curb Cut Construction and Maintenance		
Scenario 1	100%	0%
Scenario 2	0%	100%
Scenario 3	0%	100%
Scenario 4	0%	100%

6.1.2 Household Annual Cost Burden

The analyses that follow use the subset of costs associated with residential properties and their adjacent sidewalks in the City of Atlanta to examine how costs are distributed across neighborhoods. The annual cost allocated to each residential property is then linked with the demographic characteristics by spatially joining the residential parcels with household demographic data licensed from Epsilon. To calculate the tax burden of sustainable sidewalk management on residential property owners in each scenario, the previously calculated annual costs are applied using the City of Atlanta's property tax formula in the sections that follow.

For the purposes of this study, the millage rate formula was recreated to analyze the impact of raising property tax on residential households. The millage rate is the dollar amount of tax liability per $1000 assessed value (in Atlanta, assessed property value is 40% of the fair market value). The Georgia Homestead Act allows a $30,000 exemption from the assessed property value for residents under 65 and $40,000 for residents above 65 who file for an exemption and meet certain income criteria (Pitts, et al., 2021). However, the Fulton County Assessor's Office would not provide the specific breakdown as to which properties had filed for a homestead exemption, nor which properties qualified for the additional senior citizen exemption. For the purposes of this analysis, all properties are assumed to qualify only for the standard homestead exemption of $30,000. The formula used to calculate Atlanta property tax is:

$$\text{Atlanta Property Tax} = [(0.4 \cdot \text{Fair Market Value}) - \text{Exemptions}] \cdot \text{Mill Rate}$$

Equation 5. Atlanta property tax formula

For example, a household assessed at $100,000 (fair market value of $250,000) would receive a homestead exemption of $30,000, reducing the assessed value to $70,000. The assessed value would then be multiplied by the FY18 millage rate of 8.84/$1000 and return an annual property tax of $618.80 (Beard, 2017).

The analyses in the next section examine the property tax rate increase required to implement the four scenarios. Because millage rates are multiplied by assessed property values (after deducting the homestead exemptions), calculating the millage rate increase for each funding scenario requires an estimate of the tax revenue needed to implement the scenario and the sum of assessed property values from all parcels within each scenario subset. The sum of assessed residential property values (after the homestead exemption has been subtracted) is approximately $10.01 billion dollars. The following formula is used to calculate the millage increase for any scenario given the required revenue and sum of assessed property values for each scenario (Patel, 2019):

$$Mill\ Rate = 1000 \times \left(\frac{R}{\sum_i V_{assessed,i}}\right)$$

Where:

R = Needed revenue ($)

$V_{assessed,i}$ = Assessed property value ($)

6.2 Results

6.2.1 Millage Rate Increases

The equivalent annual cost to own and maintain Atlanta's sidewalk network infrastructure was allocated in varying proportions to the municipal budget and to individual households consistent with the four policy options presented earlier (Table 17). The cost burdens of sidewalk network ownership for the City of Atlanta from each scenario were tabulated and used to calculate the necessary millage rate increase to fund the cost of sidewalk network ownership (Table 18), along with the remaining cost burden that is carried by the property owners. Scenario 1 (100% of sidewalks paid via property taxes) resulted in the highest millage rate increase of 1.182, whereas Scenario 4 (private property owner pays for everything except pedestrian ramps) resulted in the lowest millage increase of 0.108.

Table 18. Scenario cost allocation to the City of Atlanta and required millage increase

	Allocated Annual Cost Burden	Required Millage Increase	Allocated to Property Owners	Total Allocated Cost
Scenario 1	$11,834,688.48	1.182	$0.00	$11,834,688.48
Scenario 2	$9,510,497.78	0.950	$2,324,190.70	$11,834,688.48
Scenario 3	$5,295,355.05	0.529	$6,539,333.43	$11,834,688.48
Scenario 4	$1,080,212.31	0.108	$10,754,476.17	$11,834,688.48

6.2.2 Cost Burden by Ethnicity

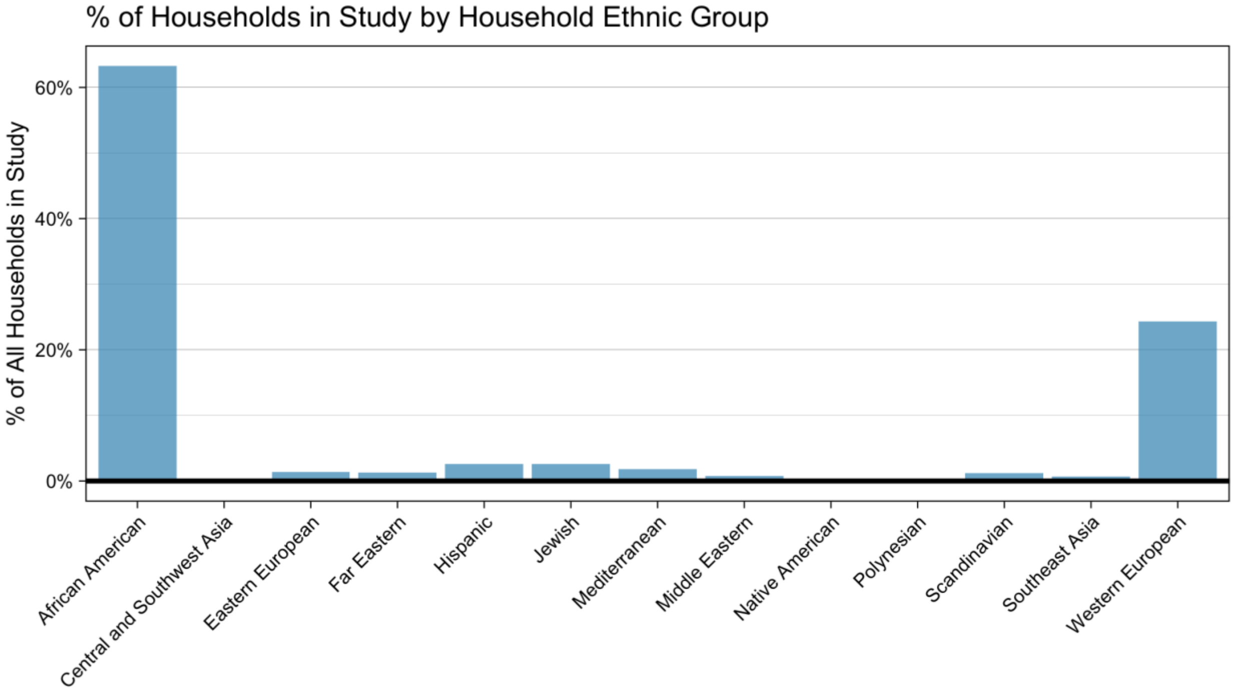
After estimating the millage increase for each scenario, the annual cost burden for each household in the Epsilon demographics data was calculating using each property owner's individualized increased tax burden and the millage rates from Table 18 (the standard homestead exemption was subtracted from the assessed value). The household annual cost burdens for owning and maintaining sidewalk infrastructure adjacent to the household's property in each scenario were also calculated (consistent with the cost share proportions presented in Table 15 and Table 17). The total annual cost burdens under each scenario (tax increase plus adjacent private sidewalk cost) were averaged across household ethnic group and summarized in Table 19 for each scenario.

Table 19. Total sidewalk cost allocation per scenario by household ethnic group

Household Ethnic Group	% of Households	Mean Frontage (feet)	Mean % Sidewalk Now Present	Mean Income Index	Mean Assessed Value*	Mean Annual Sidewalk Cost per Household S1	S2	S3	S4
African American	63%	93.7	37%	56	$30,812	$36	$53	$83	$113
Central and Southwest Asian	0%	120.3	47%	181	$234,982	$278	$249	$203	$156
Eastern European	1%	92.9	55%	157	$173,466	$205	$191	$157	$124
Far Eastern	1%	100.4	51%	106	$134,318	$159	$152	$139	$127
Hispanic	3%	93.5	44%	92	$97,927	$116	$118	$119	$120
Jewish	3%	106.8	48%	152	$181,649	$215	$198	$168	$138
Mediterranean	2%	97.9	51%	161	$189,541	$224	$205	$169	$132
Middle Eastern	1%	100.4	49%	107	$134,584	$159	$152	$140	$128
Native American	0%	81.8	49%	94	$132,401	$156	$151	$132	$113
Polynesian	0%	87.1	69%	145	$152,943	$181	$170	$142	$114
Scandinavian	1%	100.9	48%	137	$146,897	$174	$164	$146	$128
Southeast Asian	1%	99.9	56%	151	$201,181	$238	$216	$175	$133
Western European	24%	112.6	50%	211	$273,796	$324	$285	$219	$153

* After deducting the $30,000 homestead exemption (assessed value is not the same as the fair market value or appraised value, see Equation 5)

The number of households in each ethnic group as a percentage of all households within the study's subset is illustrated in Figure 23. Households identifying as African American constitute 63% of all households within the residential sidewalk network dataset. Households identifying as Western European constitute 24% of all households within the residential sidewalk network dataset.



Demographic data licensed from Epsilon.

Figure 23. Percent of households by household ethnic group

Average assessed property values after homestead exemption were calculated and graphed in Figure 24. Households identifying as African American possess on average $30,812 in assessed property value (after deducting the homestead exemption). Households identifying as Western European possess on average $273,796 in assessed property value.

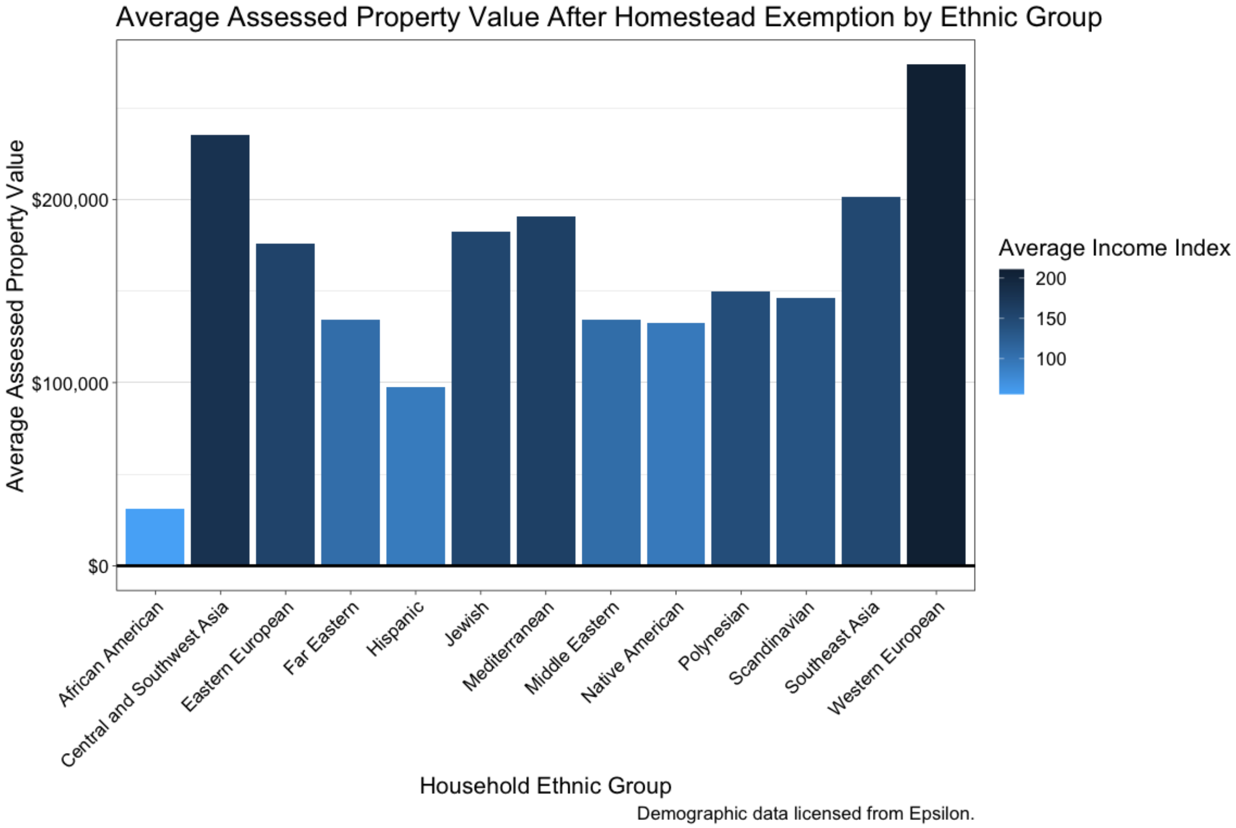
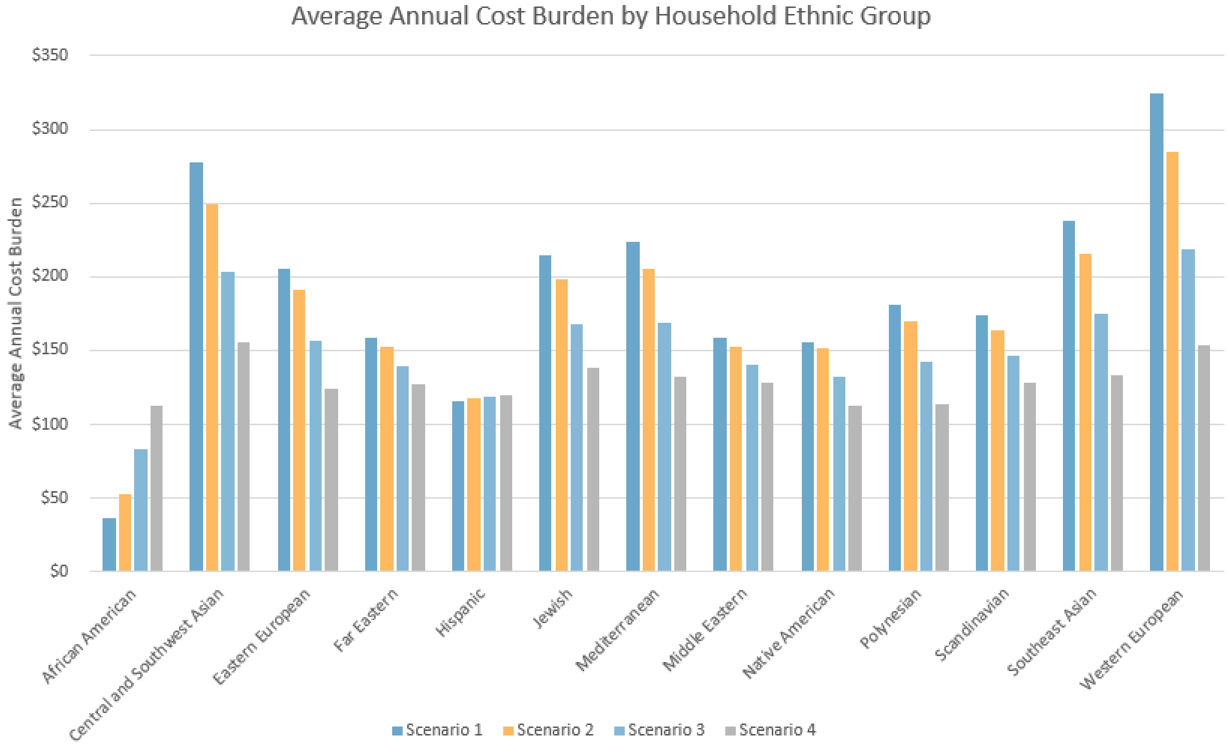


Figure 24. Average assessed property value with homestead exemption by ethnicity

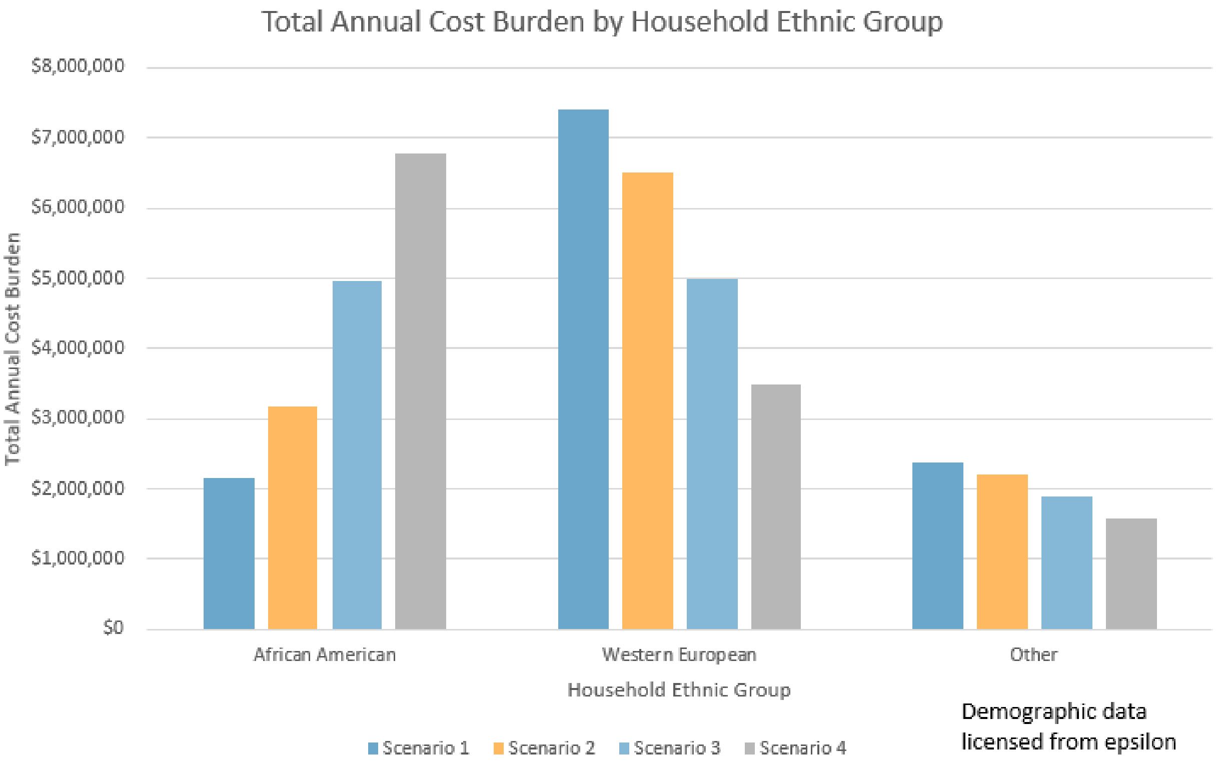
The average annual cost burden for each scenario, averaged across each household ethnic group, is further illustrated in Figure 25. The average annual cost burden for each scenario includes the scenario-specific private cost associated with maintaining assets adjacent to the property, plus any scenario-specific increase in property tax associated with the share of assets maintained with property taxes in that scenario.



Demographic data licensed frop Epsilon

Figure 25. Average annual sidewalk cost burden by household ethnic group and scenario

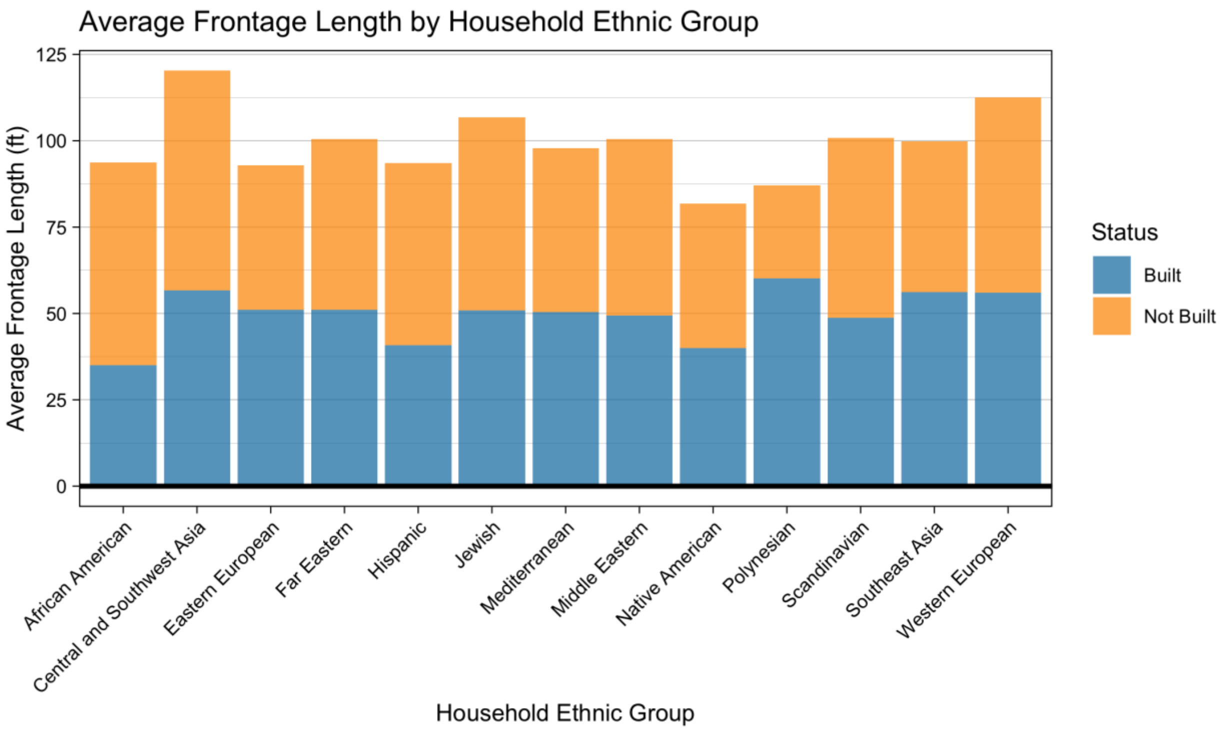
To compare the total cost burden to own and maintain the residential sidewalk network within the City of Atlanta, annual cost burdens for individual households were aggregated for each household ethnic group. Total cost burden per household ethnic group is illustrated in Figure 26 for African American and Western European households; the remaining ethnic groups with smaller number of households within the dataset were aggregated to form a third category of "Other."



Demographic data licensed from epsilon

Figure 26. Total annual sidewalk cost burden by household ethnic group

It is important to note that as the costs shift from property taxes to individual property owner, the basis for the costs also shift from value of property to the amount of sidewalk that needs to be maintained. Property values and the amount of sidewalk adjacent to each parcel vary considerably in Atlanta. For example, corner lots have sidewalks along two sides of the property. More importantly, parcel size often depends on property zoning rules at the time neighborhoods were developed (leading to spatial differences based upon neighborhood age). Average frontage lengths for residential parcels associated with households in each income group are illustrated in Figure 27. Households identifying as African American have an average of 37% of their estimated frontage lined with existing sidewalk assets. Households identifying as Western European have an average of 50% of their estimated frontage lined with existing sidewalk assets. The shift in the economic burden across the four scenarios is not obvious and has to be calculated property-by-property to generate relevant figures for any proposed cost allocation scenario.



Demographic data licensed from Epsilon.

Figure 27. Mean frontage by household ethnic group

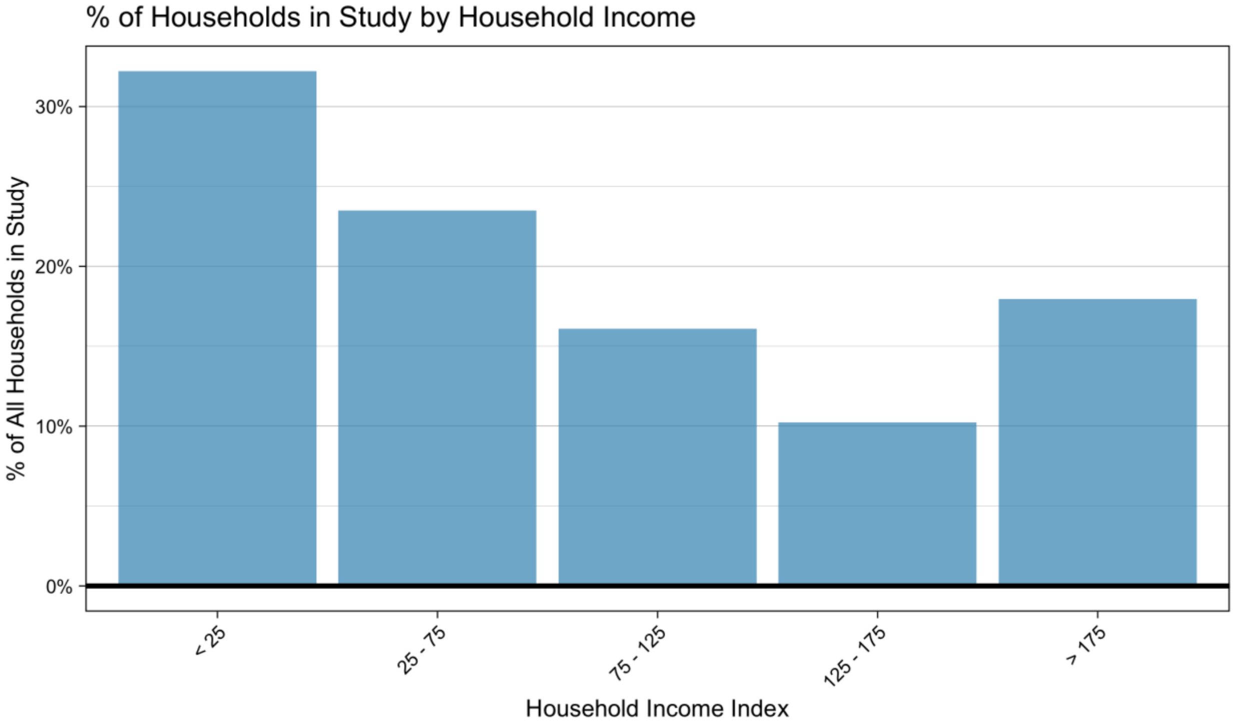
6.2.3 Cost Burden by Income

In addition to calculating mean cost burden by household ethnicity, cost burdens to maintain the residential sidewalk network were calculated by household income group. Household incomes were binned by income index in 50-unit increments. The resulting calculated annual cost burdens by income are summarized in Table 20. As noted earlier, an average income index of 100 indicates that the household earns income equal to the county's average; index values lower and higher than 100 indicate household incomes and above the county average, respectively. For example, an income index value of 150 indicates that the household earns 150% of the average household income.

Table 20. Cost allocation scenario summary by household income

Household Income Index	Percent of Atlanta Households	Mean Frontage (feet)	Mean Percent Sidewalk Now Present	Mean Assessed Property Value	Mean Annual Sidewalk Cost per Household			
					S1	S2	S3	S4
< 25	32%	87.2	33%	$7,677	$9	$30	$68	$105
25 - 74	23%	92.5	38%	$34,890	$41	$58	$86	$114
75 - 124	16%	93.4	50%	$99,152	$117	$119	$120	$120
125 - 175	10%	100.3	54%	$192,750	$227	$209	$173	$136
> 175	18%	116.6	47%	$326,570	$387	$336	$252	$168

Figure 28 illustrates the number of households in each income index bin as a percentage of the total households in the residential parcel dataset. Households falling below 25% of the area's average income constituted the largest share (32%) of the residential parcel dataset. Households with incomes between 125% and 175% of the area's average income constituted the smallest share (10%) of the residential parcel dataset.



Demographic data licensed from Epsilon.

Figure 28. Percent of households by household income

The average assessed property value for each household income group is illustrated in Figure 29. Household income and average assessed property value after homestead exemption are positively correlated, with households earning higher incomes possessing significantly higher assessed property value than households earning lower incomes.

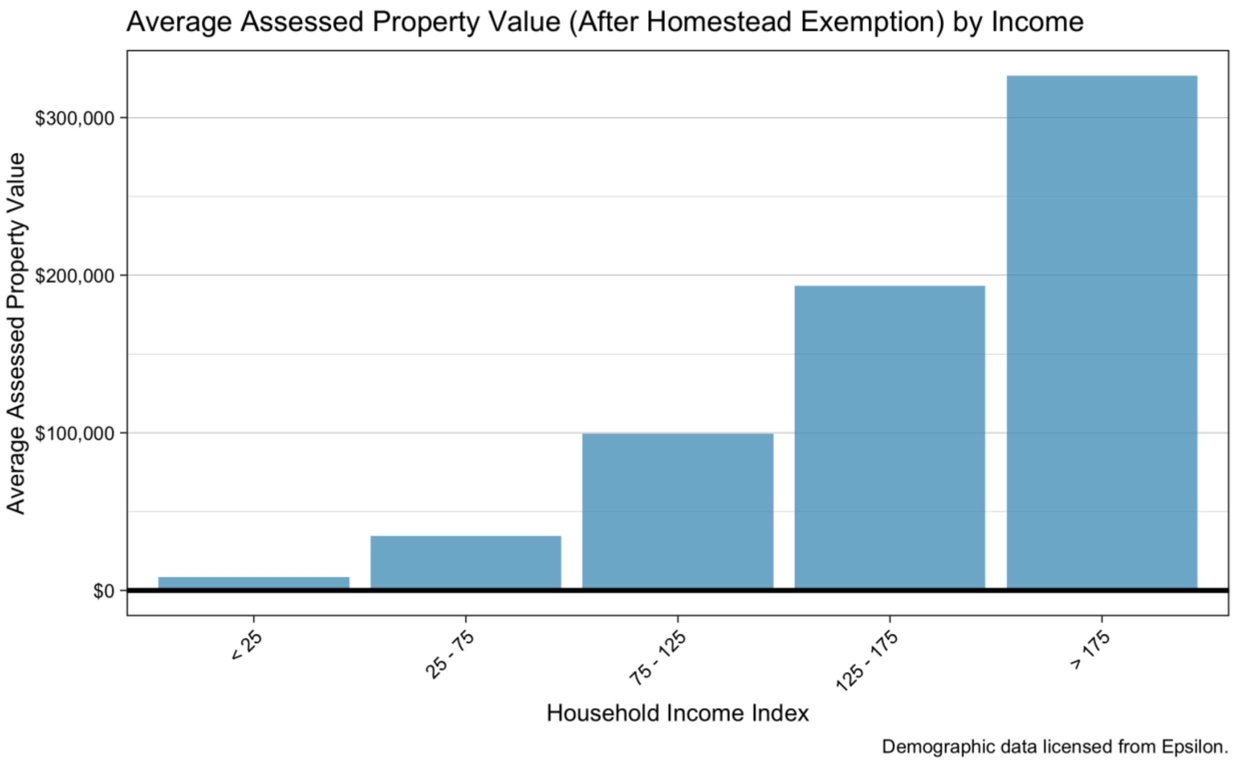


Figure 29. Average assessed property value with homestead exemption by income

The average annual cost burden for each scenario by household income index is presented in Figure 30. As before, the total annual cost burden in each scenario accounts for the increase in property taxes for that parcel, as well as the private property owner burden for maintaining sidewalks adjacent for that parcel. Households earning less than 125% of the area's average income experience increasing annual costs to maintain the residential sidewalk network as more of the lifecycle costs are directly allocated to the adjacent property owner. Households earning more than 125% of the area's average income experience decreasing annual costs to maintain the residential sidewalk network as more of the lifecycle costs are directly allocated to the adjacent property owner. The highest parcel-level burden on the lowest income households in Atlanta for sidewalk lifecycle ownership is in Scenario 4, where private property owners are responsible for maintaining all sidewalks and curb cuts adjacent to their property. The lowest parcel level burden on the lowest income households is in Scenario 1, where property taxes fund all sidewalk systems.

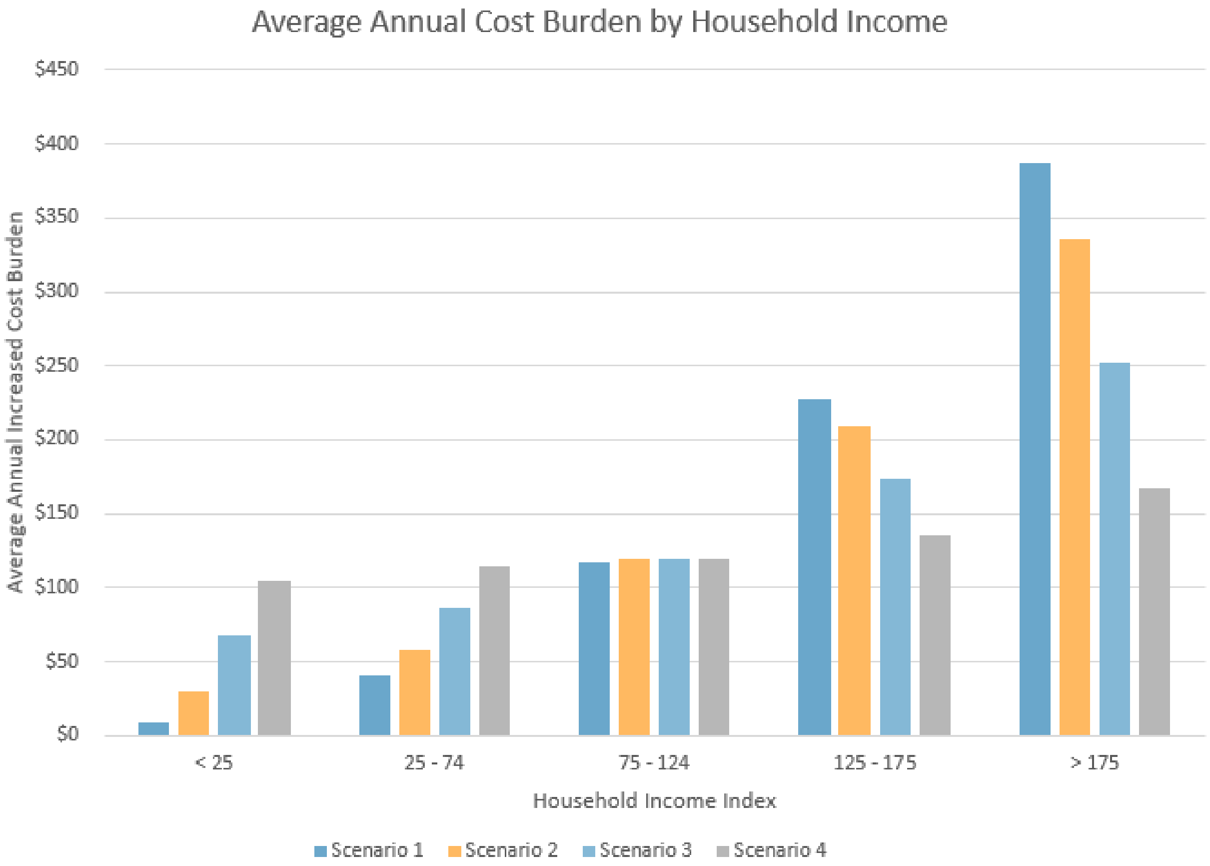


Figure 30. Average annual cost burden by household income

The effect noted at the parcel level is further exacerbated when total costs are examined, given the demographic makeup of Atlanta and large number of properties owned by low-income households. To compare the total cost burden to own and maintain the residential sidewalk network within the City of Atlanta, annual cost burdens for individual households were aggregated within each household income group. Total cost burden per household income index bin is illustrated in Figure 31. As before, the total annual cost burden in each scenario accounts for the increase in property taxes for that parcel, as well as the private property owner burden for maintaining sidewalks adjacent for that parcel. The highest total burden on the lowest income households in Atlanta for sidewalk lifecycle ownership is in Scenario 4, where private property owners are responsible for maintaining all sidewalks and curb cuts adjacent to their property. The lowest total burden on the lowest income households is in Scenario 1, where property taxes fund all sidewalk systems.

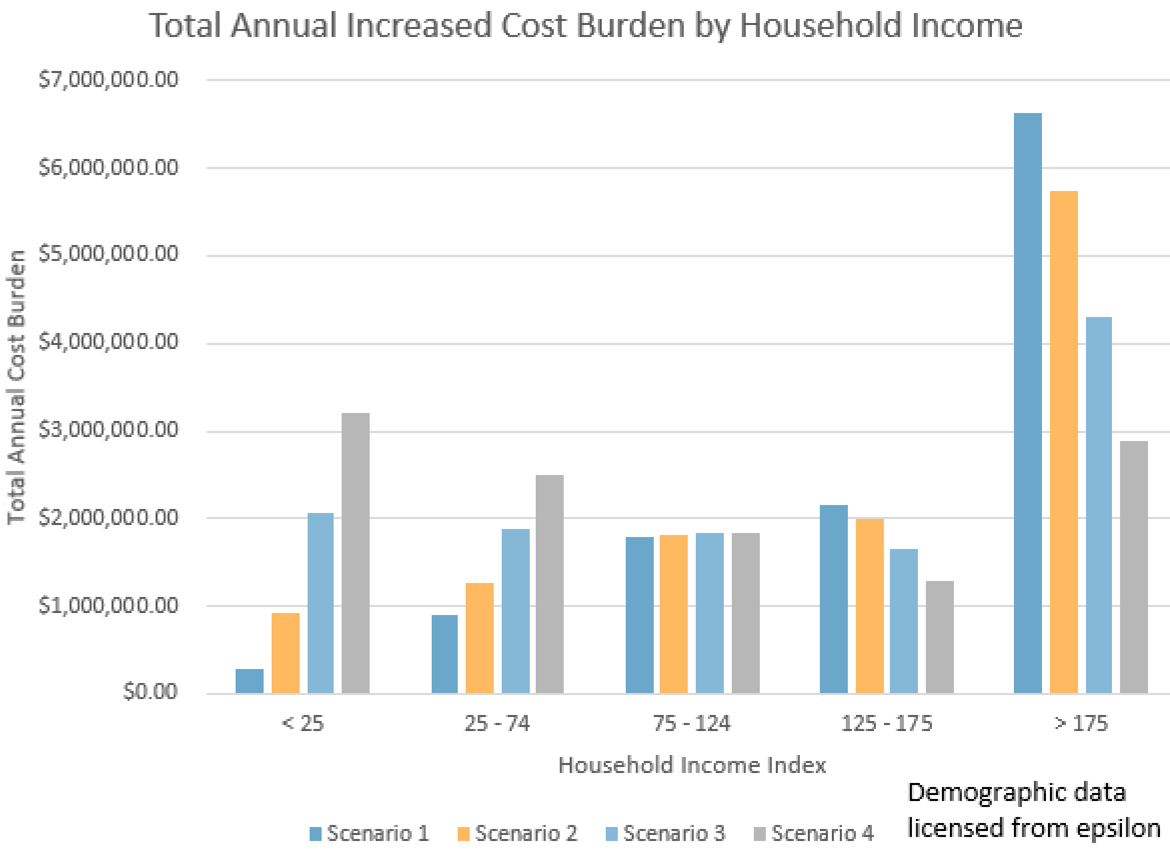


Figure 31. Total annual cost burden by household income

As discussed earlier, as sidewalk ownership costs shift from property taxes to individual property owners, the basis for the costs also shifts from value of property to the amount of sidewalk that needs to be maintained. That is, low value properties may have a little (or a lot) of linear sidewalk length and high value properties may have a little (or a lot) of linear sidewalk length. Average frontage lengths for residential parcels associated with households in each income group are illustrated in Figure 32. Households earning 75% to 175% of the area's average income have 50% or more of their estimated frontage lined with existing sidewalk assets. Households earning more than 175% of the area's average income have 47% of their estimated frontage lined with existing sidewalk assets. Households earning less than 75% of the area's average income have less than 40% of their estimated frontage lined with existing sidewalk assets. As noted earlier, the shift in the economic burden across the four scenarios is not obvious and has to be calculated property-by-property to generate relevant figures for any proposed cost allocation scenario.

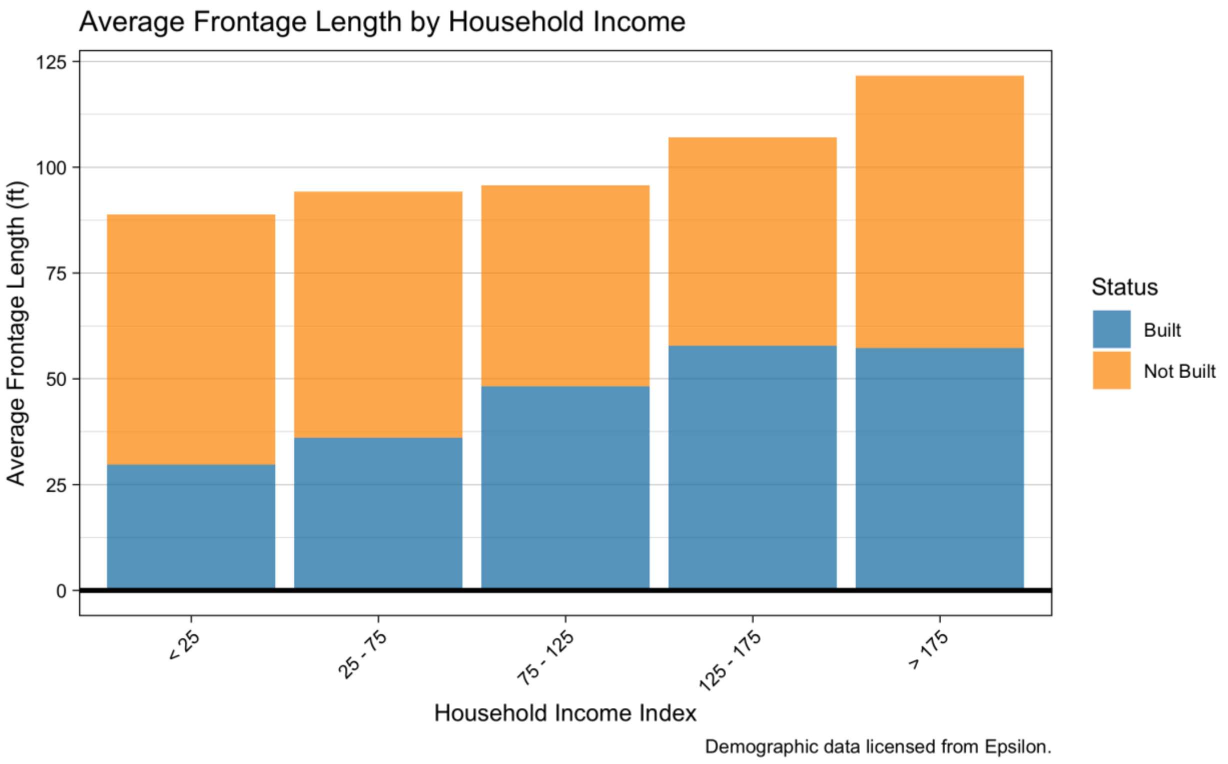


Figure 32. Mean frontage length by household income

6.3 Discussion

6.3.1 Disproportionate impacts for certain ethnic groups

That African American households are disproportionately burdened by direct cost allocation of sidewalk and curb cut ownership to adjacent properties was expected (this observation is consistent with initial analyses performed in 2019). African American households have the lowest average assessed property value of any ethnic group after deducting the standard homestead exemption, as seen earlier in Figure 24. Although the millage rate increases was the highest under Scenario 1, the additional property tax burden for African American households was significantly lower than the direct cost of owning and maintaining their associated adjacent sidewalk links in Scenarios 3 and 4 and curb cuts in Scenarios 2 through 4. Western European and other ethnic households see a change in cost burden in sharp contrast to African American households. Because the cost of sidewalk ownership and maintenance is increasingly assigned directly to the property owner across the four scenarios, the average annual cost burden on African American households increases, and the burden on Western European households decreases, across the four scenarios. The reduction in annual cost burden on Western European households across the scenarios arises because this ethnic group has the highest average assessed property values after the standard homestead exemption (Figure 24) and pays a larger total share to own and maintain the sidewalk network via taxes, relative to their representation in the demographic make-up of Atlanta's households (Figure 26).

6.3.2 Disproportionate impacts across income groups

The potential equity of cost allocation can also be viewed in terms of cost distribution across income group. Because low-income households have significantly lower assessed property values, their property taxes associated with Scenario 1 are relatively small. However, as more of the cost to maintain the network is assigned directly to adjacent property owners, the annual costs increase dramatically for these households, while higher-income households see a decrease in the annual costs to maintain the sidewalk network.

The distribution of cost burdens is noteworthy in the context of the average percentage of sidewalk is constructed for each income group. Households earning 125% or more of the area's average income benefit relatively less from new construction of sidewalk infrastructure due to the higher average percentage sidewalk in their neighborhoods that is already constructed. These same households may prefer Scenario 4, not only to minimize their annual costs, but for its consistency with the proportionate benefits of the construction and maintenance activities for the sidewalk network. The influence of property taxes on the annualized cost burdens for higher-income households is significantly higher than is the direct cost of their adjacent sidewalk mileage. Although Figure 32 clearly shows a higher total frontage length for higher-income households, the direct allocation of the costs to maintain the sidewalk along the length of their properties in Scenarios 2 through 4 is compensated by an even larger decrease in property tax burden for these households. The trend is in the opposite direction for lower-income households. Although households earning 75% or less of the area's average income have significantly less frontage than their higher-income counterparts, these households experience a much higher cost burden when the annual cost for adjacent infrastructure is directly allocated to them.

6.3.3 Complications for equity considerations

The variability in cost burden varies across household ethnicity and income group under each Scenario illustrates the complexities of equitable sidewalk network cost allocation. No single cost allocation scenario favors all households within an ethnic or income group. Because the percentage of sidewalk that is built out adjacent to a residential property varies substantially by household ethnicity and income, political tensions may arise due to the perception that certain households would pay higher property taxes to subsidize sidewalk construction for households of lesser means. Higher-income households may prefer the cost allocation in Scenario 4 (everyone pays for the sidewalks adjacent to their properties) given the lower annual cost burdens; and these same households may reject Scenario 1 due to the perception that they would be subsidizing sidewalk construction in lower-income neighborhoods (Figure 32). Lower-income households may prefer Scenario 1 for reasons exactly opposite those of the higher-income households. For lower-income households, Scenario 1 offers an annual cost burden that is much more within their means than the cost burdens in Scenarios 2 through 4.

One might argue that the most equitable cost allocation is Scenario 1, given the disparate increase in cost burdens on the average low-income or African American household across the other three scenarios (it might be reasonably argued that the prior passage of Atlanta City

Ordinance 138-14 (which appears to have been passed in 1977) placed the responsibility for sidewalk maintenance on adjacent property owners, and shifted the burden of sidewalk maintenance onto those demographic groups. Adding to equity concerns is the observation that the average income index for African American households is the lowest among all ethnic groups, raising concerns that the sharp increase in cost burdens under Scenario 4 is disproportionately burdensome compared to other ethnic groups.

The costs used to estimate annual cost burdens in these analyses are conservative, as they do not include additional potential costs associated with right-of-way acquisition, power/water/sewer alterations, and installation of pedestrian safety features. With the potential for much higher annualized lifecycle costs to account for additional costs to construct the sidewalk network, scenarios in which direct costs are assigned to adjacent property owners may present significant financial challenges to African American and low-income households.

7. Conclusion and Recommendations

This study aimed to verify the estimated sidewalk network mileage and life cycle cost estimations produced in previous studies by the Georgia Tech Sidewalk Lab. Extensive quality analysis and quality control procedures were performed on the input files used to semi-automatically generate the sidewalk network using GIS software. Streetside and aerial imagery were used to identify existing and missing sidewalk infrastructure assets to generate more detailed life cycle cost estimations for owning and maintaining the City of Atlanta's sidewalk network. Sidewalk network links were associated with adjacent property owners to further analyze the cost burdens on households associated with owning and maintaining sidewalk infrastructure adjacent to their properties.

Extensive QA/QC of the input files used to generate the City of Atlanta's sidewalk network resulted in stark differences in the network pre- and post-QA/QC in terms of overall mileage. Overall mileage in the post-QA/QC network decreased by 386 miles or 12% due in large part to addressing redundant links and closing gaps between parcels. Misplaced and redundant centroids, as well as gaps between parcels caused by railroads, affected QA/QC file correction time. QA/QC correction labor time also varied significantly across technicians.

Sidewalk identification data collected through the Sidewalk Flythrough application generated significant insights on the distribution of existing sidewalk infrastructure in the City of Atlanta. Of the 2,759 miles of sidewalk links in the post-QA/QC sidewalk network, 1,277 miles were identified as existing, constituting 46% of what would be a final comprehensive sidewalk network. Spatial analysis indicated significant clustering of sidewalk mileage in neighborhood surrounding Downtown and Midtown Atlanta. Significant QA/QC efforts were required to join the sidewalk identification data to the post-QA/QC sidewalk network. Modifying network generation procedures to automatically identify assets during network creation could reduce overall costs.

Sidewalk-parcel association yielded accurate length estimates for sidewalk links adjacent to individual parcels (they matched well with frontage estimates). Several edge cases resulted in small quantities of sidewalk mileage not correctly associated with their adjacent parcel, suggesting further attention be given to methodological improvements to address these cases in future adaptations of this work.

Life cycle cost estimates for network assets under several cost scenarios yielded compelling data to support the high costs estimated for the pre-QA/QC City of Atlanta sidewalk network in previous studies by the Sidewalk Lab. Overall, the life cycle cost analysis benefited from the inclusion of sidewalk link identification data, reducing the estimated cost of owning existing infrastructure assets. Obtaining contract cost data for pedestrian ramp and curb cut replacement costs (including demolition) would improve these estimates. Of the four investment scenarios explored in this study, the third scenario was selected as the overall investment scenario for equity assessment (missing sidewalk assets were constructed, major repairs of assets were conducted every 20 years, and 40% of assets required complete replacement at the end of the 80 year lifespan).

Annualized construction and repair costs for the City of Atlanta's sidewalk network generated compelling evidence to suggest the complex nature of equitable sidewalk cost allocation. Under scenarios where the City of Atlanta was the sole funding source of sidewalk construction and maintenance costs, residents with lower assessed property values and lower incomes were allocated much smaller increases in annual property taxes. As the cost of sidewalk network assets was increasingly allocated to adjacent property owners, the property tax burden increased for African American and Hispanic households. Analytical results suggest that policies to fund sidewalk infrastructure ownership should consider the trade-offs between cost increases direct to property owners and the relative income ability to shoulder increased tax burdens as public costs are allocated to them, regardless of whether the costs of private access assets like curb cuts are deemed to be the responsibility of the property owner.

Assessing what cost allocations are equitable is the role of public policy debate. The tools developed for this report that calculate how sidewalk asset cost burdens are allocated across demographic groups can assist in assessing the potential impacts of proposed changes to asset management policy. The public and/or private costs of owning and operating sidewalk assets in the City of Atlanta are surprisingly high, with more than $1 billion in assets at stake (previous research related to these high costs has been verified in this study). This research has yielded several methodologies and products that not only have significant value for replication of sidewalk asset studies in other regions, but the tools have also heled to identify some significant concerns related to how the burden of maintaining these assets are distributed throughout a city.

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Data Summary

The Tax Parcel data can be downloaded from the Atlanta Regional Commission Open Data and Mapping Hub: https://opendata.atlantaregional.com/datasets/coaplangis::tax-parcel-2021/about. The following citation is recommended for users of this data:

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The Georgia Department of Transportation Road Inventory data can be downloaded from the GDOT Road & Traffic Data webpage here: http://www.dot.ga.gov/DS/Data#tab-4. The following citation is recommended for users of these data:

- Georgia DOT. "Road & Traffic Data." *GDOT*, 31 Dec. 2020, http://www.dot.ga.gov/DS/Data#tab-4. Accessed 31 May 2022.

A Sidewalk Flythrough application was created using JavaScript and HTML code (Bing Maps V8 Web Control functionality was implemented through procurement of a software key). Bing Maps V8 Web Control can be found here: https://docs.microsoft.com/en-us/bingmaps/v8-web-control/. Because Bing Maps data are proprietary and the use agreement does not stipulate that software designed to work with Bing Maps features can be freely shared, the sidewalk flythrough application cannot be shared at this time. The research team was unable to negotiate an agreement with Microsoft that would allow the code to be shared. The team is currently developing similar code to process user-collected street view video images.

The household annual cost burden data can be downloaded here: https://zenodo.org/record/7290308#.Y21QUOzML0q. The following citation is recommended for users of these data:

- Guensler, Randall , Vincent Micah Bray, Freyja Brandel-Tanis, Will Reichard, & Scott O'Brien. (2022). Economic Sustainability of Sidewalk Networks and Funding Scenario Cost Distributions in Atlanta, GA (Version V1) [Data set]. https://zenodo.org/record/7290308#.Y21QUOzML0q

Data Format and Content, Data Access and Sharing, Reuse and Redistribution

Data can be downloaded in a variety of formats from the sources noted above.

Appendix A. Time Estimation for Sidewalk Network Phase 1 QA/QC

Table A-1. Time Estimation for Sidewalk Network Phase 1 QA/QC

Neighborhood	Centroids	Parcels	Centroid Correction Time (seconds)	Parcel Correction Time (seconds)	Other Correction Time (seconds)	Total Neighborhood QA/QC Time (seconds)	Percent Time Spent Correcting
Adair Park	53	48	811	1235	0	9000	23
Adams Park	51	29	81	826	0	4800	19
Adamsville	47	29	158	1799	0	10800	18
Allen Temple	10	6	0	782	0	3720	21
Almond Park	41	20	58	1567	0	6900	24
Amal Heights	4	1	0	81	0	1080	8
Ansley Park	72	0	2524	7059	172	0	0
Aramore	6	2	33	581	0	840	73
Arden/Habersham	0	0	120	393	0	900	57
Ardmore	9	5	113	240	0	5400	7
Argonne Forest	13	6	0	170	0	540	31
Arlington Estates	34	18	75	1842	0	5100	38
Armour	2	3	34	284	0	6000	5
Ashley Courts	8	1	0	85	307	1800	22
Ashview Heights	52	50	324	1140	0	5040	29
Atkins Park	9	15	0	119	0	5400	2
Atlanta Industrial Park	8	2	21	1464	0	5400	28
Atlanta University Center	73	54	644	1272	0	9000	21
Atlantic Station	27	22	710	1708	0	10800	22
Audobon Forest	15	6	27	536	0	1920	29
Audobon Forest West	7	4	0	112	0	1500	7
Baker Hills	30	12	16	621	0	4500	14
Bakers Ferry	7	1	15	495	74	2340	25
Bankhead	52	46	982	18101	35	0	0

Neighborhood	Centroids	Parcels	Centroid Correction Time (seconds)	Parcel Correction Time (seconds)	Other Correction Time (seconds)	Total Neighborhood QA/QC Time (seconds)	Percent Time Spent Correcting
Bankhead Courts	57	2	15	257	0	1680	16
Bankhead/Bolton	0	0	31	1103	0	5160	22
Beecher Hills	15	10	187	1044	0	4440	28
Ben Hill	14	7	111	2261	0	10500	23
Ben Hill Acres	9	3	14	154	315	2100	23
Ben Hill Forest	4	2	0	416	0	1860	22
Ben Hill Park	2	2	12	413	0	3900	11
Ben Hill Pines	9	5	35	241	0	2400	12
Ben Hill Terrace	9	5	7	548	0	2820	20
Berkeley Park	27	31	376	1242	0	8400	19
Betmar LaVilla	8	0	0	304	0	1500	20
Biscayne	11	4	109	1213	0	7200	18
Blair Villa/Poole Creek	0	0	7	207	45	3900	7
Blandtown	40	13	97	1737	0	5700	32
Bobby Jones	2	1	20	15	0	1800	2
Bolton	42	16	70	2427	0	8760	29
Boulder Park	4	6	25	849	0	3060	29
Boulevard Heights	26	18	45	693	0	1500	49
Brandon	27	10	46	187	0	9000	3
Brentwood	7	5	0	293	0	2100	14
Briar Glen	3	1	0	503	0	3360	15
Brookhaven	54	28	501	1179	0	5100	33
Brookview Heights	16	7	27	1410	0	9120	16
Brookwood	10	6	210	570	0	8400	9
Brookwood Hills	20	11	170	509	0	9000	8
Brownlee	13	5	30	1739	0	5340	33
Browns Mill Park	47	14	10	798	0	2400	34

Neighborhood	Centroids	Parcels	Centroid Correction Time (seconds)	Parcel Correction Time (seconds)	Other Correction Time (seconds)	Total Neighborhood QA/QC Time (seconds)	Percent Time Spent Correcting
Buckhead Forest	13	6	209	177	0	840	46
Buckhead Village	20	15	193	591	0	1020	77
Bush Mountain	11	6	82	354	0	720	61
Butner/Tell	0	0	9	416	0	2700	16
Cabbagetown	30	24	273	385	0	9000	7
Campbellton Road	14	12	312	1199	0	7320	21
Candler Park	57	35	581	2970	0	19920	18
Capitol Gateway	20	14	172	843	0	7200	14
Capitol View	58	44	61	1282	0	1980	68
Capitol View Manor	22	10	30	966	0	1860	54
Carey Park	56	26	53	3077	0	12600	25
Carroll Heights	35	16	8	1170	0	4020	29
Carver Hills	20	12	0	975	0	3720	26
Cascade Avenue/Road	0	0	335	1244	0	6480	24
Cascade Green	4	1	0	529	125	3060	21
Cascade Heights	29	15	44	1251	127	5700	25
Castleberry Hill	47	45	839	1265	0	9000	23
Castlewood	13	7	49	523	0	5400	11
Center Hill	76	57	37	2825	0	14280	20
Channing Valley	8	2	43	347	0	720	54
Chastain Park	59	28	272	1254	0	2760	55
Chattahoochee	5	2	8	763	45	2700	30
Chosewood Park	41	18	179	1370	0	3660	42
Collier Heights	111	49	11	2633	0	9360	28
Collier Hills	0	0	48	1079	0	1560	72
Collier Hills North	5	5	0	743	0	960	77
Colonial Homes	13	6	131	620	0	4800	16

Neighborhood	Centroids	Parcels	Centroid Correction Time (seconds)	Parcel Correction Time (seconds)	Other Correction Time (seconds)	Total Neighborhood QA/QC Time (seconds)	Percent Time Spent Correcting
Coronet Way Park	11	6	423	1120	0	7200	21
Coventry Station	1	2	0	357	0	2160	17
Cross Creek	7	2	320	837	0	9900	12
Custer/McDonough/Guice	0	0	23	358	0	1680	23
Deerwood	15	8	24	726	0	2100	36
Dixie Hills	56	24	58	1964	0	7680	26
Downtown	263	303	1580	3617	0	38700	13
Druid Hills	26	26	439	556	0	9000	11
East Ardley Road	6	4	23	304	0	1800	18
East Atlanta	164	101	796	2605	0	5940	57
East Chastain Park	22	0	116	1040	0	1560	74
East Lake	97	118	581	1378	0	16200	12
Edgewood	84	102	552	1816	0	27000	9
Elmco Estates	8	3	43	377	0	5100	8
Englewood Manor	1	2	140	0	0	300	47
English Avenue	142	199	0	3574	0	15720	23
English Park	3	3	0	973	0	3480	28
Fairburn	17	11	38	911	0	5400	18
Fairburn Heights	21	14	9	1034	0	4500	23
Fairburn Mays	13	5	46	891	125	4380	24
Fairburn Road/Wisteria Lane	0	0	0	255	0	2460	10
Fairburn Tell	5	4	45	465	0	3000	17
Fairway Acres	11	7	13	601	0	4500	14
Fernleaf	0	0	0	408	0	3600	11
Florida Heights	33	11	195	1803	0	7080	28
Fort Valley	0	0	0	841	0	3900	22

Neighborhood	Centroids	Parcels	Centroid Correction Time (seconds)	Parcel Correction Time (seconds)	Other Correction Time (seconds)	Total Neighborhood QA/QC Time (seconds)	Percent Time Spent Correcting
Fulton	1	6	0	481	0	3180	15
Garden Hills	56	28	177	2025	0	1920	115
Georgia Tech	44	57	148	3773	0	19200	20
Georgian Hills	6	2	184	191	0	8100	5
Glenrose Heights	41	22	209	2413	0	3840	68
Grant Park	200	129	612	1260	0	4980	38
Green Acres Valley	5	4	0	215	0	1620	13
Green Forest Acres	13	7	0	305	0	1560	20
Greenbriar	36	21	147	1949	125	12000	19
Greenbriar Village	5	3	0	387	0	2760	14
Grove Park	163	100	136	3322	0	11640	30
Hadlock	29	5	10951	433	0	2820	404
Hammond Park	34	17	666	2028	0	3060	88
Hanover West	9	3	199	258	0	7200	6
Harland Terrace	15	7	0	787	0	1140	69
Harris Chiles	13	12	117	999	0	7200	16
Harvel Homes Community	4	2	6	415	0	2940	14
Heritage Valley	20	13	15	561	0	3300	17
High Point	12	5	25	2009	0	2160	94
Hills Park	40	20	79	1806	0	5820	32
Home Park	106	123	683	1963	0	18000	15
Horseshoe Community	4	2	23	75	0	1500	7
Hunter Hills	69	29	61	1731	0	6360	28
Huntington	3	3	27	532	171	3300	22
Inman Park	73	48	1484	3421	0	29100	17
Ivan Hill	3	0	6	339	0	1380	25
Joyland	20	9	0	0	261	0	0

Neighborhood	Centroids	Parcels	Centroid Correction Time (seconds)	Parcel Correction Time (seconds)	Other Correction Time (seconds)	Total Neighborhood QA/QC Time (seconds)	Percent Time Spent Correcting
Just Us	6	3	58	141	0	1800	11
Kimberly	1	5	0	431	0	4500	10
Kings Forest	25	7	18	783	0	6900	12
Kingswood	16	5	200	285	0	1260	38
Kirkwood	145	180	897	4811	0	18000	32
Knight Park/Howell Station	0	0	0	1901	0	13380	14
Lake Claire	56	40	699	2271	0	20700	14
Lake Estates	1	1	0	483	0	3000	16
Lakewood	28	16	0	71	662	1320	56
Lakewood Heights	86	49	275	2632	0	6480	45
Laurens Valley	8	6	23	394	0	2400	17
Leila Valley	21	11	517	1162	0	2160	78
Lenox	27	18	516	914	0	2700	53
Lindbergh/Morosgo	0	0	547	2622	0	14400	22
Lindridge/Martin Manor	0	0	502	1830	0	15300	15
Loring Heights	34	22	277	1596	0	10800	17
Magnum Manor	13	8	0	465	0	1500	31
Margaret Mitchell	34	13	105	795	0	5400	17
Marietta Street Artery	22	19	423	671	0	15120	7
Mays	56	144	400	4631	0	11820	43
Meadowbrook Forest	4	1	0	370	0	2460	15
Mechanicsville	102	140	778	2308	0	14400	21
Mellwood	4	1	21	314	0	2100	16
Melvin Park	2	2	0	608	0	3120	19
Memorial Park	9	5	0	1034	0	7200	14
Midtown	186	221	4470	6053	0	24540	43
Midwest Cascade	53	11	144	3069	0	9600	33

Neighborhood	Centroids	Parcels	Centroid Correction Time (seconds)	Parcel Correction Time (seconds)	Other Correction Time (seconds)	Total Neighborhood QA/QC Time (seconds)	Percent Time Spent Correcting
Monroe Heights	9	0	0	1757	0	5280	33
Morningside/Lenox Park	0	0	799	5281	0	14400	42
Mozley Park	64	33	72	2436	0	7920	32
Mt. Gilead Woods	4	2	22	227	0	2100	12
Mt. Paran Parkway	4	2	112	357	0	900	52
Mt. Paran/Northside	0	0	113	1205	0	2700	49
Niskey Cove	6	2	19	1135	0	5700	20
Niskey Lake	12	8	138	1278	0	5400	26
North Buckhead	113	45	388	4046	0	8160	54
Norwood Manor	12	6	1466	180	0	2400	69
Oakcliff	2	1	0	459	0	2940	16
Oakland	11	6	264	405	0	7260	9
Oakland City	88	65	311	2278	0	4560	57
Old Fairburn Village	0	0	0	274	0	2100	13
Old Fourth Ward	141	148	1188	1873	0	16200	19
Old Gordon	6	3	25	773	0	4140	19
Orchard Knob	18	9	19	45	0	2400	3
Ormewood Park	87	55	640	1787	0	4440	55
Overlook Atlanta	8	5	8	1227	0	3180	39
Paces	49	27	620	2229	0	18000	16
Peachtree Battle Alliance	42	26	93	665	0	7800	10
Peachtree Heights East	26	16	242	97	0	1800	19
Peachtree Heights West	33	18	93	932	0	1800	57
Peachtree Hills	34	23	677	1706	0	3180	75
Peachtree Park	26	12	151	1325	0	2580	57
Penelope Neighbors	24	12	0	1017	0	4020	25
Peoplestown	55	38	308	1310	0	2640	61

Neighborhood	Centroids	Parcels	Centroid Correction Time (seconds)	Parcel Correction Time (seconds)	Other Correction Time (seconds)	Total Neighborhood QA/QC Time (seconds)	Percent Time Spent Correcting
Perkerson	39	23	110	1557	0	2280	73
Peyton Crossing	11	6	11	287	0	2880	10
Peyton Forest	20	10	0	487	0	720	68
Piedmont Heights	30	14	647	877	0	5400	28
Piedmont Park	6	1	325	0	0	1860	17
Pine Hills	44	25	258	4550	0	6900	70
Pittsburgh	113	86	640	1522	0	3480	62
Plasamour	9	9	1596	0	0	9900	16
Pleasant Hill	0	0	0	743	0	5400	14
Polar Rock	21	14	135	1258	0	2280	61
Pomona Park	28	5	241	518	0	3300	23
Poncey Highland	25	58	472	935	0	16200	9
Princeton Lakes	38	16	239	1625	0	9900	19
Ralph Bunche	8	3	23	736	0	4800	16
Randall Mill	29	5	65	349	0	5400	8
Rebel Valley Forest	7	6	0	409	0	720	57
Regency Trace	0	1	0	0	65	1140	6
Reynoldstown	77	47	709	2519	0	18900	17
Ridgecrest Forest	7	4	0	482	0	2400	20
Ridgedale Park	4	4	0	400	0	480	83
Ridgewood Heights	0	0	0	511	0	10800	5
Riverside	45	22	47	1620	0	5880	28
Rockdale	15	12	37	1126	0	4680	25
Rosedale Heights	11	0	5	64	0	900	8
Rue Royal	3	2	9	230	0	1800	13
Saint Annes	14	6	19	545	0	900	63
Sandlewood Estates	13	1	70	1151	0	8280	15

Neighborhood	Centroids	Parcels	Centroid Correction Time (seconds)	Parcel Correction Time (seconds)	Other Correction Time (seconds)	Total Neighborhood QA/QC Time (seconds)	Percent Time Spent Correcting
Scotts Crossing	20	14	39	904	0	4320	22
Sherwood Forest	21	11	308	428	0	7200	10
South Atlanta	72	56	49	1112	0	3300	35
South River Gardens	46	16	338	1505	149	4860	41
South Tuxedo Park	27	13	16	270	0	780	37
Southwest	50	32	195	1932	509	8460	31
Springlake	24	12	29	923	0	7200	13
Stone Road	9	3	50	526	0	4920	12
Stonecreek	4	2	17	453	0	2700	17
Summerhill	78	51	225	1207	0	2400	60
Swallow Circle/Baywood	0	0	0	404	0	720	56
Sweet Auburn	44	43	432	956	0	8940	16
Sylvan Hills	103	59	254	2931	0	4260	75
Tampa Park	4	1	27	125	0	1200	13
The Villages at Carver	13	9	78	0	0	900	9
The Villages at Castleberry Hill	14	9	100	86	0	5400	3
The Villages at East Lake	8	8	257	207	0	2700	17
Thomasville Heights	42	23	246	856	0	2700	41
Tuxedo Park	28	12	359	620	0	1740	56
Underwood Hills	72	44	370	1606	0	7200	27
Venetian Hills	41	38	157	1266	0	6300	23
Vine City	82	80	326	2124	0	8280	30
Virginia Highland	121	168	677	3717	0	14400	31
Washington Park	33	13	0	2003	0	6300	32
Wesley Battle	9	6	20	369	0	5400	7
West End	110	78	353	2072	0	4500	54
West Highlands	4	2	14	627	0	4500	14

Neighborhood	Centroids	Parcels	Centroid Correction Time (seconds)	Parcel Correction Time (seconds)	Other Correction Time (seconds)	Total Neighborhood QA/QC Time (seconds)	Percent Time Spent Correcting
West Lake	17	11	8	765	0	3900	20
West Manor	17	10	7	581	0	2820	21
West Paces Ferry/Northside	0	0	176	255	0	1020	42
Westhaven	12	6	37	700	0	960	77
Westminster/Milmar	0	0	108	423	0	2700	20
Westview	85	46	297	1422	0	3180	54
Westview Cemetery	9	9	140	2223	0	5520	43
Westwood Terrace	29	15	201	442	0	840	77
Whitewater Creek	7	8	147	848	0	7200	14
Whittier Mill Village	18	8	8	1074	40	4320	26
Wildwood (NPU C)	31	12	680	846	0	12600	12
Wildwood (NPU H)	11	5	0	361	135	3240	15
Wildwood Forest	10	6	33	816	0	5100	17
Wilson James	4	3	6	1148	0	3480	33
Wilson Mill Meadows	24	11	10	456	0	2520	18
Wisteria Gardens	11	7	0	531	0	2280	23
Woodfield	5	3	48	334	0	7200	5
Woodland Hills	13	7	253	48	22	1380	23
Wyngate	8	4	0	468	0	720	65

Appendix B. Household Income Characteristics by Neighborhood

Table B-1. Household Income Characteristics by Neighborhood

Neighborhood	Average % Household Sidewalk Built	Household Count	Average Income Index
Adair Park	93	551	40
Adams Park	6	695	50
Adamsville	26	722	29
Almond Park	5	348	26
Ansley Park	82	806	197
Arden/Habersham	13	120	364
Ardmore	66	250	161
Argonne Forest	27	217	363
Arlington Estates	2	352	50
Ashley Courts	25	4	19
Ashview Heights	65	598	28
Atkins Park	100	122	144
Atlanta Industrial Park	21	7	26
Atlanta University Center	92	242	24
Atlantic Station	100	3	96
Audobon Forest	9	350	79
Audobon Forest West	17	176	71
Baker Hills	9	387	40
Bakers Ferry	36	101	48
Bankhead	44	571	27
Bankhead/Bolton	47	33	23
Beecher Hills	5	291	51
Ben Hill	44	260	74
Ben Hill Acres	10	83	44
Ben Hill Forest	4	60	46
Ben Hill Pines	33	129	36
Ben Hill Terrace	14	230	43
Benteen Park	42	287	64
Berkeley Park	45	267	90
Betmar LaVilla	63	126	47
Blair Villa/Poole Creek	21	182	28
Blandtown	82	71	116
Bolton	53	507	113
Bolton Hills	22	106	39

Neighborhood	Average % Household Sidewalk Built	Household Count	Average Income Index
Boulder Park	41	117	45
Boulevard Heights	23	315	84
Brandon	30	343	374
Brentwood	0	81	46
Briar Glen	43	106	52
Brookhaven	30	753	291
Brookview Heights	11	18	27
Brookwood	100	252	152
Brookwood Hills	85	379	291
Browns Mill Park	15	590	39
Buckhead Forest	77	534	155
Buckhead Heights	83	66	159
Buckhead Village	100	357	195
Bush Mountain	6	143	28
Butner/Tell	0	105	38
Cabbagetown	97	699	73
Campbellton Road	30	351	38
Candler Park	93	1048	190
Capitol View	74	883	38
Capitol View Manor	62	330	44
Carey Park	12	473	27
Carroll Heights	8	564	31
Carver Hills	0	355	25
Cascade Avenue/Road	25	935	36
Cascade Green	98	90	93
Cascade Heights	19	515	68
Castleberry Hill	99	68	102
Castlewood	16	277	343
Center Hill	13	1141	28
Chalet Woods	10	125	54
Channing Valley	42	123	173
Chastain Park	22	807	376
Chosewood Park	65	324	36
Collier Heights	5	2046	42
Collier Hills	18	295	185
Collier Hills North	36	125	160
Colonial Homes	61	221	153

Neighborhood	Average % Household Sidewalk Built	Household Count	Average Income Index
Cross Creek	0	787	95
Custer/McDonough/Guice	21	379	47
Deerwood	0	246	44
Dixie Hills	19	831	29
Downtown	100	515	79
Druid Hills	90	190	272
East Ardley Road	24	106	57
East Atlanta	47	2311	98
East Chastain Park	57	585	190
East Lake	43	1245	118
Edgewood	76	1352	95
Edmund Park	13	8	196
Elmco Estates	4	186	45
English Avenue	65	962	27
English Park	40	108	34
Fairburn	2	217	31
Fairburn Heights	8	435	31
Fairburn Mays	32	141	34
Fairburn Road/Wisteria Lane	4	53	45
Fairburn Tell	30	79	80
Fairway Acres	0	159	49
Fernleaf	2	94	182
Florida Heights	25	561	33
Fort McPherson	1	8	23
Garden Hills	54	1192	194
Georgia Tech	88	4	76
Glenrose Heights	8	632	27
Grant Park	90	2409	113
Green Acres Valley	0	91	58
Green Forest Acres	4	144	51
Greenbriar	5	501	54
Greenbriar Village	59	110	56
Grove Park	18	2180	28
Hammond Park	2	464	26
Hanover West	27	134	256
Harland Terrace	21	278	55
Harris Chiles	97	6	21

Neighborhood	Average % Household Sidewalk Built	Household Count	Average Income Index
Harvel Homes Community	5	54	42
Heritage Valley	2	383	51
High Point	82	104	76
Hills Park	16	282	110
Home Park	87	764	73
Horseshoe Community	8	37	86
Hunter Hills	20	1012	27
Huntington	0	38	110
Inman Park	97	767	163
Ivan Hill	19	125	51
Joyland	22	260	25
Just Us	16	54	35
Kings Forest	17	376	61
Kingswood	0	228	425
Kirkwood	64	2306	120
Knight Park/Howell Station	15	338	91
Lake Claire	82	1022	211
Lake Estates	0	53	59
Lakewood	11	571	29
Lakewood Heights	30	910	31
Laurens Valley	6	137	63
Leila Valley	5	245	23
Lincoln Homes	20	283	29
Lindbergh/Morosgo	100	10	55
Lindridge/Martin Manor	15	456	119
Loring Heights	7	337	145
Magnum Manor	37	179	78
Margaret Mitchell	25	403	289
Marietta Street Artery	0	10	47
Mays	11	23	45
Meadowbrook Forest	9	95	48
Mechanicsville	93	766	41
Mellwood	0	43	40
Memorial Park	19	130	279
Midtown	95	2275	140
Midwest Cascade	11	692	115
Monroe Heights	44	203	46

Neighborhood	Average % Household Sidewalk Built	Household Count	Average Income Index
Morningside/Lenox Park	76	2713	222
Mozley Park	44	844	31
Mt. Gilead Woods	66	83	46
Mt. Paran Parkway	0	72	343
Mt. Paran/Northside	3	577	351
Niskey Cove	32	129	102
Niskey Lake	4	112	118
North Buckhead	36	1780	244
Norwood Manor	17	212	30
Oakcliff	25	91	30
Oakland City	39	1477	27
Old Fairburn Village	11	32	53
Old Fourth Ward	94	1448	99
Old Gordon	32	25	32
Orchard Knob	16	312	28
Ormewood Park	62	1476	118
Paces	9	578	316
Peachtree Battle Alliance	49	517	291
Peachtree Heights East	23	345	196
Peachtree Heights West	62	1488	158
Peachtree Hills	33	813	168
Peachtree Park	24	530	205
Penelope Neighbors	2	241	31
Peoplestown	81	729	41
Perkerson	4	537	32
Peyton Forest	27	403	69
Piedmont Heights	54	452	152
Pine Hills	56	965	150
Pittsburgh	73	1513	24
Pleasant Hill	1	101	299
Polar Rock	8	487	29
Pomona Park	3	140	41
Poncey-Highland	96	312	142
Princeton Lakes	99	717	85
Randall Mill	24	107	378
Rebel Valley Forest	0	171	25
Regency Trace	10	7	111

Neighborhood	Average % Household Sidewalk Built	Household Count	Average Income Index
Reynoldstown	83	833	79
Ridgecrest Forest	2	187	38
Ridgedale Park	51	237	137
Ridgewood Heights	9	208	172
Riverside	7	731	89
Rockdale	94	43	92
Rosedale Heights	7	169	33
Rue Royal	18	52	27
Sandlewood Estates	31	206	57
Scotts Crossing	19	158	37
Sherwood Forest	1	199	292
South Atlanta	41	603	28
South River Gardens	13	699	38
South Tuxedo Park	32	285	202
Southwest	21	762	56
Springlake	59	404	254
Summerhill	81	770	60
Swallow Circle/Baywood	0	244	30
Sweet Auburn	100	62	56
Sylvan Hills	47	1670	34
Tampa Park	48	81	38
The Villages at Carver	100	1	16
The Villages at Castleberry Hill	100	1	10
The Villages at East Lake	40	1	62
Thomasville Heights	50	532	25
Tuxedo Park	4	411	342
Underwood Hills	30	563	127
Venetian Hills	13	1603	31
Vine City	77	714	30
Virginia Highland	95	1944	189
Washington Park	87	599	29
Wesley Battle	35	179	334
West End	82	1312	39
West Highlands	96	53	99
West Lake	17	416	27
West Manor	13	315	57
West Paces Ferry/Northside	32	506	313

Neighborhood	Average % Household Sidewalk Built	Household Count	Average Income Index
Westhaven	6	204	31
Westminster/Milmar	39	241	228
Westover Plantation	100	280	99
Westview	64	1273	38
Westwood Terrace	2	373	36
Whitewater Creek	0	118	299
Whittier Mill Village	4	139	139
Wildwood (NPU-C)	6	322	265
Wildwood (NPU-H)	35	216	35
Wildwood Forest	5	124	48
Wilson Mill Meadows	35	415	43
Wisteria Gardens	5	234	38
Woodfield	30	49	323
Woodland Hills	48	207	84
Wyngate	2	141	380