An Evaluation of Sidewalk Availability and Width: Analyzing Municipal Policy and Equity Disparities

ABSTRACT

To evaluate an urban mobility option gaining attention in the shadows of bike paths and public transit, this research explores sidewalk availability, width, and potential socio-demographic and socio-economic disparities resulting from differing municipal policies. Responsibility for sidewalk maintenance tends to take one of two approaches: placing the onus on city agencies or on the abutting property owner. Existing sidewalk studies generally focus on smaller cities or limit analyses to micro-scale sample areas. Utilizing advances in geospatial technology, this paper evaluates larger city sidewalk availability and width across four major U.S. cities: two cities that take on the responsibility of sidewalks and two cities placing responsibility onto the abutting property owners. This research also considers potential socio-demographic and socio-economic disparities as well as mode choice to work at the Census block group geography.

The results suggest that overall sidewalk availability in all of our cities is deficient but does not find substantial differences based on sidewalk policy. Regarding socio-economic disparities, those living below the poverty line in cities that take on sidewalk maintenance themselves tended to have increased sidewalk availability as compared to lower income residents of cities where the onus falls on the homeowner. However, all of our cities, regardless of policy, show an unexpected correlation between wider sidewalks and lower incomes. In terms of mode choice, better sidewalk availability correlated with lower driving rates and increased walking and public transit use only in cities responsible for sidewalk maintenance. Wider sidewalks had a similar outcome in both sets of cities.

INTRODUCTION

Hidden in plain sight next to the more prevalent urban mobility topics of bike lanes and public transit, sidewalks are quickly gaining traction as a fundamental element of transportation infrastructure discussions. When it comes to the provision of sidewalks in the right-of-way (ROW) and their associated maintenance, cities tend to take one of two approaches: i) placing the onus on city agencies; or ii) on the abutting property owner. This stark difference leads to a relevant question: does municipal policy influence the availability and width of sidewalks in the ROW? Given that the costs of sidewalks can be considerable, it also stands to reason that differing municipal sidewalks policies could lead to equity disparities (Bushell, Poole, Zegeer, & Rodriguez, 2013). Due to a general lack of comprehensive sidewalk data, there is little in the way of existing research on either of these issues. With recent advances in remote sensing technology, however, this is beginning to change.

This research will first conduct a comprehensive review of sidewalk infrastructure utilizing Geographic Information Systems (GIS) to evaluate sidewalk availability and width with respect to national and federal sidewalk guidelines and municipal policies in four major U.S. cities: two cities that take on the responsibility of sidewalks; and two that put that responsibility onto the abutting property owners. This will provide a baseline understanding of where these cities stand on meeting, possibly exceeding, or even failing guidelines. To accomplish this, we evaluate availability of sidewalks based on the FHWA and NACTO statement that sidewalks should be provided on both sides of every road. (National Association of City Transportation Officials, Summit Foundation, & Rockefeller Foundation, 2013; Zegeer, Nabors, & Lagerwey, 2003). When discussing sidewalk availability, this paper refers to complete coverage as a 2:1 ratio (sidewalks: roadways) or higher. With respect to sidewalk width, we focus on the Americans with Disabilities Act (ADA) width compliance, with the understanding that future work should assess pavement condition and issues such as heaved or displaced sidewalk sections. These sidewalk availability and width measures enable further inquiries of patterns emerging from cities with differing municipal policies, including analyzing socio-demographic and socio-economic differences (i.e. race, poverty, median household income, household language, and means of transportation to work).

Insufficient research denotes a deficit in information on city-level sidewalk policy and consequences to city infrastructure quality and societal inequity. This paper will provide quantifiable insight to potential trends emerging from municipal sidewalk policies and offer a greater understanding on the impacts of these policies on walkability and equity. The next section discusses the existing literature, followed by a detailed overview of the project, including our data and methods. We then present the results and discuss the implications of this work. The overarching goal is to enhance urban mobility options for those that rely on sidewalks or would like to have the freedom to do so.

LITERATURE REVIEW

We were not able to find any studies comparing sidewalks in cities with different municipal maintenance policies. Moreover, the research looking at sidewalks and equity disparities was relatively sparse, and most of those studies focused on smaller cities or sample segments. For instance, del Pilar Rodriguez and Rowangould studied Albuquerque, New Mexico, where the abutting landowner is responsible for sidewalk maintenance. Based on field-based observations in low and high-income areas, the results show no evidence of disparity between width of sidewalks and income (del Pilar Rodriguez & Rowangould, 2017; National Association of City Transportation Officials et al., 2013). However, the study consisted of reviewing 100 intersections in the city, which is less than 1% coverage of approximately 22,000 Albuquerque intersections (Boeing, 2017). This leaves a considerable amount of the city overlooked.

A study by Bise et al. in Starkville, Mississippi, a small college town of 25,000 people where the responsibility of sidewalks in the ROW on this city, showed relatively equal access to sidewalks for Whites and Blacks but considerably worse quality for Blacks (Bise et al., 2018). Their methodology consisted of structured (or unstructured) site reconnaissance/windshield survey, noting various sidewalk criteria, and later digitizing sidewalk segments in GIS. For a small city such as this, manual data collection seems very time consuming but still feasible. However, the study also mentions that not all sidewalks are uniform in width along a roadway, but the research does not define if variations in width are accounted for or how those measurements were attained (i.e. subjective visual estimate or on the ground measurement). The authors also note limited research conducted on sidewalks with the use of GIS and suggest conducting more studies on demographic correlations to sidewalk networks.

These prior studies are limited in geographic coverage, analyzing partial cities or small towns; in addition, there are no comparisons between cities with differing municipal policies. National Cooperative Highway Research Program (NCHRP) Synthesis 371 surveyed infrastructure asset agencies at the state, provincial, county, and city levels from across the U.S. about their management policies. (Markow, United States Federal Highway Administration, National Research Council Transportation Research Board, National Cooperative Highway Research Program, & American Association of State Highway Transportation Officials, 2007). The results indicate that agencies lack information regarding sidewalk inventory, location, condition, and understanding of codes and practices related to maintenance responsibility (Markow et al., 2007). These results – in addition to the dearth of research comparing sidewalks of cities with differing municipal policies – suggests a need for studies such as this.

The goal in this paper is to analyze cities utilizing GIS sidewalk data and U.S. Census block group geographic regions. Planimetric or similar spatial data created from high-resolution aerial imagery afford a considerable advantage because it can provide detailed inventories of the sidewalk built environment. Analyzing this data with national and federal sidewalk guidance, American Community Survey (ACS) 5 year socio-economic and socio-demographic criteria, and differing municipal policies may provide insight to sidewalk width, accessibility, and any potential demographic disparities.

STUDY OVERVIEW

The United States is undergoing a shift in mentality to support increased access to mobility beyond the vehicle. Legislation, policies, projects, and programs from the federal government and advocacy groups have been paving the way to increase support and awareness (America Walks, 2008-2019; The National Center for Bicycling and Walking, 2002-2019; United States Department of Transportation, 2019a, 2019b; Walk Denver, 2018). Sidewalks provide access to safety, comfort, and greater opportunity for people of all ages and abilities to walk in our communities. Recent advances in technology is beginning to facilitate higher accuracy GIS data and provide access to detailed sidewalk built environment information in a select number of cities. This data, analyzed in comparison to national and federal guidance and municipal policy, can provide insight on sidewalk availability and width. This paper analyzes spatial sidewalk data at the Census block group level of geography through GIS spatial analyses to provide approximations for: i) sidewalk availability, measured as the ratio of sidewalk length to roadway length; and ii) average sidewalk width. Census data at the block group level also affords us the ability to incorporate demographic data into the investigation; therefore, we combine the quantitative results calculated in GIS with Census information in order to provide insight into potential disparities emerging.

City Selection

The initial step included selecting cities in the United States based on the following criteria: availability of high accuracy planimetrics sidewalk Geographic Information System (GIS) polygon data, similar population size based on American Community Survey (ACS) estimates of incorporated places, and an initial review of city sidewalk policies. The resulting cities with a policy placing the responsibility on the landowner were Denver and Portland. The cities with a municipal policy placing the responsibility on the city were Raleigh and Austin

Municipal Code and National Guidance

The following publications provide guidance on sidewalk metrics in the United States: the ADA, Federal Highway Administration (FHWA) Designing Sidewalks and Trails for Access, American Association of State Highway and Transportation Officials (AASHTO) Green Book, and the NACTO Urban Street Design Guide. The ADA law provides requirements and the aforementioned organizations publish guidelines on sidewalk width for people of all abilities to be able to walk safely and comfortably. This provides quantitative metrics to evaluate if each city's sidewalk width averages.

The ADA, most recently revised in 2010, states that an accessible path of travel must be provided, which is defined as an unobstructed pedestrian passage for approach, entrance, exit, and connection on sidewalks (Mahoney, 2012). More specifically, ADA Standards for Accessible Design (Chapter 4) states a standard clear width for accessible routes is 36 inches (91.44cm) (Mahoney, 2012). Please note that the 2011 US Access Board proposed guidelines, which will be enforceable under title II of the ADA when approved by the Department of Justice, state a continuous clear width of 4 feet (1.2m) (United States Access Board, 2011). The FHWA Designing Sidewalks and Trails for Access section (4.3.3) on width reiterates the ADA required continuous minimum width of 3 feet (0.91m) (Axelson et al., 1999). This research initially aimed to include additional sidewalk metrics such as ADA curb ramps, driveways, streetlights, signs, parking meters, and / or benches; however, for every dataset mentioned, at least one city does not readily provide a dataset. Therefore, the sidewalk data consists of a theoretical unobstructed pedestrian passage in all scenarios. As data collection and availability increases, these metrics may provide additional detail pertaining to sidewalk quality.

The AASHTO Green Book provides more detailed design metrics relevant to sidewalk width. The guidelines state a range in residential areas of 4 to 8 feet (1.2m to 2.4m) and 8 feet (2.4m) or greater in commercial areas (AASHTO, 1995). The overall minimum recommended width is 4 feet (1.2m). The NACTO Urban Street Design Guide has a slightly wider recommendation of an absolute minimum of 5 feet (1.52m) for all sidewalks; in addition, ranges are provided for residential and commercial of 5 – 7 feet (1.52m – 2.13m) and 8 – 12 feet (2.44m – 3.66m), respectively .

With a finalized selection of cities providing high accuracy spatial data and a baseline understanding of sidewalk guidelines, additional data and information obtained facilitated proper analysis. An evaluation of details such as timeframes, geographic boundaries, extent of data, and policy details, to name a few, enabled next steps formulating methodology and extracting results.

DATA

Sidewalks

Sidewalk geospatial data, year, and availability varied for each city in this study. Portland, Austin, and Raleigh have polygon geospatial data relevant to sidewalks through their city GIS data website. A third-party ArcGIS 10.2 extension, XTools Pro, provided a tool to create polyline (centerline) data from polygons for each of these cities. Denver is the exception where both polyline (centerline) and polygon data is available through the Denver Regional Council of Governments (DRCOG) website. The years for Denver, Portland, Austin, and Raleigh's data are 2016, 2018, 2015, and 2018, respectively.

Evaluation of metadata typically provided all of the details needed, and phone calls to city agencies verified information. One dataset for Denver, DRCOG 2016 planimetrics sidewalk polygons, contains a section in the metadata stating, "This feature includes paved sidewalks and paved trails with width greater than 5 feet." Phone conversation with DRCOG indicates the 5 foot or greater statement is subjective based on GIS staff visual judgement when digitizing the data. Further investigation reveals 282 out of 596 block groups contains an average less than 5 feet with data coverage for the entire city. This additional research identifies inclusion of sidewalks less than 5 feet in width and identifies a potential error in wording of the metadata.

Right-of-Way (ROW)

Municipal policies for all cities in this research mention responsibility pertaining to sidewalks within the ROW, which indicates an essential boundary needed for the analysis. After speaking with the GIS departments in Portland, Denver, and Raleigh, the GIS staff indicated that parcel lines typically denote private or commercial land and areas outside of these boundaries indicate the ROW. Spatial data denoting ROW boundaries only exists in Denver in polyline format, which cannot be used for analysis; therefore, utilizing parcel data provides an implied area denoting the ROW.

5-Year American Community Survey (ACS)

All ACS data provide estimated demographic economic statistical information obtained from the U.S. Census Bureau TIGER website (United States Census Bureau Geography Division, 2018). Please note that ACS data provide statistical estimates based on a sample of the population, which includes a varying degree of error, and differs from the decennial census provided to every U.S. household. The ACS five-year period corresponds to the year of each additional dataset obtained. This helps ensure continuity of data and the period represented. For instance, the sidewalk data available for Austin, Texas, was from 2015; therefore, the analysis incorporates the 2015 Census city boundary and the 2011-2015 5-year ACS data estimates. Census data availability at the time of analysis limited the data to 2016 as the most recent; therefore, any sidewalk data from 2017 or 2018 consists of analysis with Census data from 2016.

Data Omission

A review of the spatial data resulted in one anomaly omitted from the analysis. Denver contained one block group (GEOID: 080010084011) with no sidewalks where the Denver International Airport (DIA) is located.

METHODS

GIS Analysis

Step 1: Data projection

We projected all geospatial data for each city to the correct geographic and projected coordinate system.

Step 2: Prepare geospatial data for analysis

The datasets obtained for analysis did not align perfectly to city boundaries; furthermore, the boundaries for all data typically did not line up with each other (Figure 1). To elaborate on this, the analysis area consisted of Census block groups completely within each city boundary. Either the sidewalk or the parcel data, which approximates the ROW, only covered partial areas within block groups that intersected the city boundary and extended beyond. Therefore, analysis coverage did not consist of the entirety of the geographic area denoting the city boundary, only the entirety of block groups within it (Figure 1).

Figure 1: GIS data boundaries did not align, and sidewalk data only covered part of an intersecting block group outside of the city

Analyzing the comparative length of sidewalks and roads per block group in a GIS contains errors to note. Theoretically, for every mile of road, two miles of sidewalk should exist to represent availability on both sides of the road. Road centerlines extracted from Open Street Map through Boeing's OSMnx provide an efficient and effective method to export roadway network spatial data to conduct this analysis (Boeing, 2017).

Some roads represent a block group boundary; therefore, the roadway area spans into two separate block groups. GIS data introduces various difficulties in correctly accounting for this. First, GIS is not survey-grade data. Road centerlines can crisscross between boundaries or the line may only be present on one side of the boundary even though the roadway area spans into two boundaries, as shown in figures 2(a) and 2(b). Second, some sidewalk centerlines tend to "straddle" the block group boundary and road centerline in these scenarios, as shown in figure 2(c).

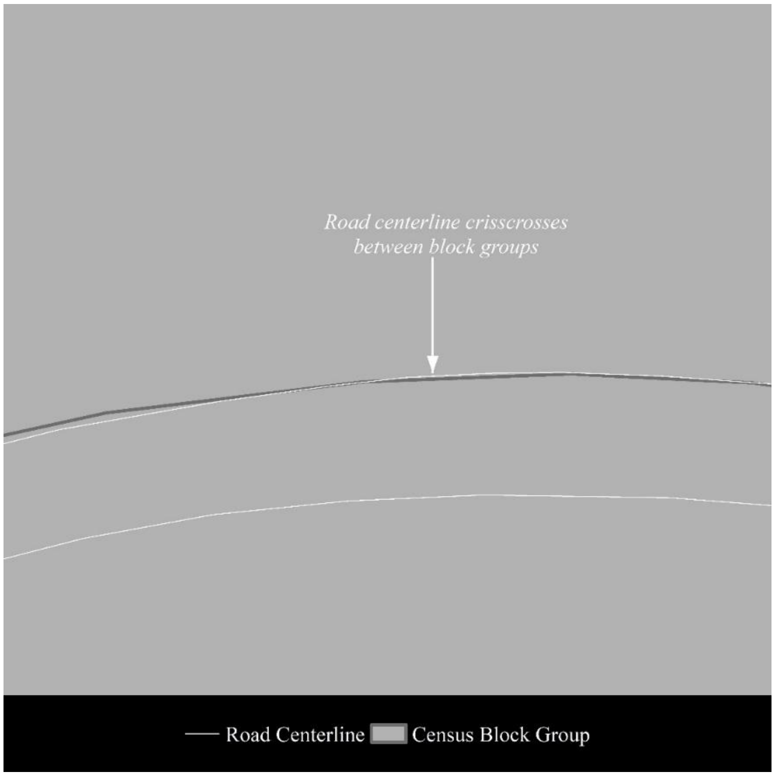

Figure 2(a): Road centerline crisscrossed between block groups

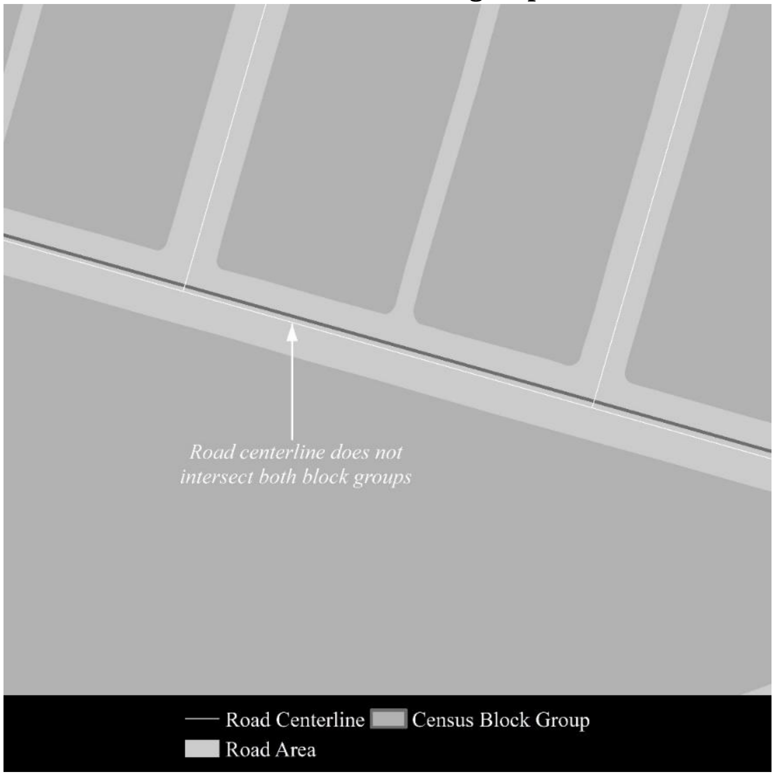

Figure 2(b): Road centerline only present in one block group

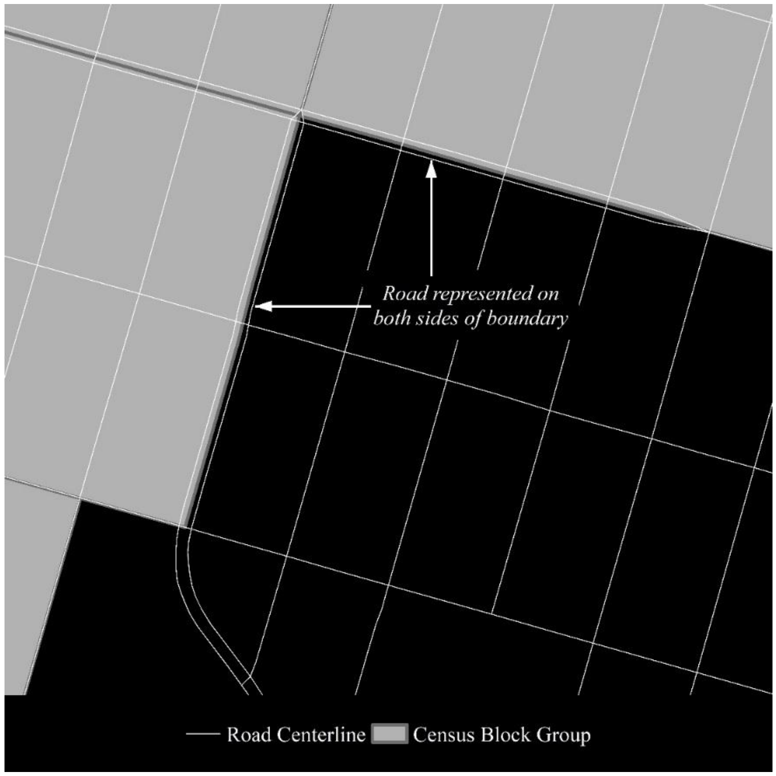

Figure 2(c): Parallel road centerline and block group boundary

Two tools in ArcGIS provide options to approach this issue: clip and spatial join. The clip tool, which cuts the road line and identifies it with the block group boundary it falls within, presented the lowest level of error. When roads crisscrossed block group boundaries as noted in figure 2(a), this tool resulted in some boundaries containing partial roads. In some instances, this tool omitted some roads in block groups due to the lines falling outside of the boundary as noted in figure 2(b). However, in cases where the original data contained parallel road centerlines placing it in both boundaries, each block group correctly accounted for the entire road as shown in figure 2(c).

Alternative attempts included using various approaches with the spatial join tool in ArcGIS to account for roads in more than one block group. Spatial join allows attributes from one feature to be integrated into either one or multiple other features based on query design. GIS provides a multitude of options for queries and analyses, so please note that these are not the only methods available.

The one-to-many spatial join identifies a road line intersecting more than one block group boundary. The result created a line for each block group, therefore duplicating its geometry. This approach proved to over exaggerate roadway mileage for the entire city. The one-to-one spatial join identifies a road line intersecting a block group boundary and identifies with only one of the intersecting boundaries. This approach proved to over exaggerate roadway mileage in some sections and under represent in other areas. An alternative one-to-one spatial join approach identifies with a road line if the center falls within a block group boundary. This approach resulted in exaggerated roadway mileage in some sections and underrepresented mileage in other areas, similar to the prior method.

Step 3: Clip sidewalk data to the ROW

The ROW constituted the area of interest to conduct analysis of sidewalks relevant to municipal policy. Sidewalk polygons and centerlines, as well as roadway centerlines clipped to this boundary, provided the essential areas and lengths to calculate availability and length. The cities in this research did not have

ROW spatial data, but as mentioned prior, parcel data provided an implied ROW. Implied essentially means that parcel data does not provide survey grade spatial locations and easements or other exceptions may not be accounted for in these datasets.

Boundaries from the parcel data did not always align with the sidewalk polygons, which sometimes omitted sections of a sidewalk area. The sidewalk centerlines were created in ArcGIS using the sidewalk polygons; therefore, in some instances, segments of sidewalk length were not accounted for when the parcel boundary encroached past the center of the sidewalk polygon. These omissions from the sidewalk polygons and centerlines resulted in errors for average sidewalk width and ratio of sidewalk length to roadway results as presented in Figure 3.

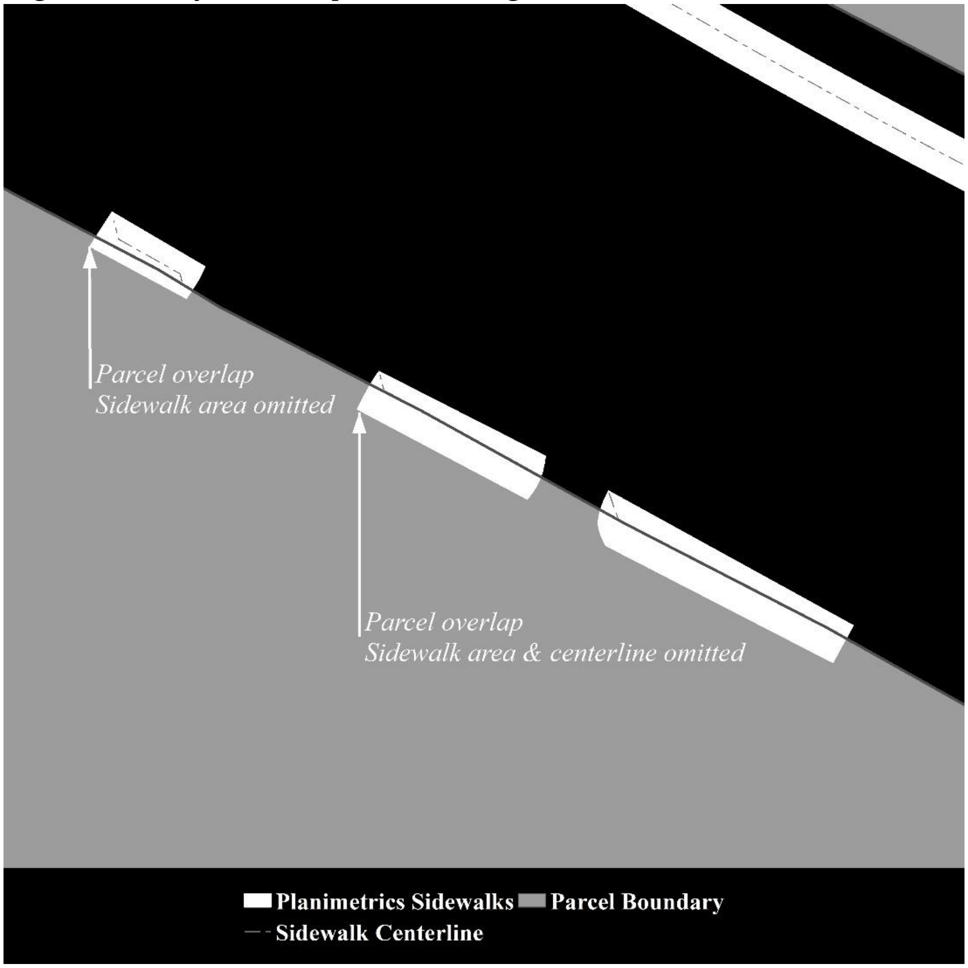

Figure 3: Sidewalk area and centerline omitted by ROW boundary

Step 4: Intersect Census block groups with sidewalk data in the ROW.

The Census block group was the primary container for the analysis to introduce socio-economic and socio-demographic numbers from the ACS. Sidewalk data intersected with block group boundaries provided the total length and total width of sidewalks per block group. The total sidewalk area (per block group) divided by the total centerline length (per block group) equaled the average sidewalk width (per block group).

RESULTS

Citywide Sidewalk Availability

The results show similar mean and median percent sidewalk coverage between Austin and Raleigh (city responsibility) at approximately 35 percent; in addition, Denver and Portland (landowner responsibility) are similar at approximately 60+ percent. The results also indicate that 97 to 100 percent of block groups in all cities, whether city or landowner responsibility, contain a ratio below 2:1 (sidewalk: road).

Table 1: Block group percent sidewalk coverage (100% represents 2:1 ratio)

Policy	City	Block Groups (n)	Mean	Median	Min	Max	≥100%
City	Austin	437	34.72%	31.18%	1.37%	100.00%	0.92%
	Raleigh	131	35.15%	33.56%	2.29%	78.63%	0%
Landowner	Denver	481	66.32%	67.71%	9.75%	100.00%	2.29%
	Portland	410	60.04%	68.99%	0.77%	95.05%	0%

Citywide Sidewalk Width

National guidance on sidewalk design from FHWA, AASHTO, and NACTO provided sidewalk width measures for comparison in each city. FHWA states the lowest width guidance requiring 3 ft (0.91m), followed by AASHTO at 4 ft (1.22m), and NACTO is the highest at 5 ft (1.52m). The sidewalks widths we show here represent the average width of existing sidewalks.

A correlation between municipal policy placing the responsibility on the city and national and federal guidance resulted from the analysis. Austin and Raleigh, city based sidewalk policy, show very similar overall percentages for sidewalks conforming to these guidelines.

Municipal policy for landowner responsibility reveals a stark difference in percentages. Portland shows the best numbers overall with a 97.6% width average of 5 ft (1.52m) or greater for every block group; however, Denver reflects the lowest average widths overall. Denver's narrow sidewalks would cost less to install and maintain, which may account for the availability numbers shown above.

Table 2: Number and percent of block groups at or below sidewalk guidance (FHWA, AASHTO, and NACTO)

Note: 1 ft = 0.305m

			Sidewalk width guidance in feet		
Policy	City	Below guidance	FHWA	AASHTO	NACTO
		< 3	*≥ 3 and <4*	*≥ 4 and < 5*	*≥ 5*
City	Austin	0 (0%)	9 (2.1%)	205 (46.9%)	223 (51.0%)
	Raleigh	0 (0%)	0 (0%)	65 (49.6%)	66 (50.4%)
Landowner	Denver	6 (1.3%)	112 (23.3%)	178 (37.0%)	185 (38.5%)
	Portland	0 (0%)	0 (0%)	10 (2.4%)	400 (97.6%)

Equity Disparities (Socio-Economic and Socio-Demographic)
The figures in this section depict the relative availability of sidewalks, or average sidewalk width, at the block group level with respect to various socio-economic or socio-demographic variables for each city individually. The intent of these graphs is to help us look for trends by city and/or municipal policy. While a linear best-fit regression line is not always the most representative of the underlying data, we include them for the sake of reference.

Median Household Income
Sidewalk Availability Figure 3a shows the relative availability of sidewalks at the block group level with respect to median household income. No obvious correlations to municipal policy exist in this category. Denver, Austin, and Raleigh show a decrease in ratio as median household income increases. Portland is a slight anomaly, showing an increase in ratio as income increases.

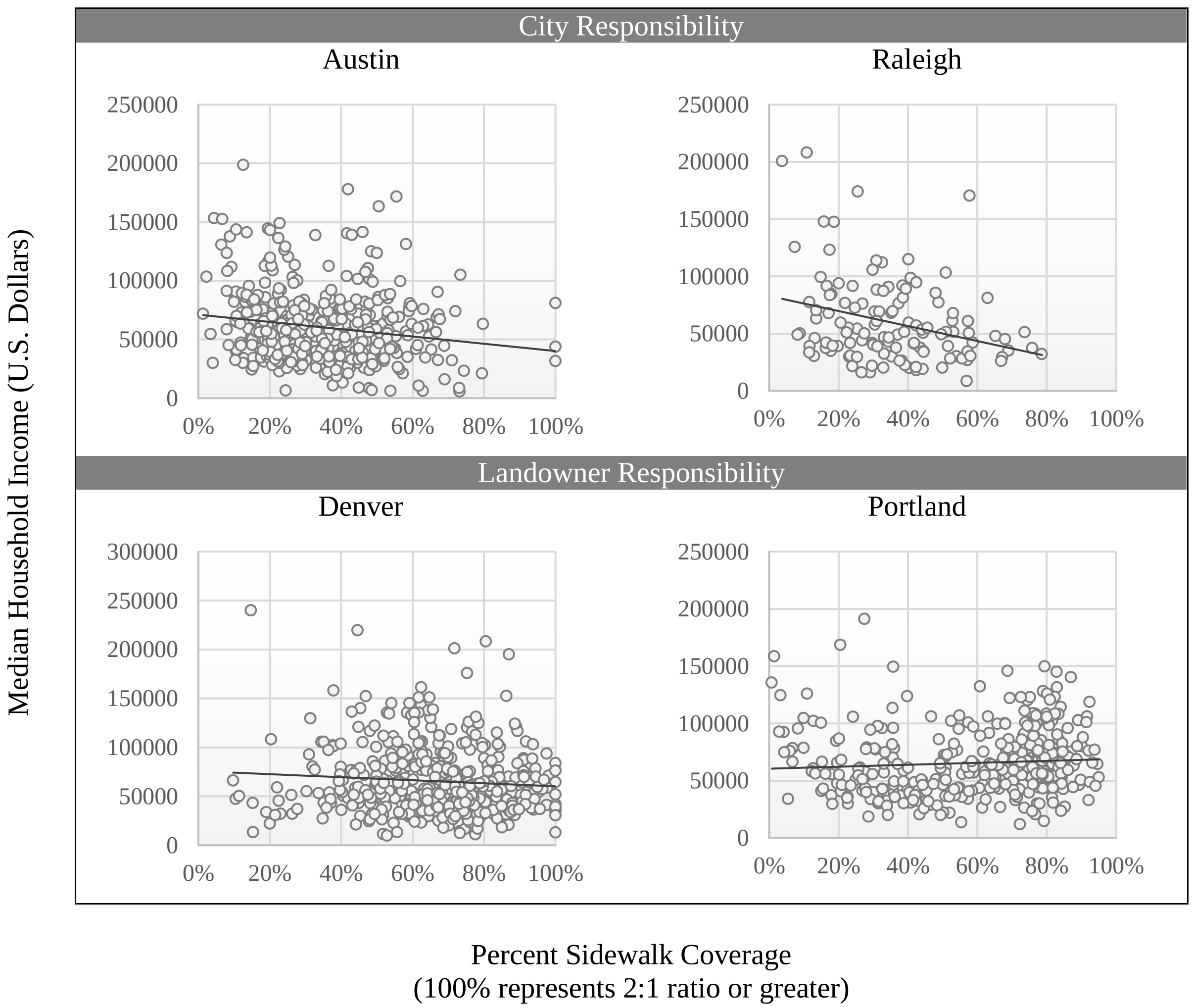

Figure 3(a): Availability: Median Household Income

Sidewalk Width Figure 3b depicts average sidewalk width in terms of median household income at the block group level. No correlations to municipal policy seem to exist in this category. As median household income increases for all four cities, the average sidewalk width tends to decrease.

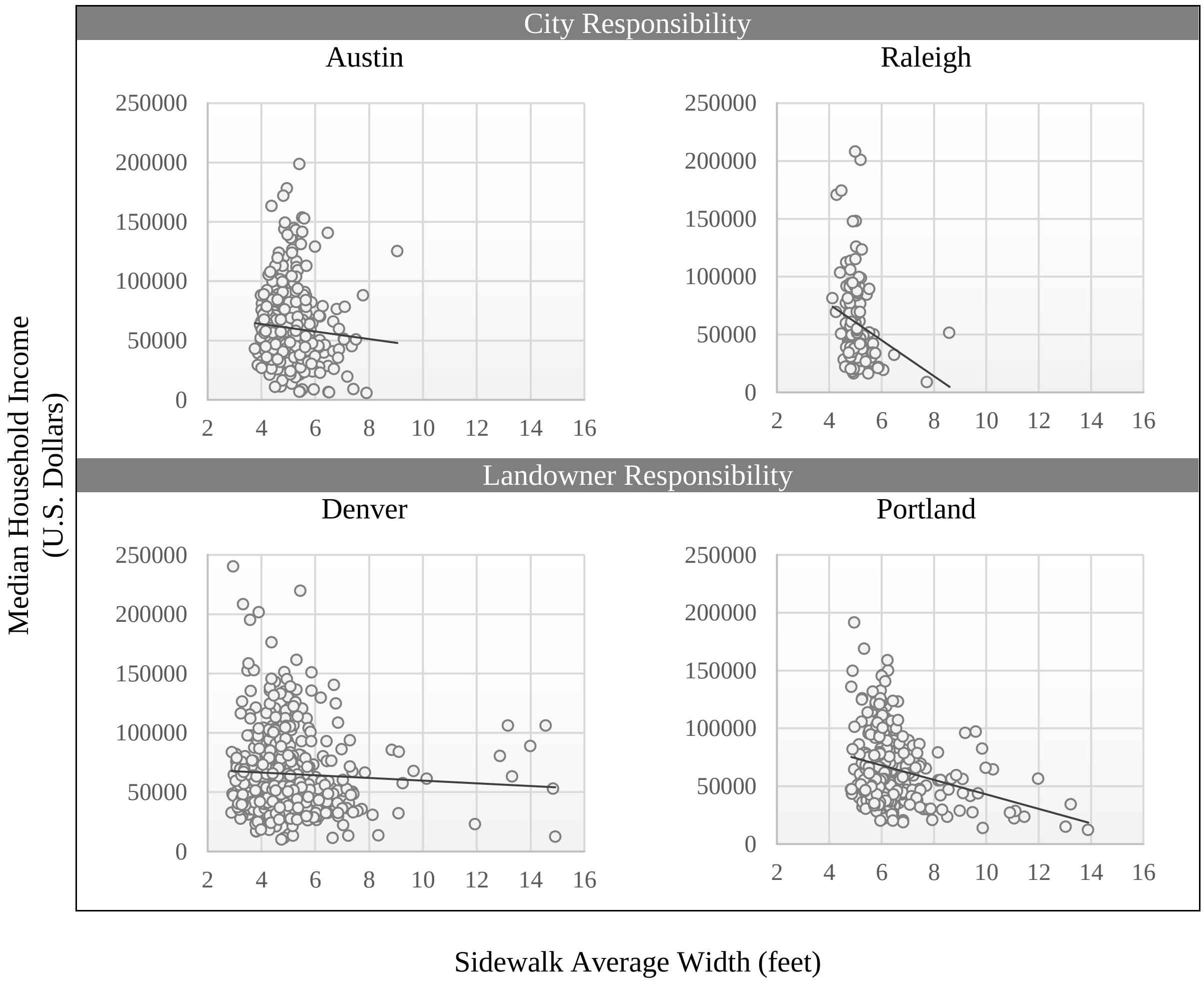

Figure 3(b): Width: Median Household Income

Poverty

Sidewalk Availability Figure 4a presents sidewalk availability in terms of the percent of residents living below the poverty line in a block group. The analysis seems to reveal some correlation among municipal policy, poverty, and sidewalk availability. The two cities that perform sidewalk maintenance themselves see a similar increasing trend of sidewalk availability and increasing percent below poverty while the two cities that place that responsibility on the homeowner show relatively flat trends with negligible increasing and decreasing trends respectively.

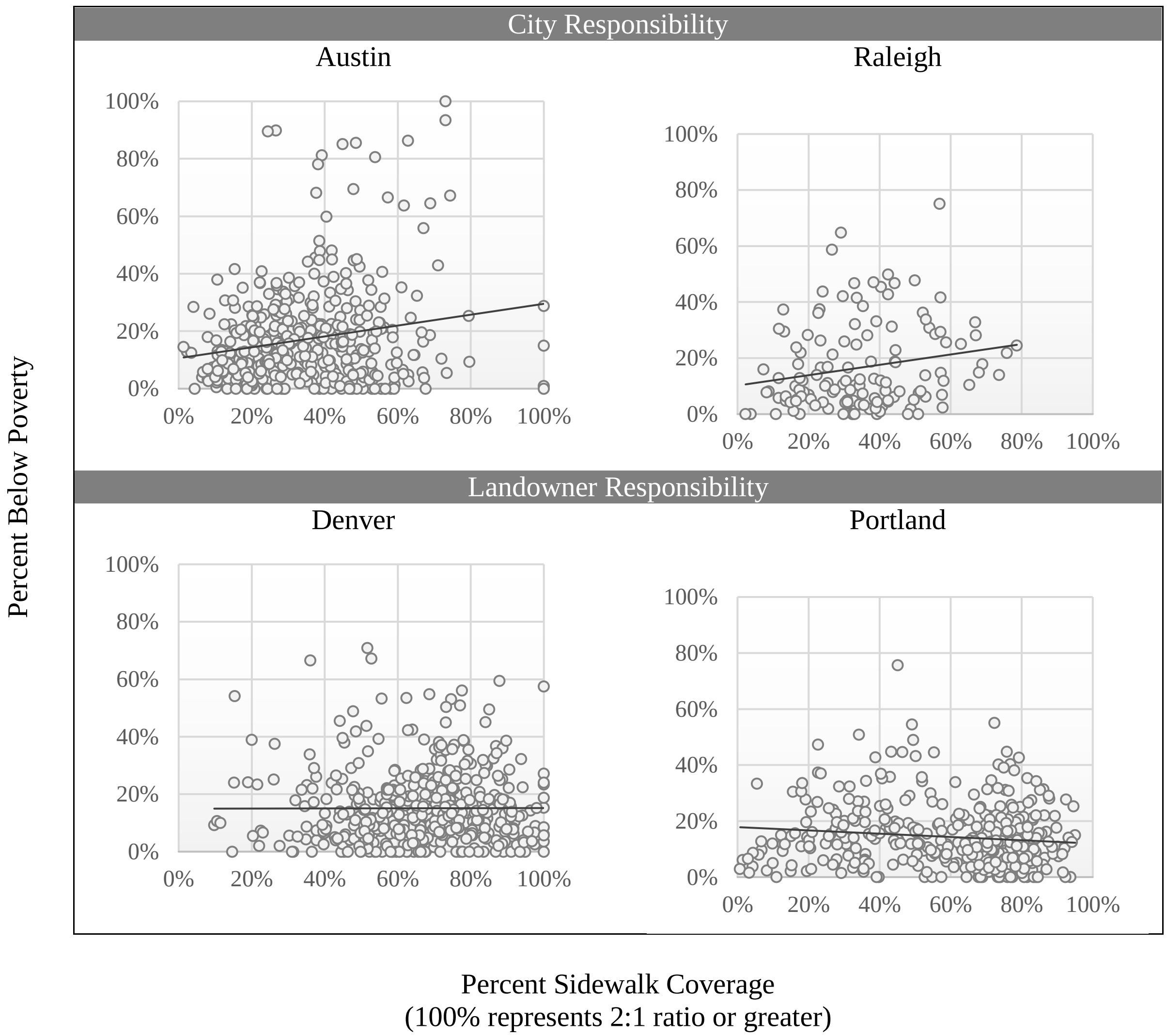

Figure 4(a): Availability: Percent Below Poverty

Sidewalk Width Figure 4b also shows the percent of residents living below the poverty line in a block group but this time in terms of average sidewalk width. No correlations to municipal policy seem to exist in this category. As the percentage of the population below poverty increases, the average sidewalk width increases for all four cities. The trend line is considerable for Austin and Portland but relatively modest for Raleigh and Denver, which suggest that city policy is not the defining factor.

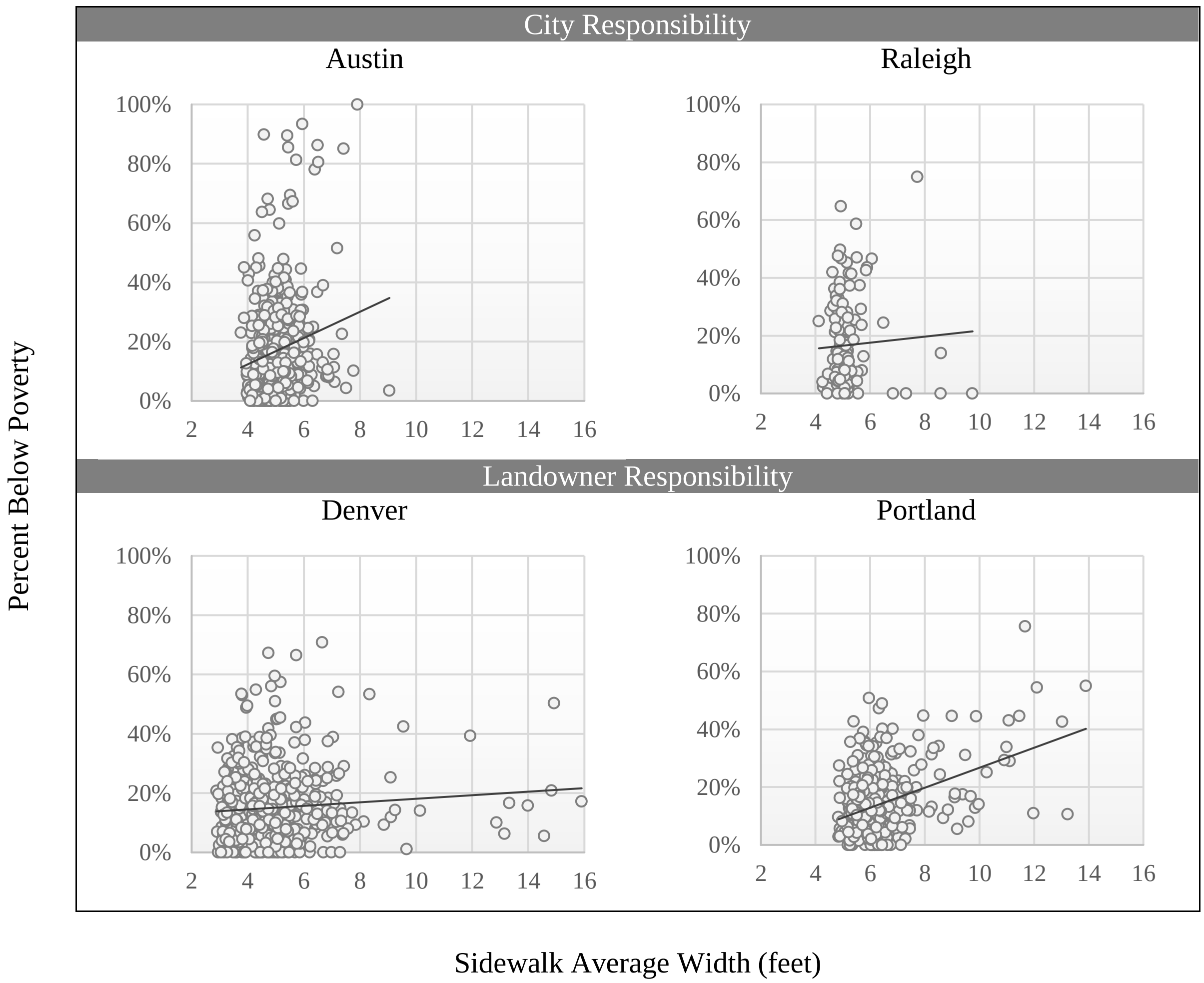

Figure 4(b): Width: Percent Below Poverty

Race/Ethnicity

Sidewalk Availability Figure 5a shows sidewalk availability in terms of three race/ethnicity variables the percent of block group residents that identify as White, the percent that identify as Black, and the percent that identify as Hispanic. No correlations to municipal policy seem to exist in this category. Denver and Raleigh show a trend of decreasing white population with an increasing ratio of sidewalk to road. Austin and Portland show the opposite with an increase for the White population as availability increases.

The trend line for the Black or African American population in Austin and Denver show a minor decrease, a steady increase in Raleigh, and a negligible increase in Portland.

Austin and Portland show a decrease in the Hispanic / Latino population as availability increases. Denver shows the opposite with an increasing population, although much less drastic, and Raleigh shows a negligible increase.

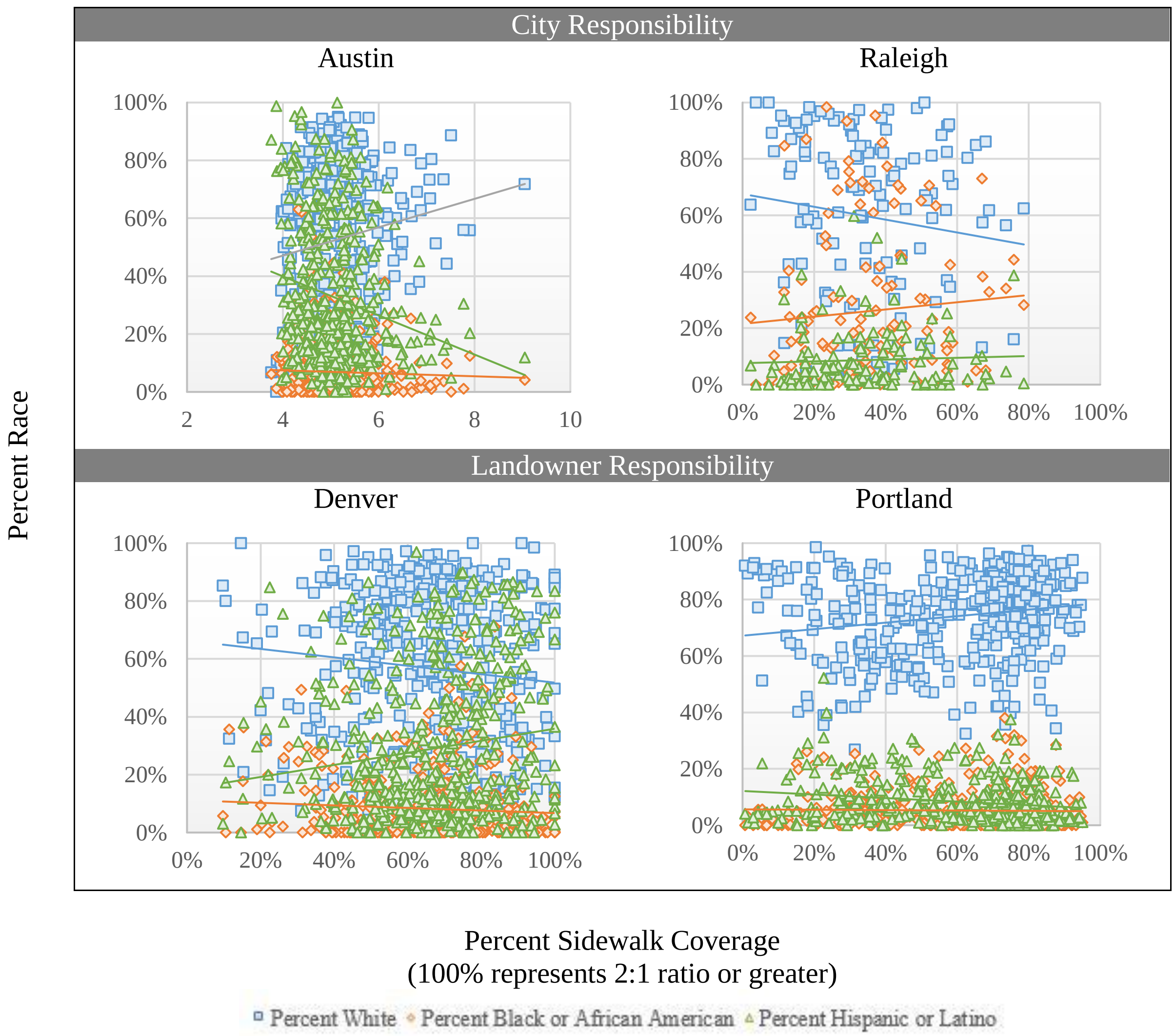

Figure 5(a): Availability: Percent Race

Sidewalk Width Figure 5b illustrates the same race/ethnicity variables as figure 5a but with respect to sidewalk width. No correlations to municipal policy seem to exist in this category either. Portland stays fairly level with little change for all groups; however, Denver shows a drastic increase in average sidewalk width correlating to the white population and decrease in width correlating to the Hispanic / Latino population.

Austin shows a similar trend to Denver with a drastic increase in average sidewalk width correlating to the white population and decrease in width correlating to the Hispanic / Latino population. Raleigh appears to be the anomaly showing a slight decrease for all races, with almost no change to the Hispanic/Latino population.

Figure 5(b): Width: Percent Race

Mode of Transportation to Work

Sidewalk Availability Figure 7(a) illustrates sidewalk availability in terms of four mode choice to work variables: driving, public transit, bicycling, and walking. A correlation between municipal policy placing the responsibility on the city and mode of transportation to work seems to result from this analysis. The cities that take on the responsibility, Austin and Raleigh, mirror each other with a decrease in driving and minor increase in walking and public transit as sidewalk availability increases. On the other hand, Denver shows a negligible increase for driving, walking, biking and public transit as sidewalk availability increases. Portland shows a considerable decrease in driving as sidewalk availability increases, a minor increase in biking, and increases in walking and public transit. Bicycling showed little change in all cities; therefore, the charts below do not display this to enhance clarity for the reader.

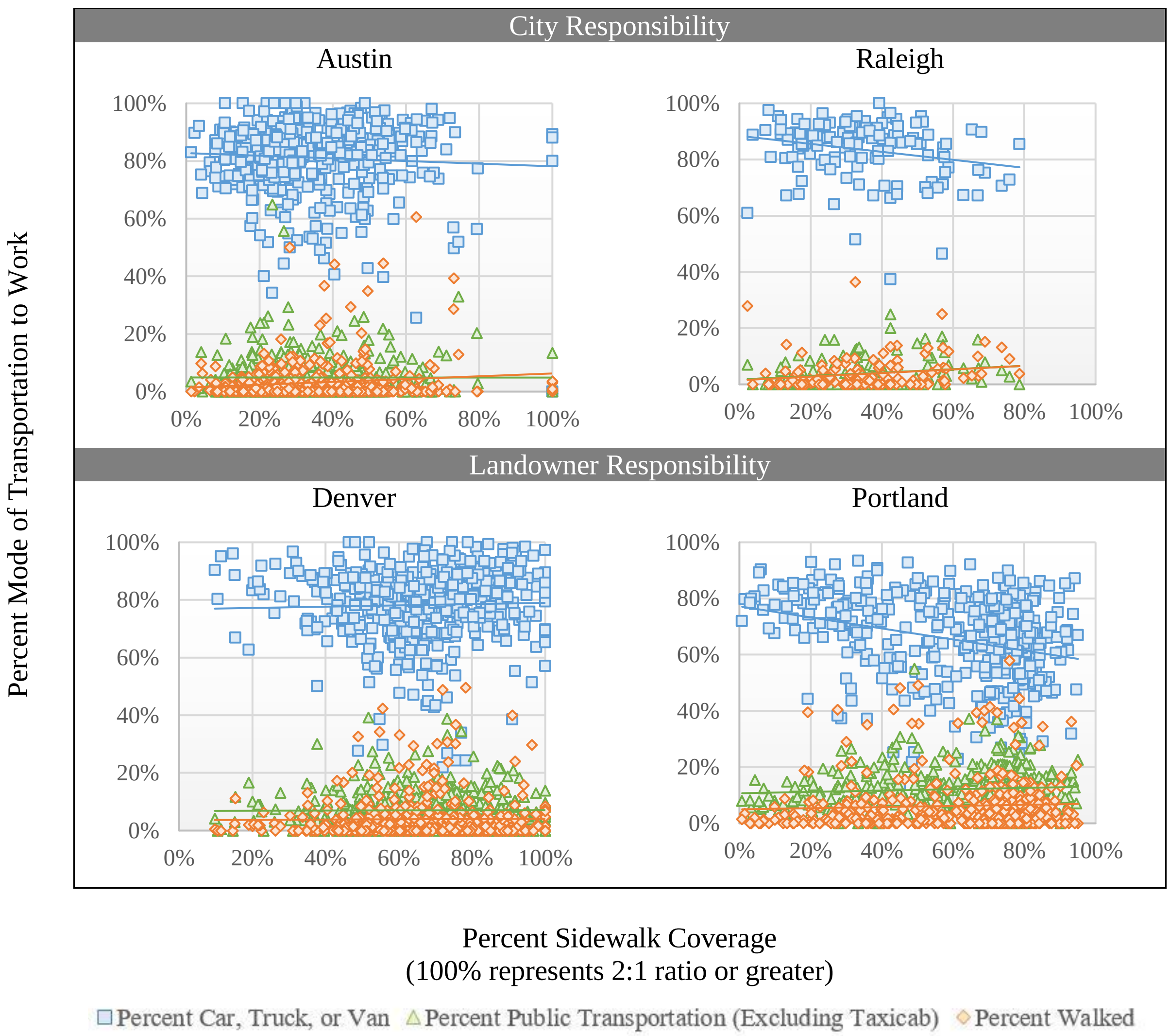

Figure 7(a): Availability: Percent Mode of Transportation to Work

Sidewalk Width Figure 7b shows similar mode choice results to figure 7a but with now with sidewalk width. Regardless of municipal policy, a correlation among all cities, mode of transportation to work, and sidewalk width resulted from the analysis. For every city, walking increased and driving (car, truck, or van) reflected a significant decrease as the average sidewalk widths increased. In addition, all cities show a slight increase for public transportation as widths increased. Bicycling showed little to no change in all cities; therefore, the charts below do not display this to enhance clarity for the reader.

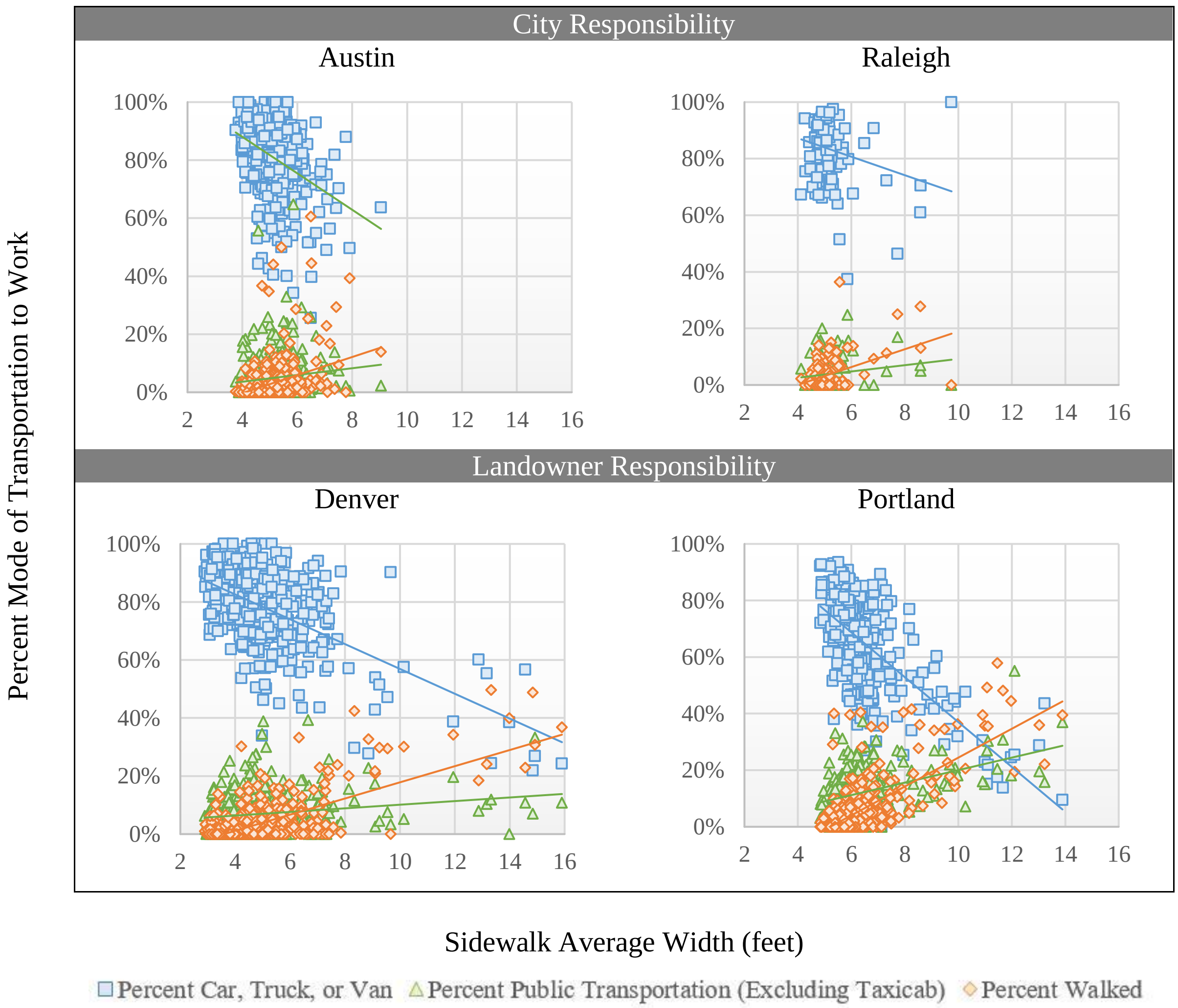

Figure 7(b): Width: Percent Mode of Transportation to Work

CONCLUSION

Sidewalk availability in all four cities seems to be lacking; however, please note that this research did not account for nuances within these cities such as zoning, planning, and historical annexation. Delving further into these intricacies of each city may prove to reveal detail to this subject. NACTO states: "sidewalks should be provided on both sides of all streets in all urban areas," (National Association of City Transportation Officials et al., 2013) and this analysis shows a poor result with many block groups falling well below 100% sidewalk coverage regardless of policy. Digging further into the numbers, though, municipal policy shows a strong correlation of availability of sidewalks with mean and median coverage percentages. However, the cities in our dataset that place the onus on landowners tended to have much better sidewalk availability than cities that take on that responsibility themselves. This may introduce new topics worth researching, such as sidewalk policies in areas *prior* to land ascertained by the city or policies in place for new development. These may reveal why more or less sidewalks appear in newly attained land or with new developments erected in cities.

Our results suggest various equity issues with respect to sidewalk availability and width in all four cities, but at this point, there is little to suggest that municipal policy is the key difference. For instance, Denver and Austin, even though having different policies, show a correlation among race, sidewalk availability and width. The result with the strongest link to municipal policy seemed to be percent living in poverty and sidewalk availability. In other words, those living below the poverty line in cities that take on sidewalk maintenance tended to have better sidewalk availability as compared to lower income residents of cities where the onus falls on the homeowner. In terms of mode choice, blocks groups with better sidewalk availability and wider sidewalks also tended to be those with lower driving rates and higher walking rates.

An additional note worth mentioning pertains to the overall cost and allotted funding in cities. Denver states at average cost of $1.1 billion to complete the sidewalk network (City and County of Denver Department of Public Works, 2017). Based on funding scenarios provided by the city, it could take 27.5 to 440 years to complete (City and County of Denver Department of Public Works, 2017). Another impractical and overlooked part to this is the expected life of the sidewalk before requiring repairs or replacement. According to a National Academies Press report with responses from U.S. and Canadian cities, the estimated service life of asphalt sidewalks is 5 to 20 years and concrete sidewalks is 20 to 60 years (Markow et al., 2007). In addition, to the life expectancy, this same study revealed that no city chose preventative maintenance for sidewalks (Markow et al., 2007). The implication is that sidewalks are an afterthought and the infrastructure is only evaluated, upgraded, or managed when needed from the city's viewpoint.

Even though spatial data has become considerably more accurate and pervasive, there still exists inaccuracies noted in this paper such as differing boundaries among datasets, which could lead to some inaccuracies. GIS provides the ability to analyze data with various approaches and thus the ability to refine these results exists with the potential advent of higher accuracy data, refined software, or an alternative approach to the methods noted in this paper.

The results from this study add to the sparse literature on this topic, but we primarily show that more research is needed. Sidewalks can be a major benefit to cities as well as those that live, work, or play there. Rarely is the issue of sidewalk maintenance a hot topic of conversation. Yet, few transportation topics are more talked about than active transportation. Disparities in funding and maintenance for streets versus sidewalks needs to be discussed and the implications of these differences better understood.

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