MPC-579
December 14, 2018

Project Title

Where the Sidewalk Ends: Equity Disparities with Respect to Municipal Maintenance Policy

University

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Research Needs

Sidewalks are a fundamental – yet undervalued – component of urban transportation networks. Not only do they facilitate pedestrian movement, but even those traveling by other modes such as transit, bicycling, or driving typically need to use a sidewalk to reach their destination. Yet unlike the rest of the right-of-way, many municipalities place the financial onus for the maintenance and replacement of sidewalks on the adjacent property owner. The resulting sidewalk network can often be inconsistent and the means to fix them inefficient. Moreover, there may be disparities in the provision and quality of sidewalk infrastructure based on race, ethnicity, and/or income. This issue is of particular importance because lower income groups and minority populations tend to be more reliant upon walking (McKenzie 2014). Related to this issue, these populations also experience disproportional health (Kelly, Schootman et al. 2007) and road safety (Marshall and Ferenchak 2017) impacts.

The conveyance of responsibility for sidewalk construction and repair onto adjacent property owners is commonplace in the United States and includes cities such as Atlanta, Cincinnati, Denver, New Orleans, New York, Philadelphia, Phoenix, and Seattle (Hicks 2014, del Pilar Rodriguez and Rowangould 2017). Before cars came to prominence in the early 1900s, however, sidewalks were viewed as an essential component of urban transportation and a public good that was more often built and maintained by the municipality (Ehrenfeucht and Loukaitou-Sideris 2007). Soon, our collective conceptualization of streets began to shift away from people and more towards a need for the through movement of cars (Norton 2008). This shift seemed to coincide with the view that sidewalks were an amenity that mostly benefited the abutting property owner (Ehrenfeucht and Loukaitou-Sideris 2007). Instead of subsidizing sidewalk infrastructure that would supposedly only serve to increase the value of the surrounding properties, many cities chose instead to put the onus onto those that would notionally stand to benefit, the adjacent property owners (Ehrenfeucht and Loukaitou-Sideris 2007). Although some cities such as Boston and Washington DC continue to maintain responsibility for sidewalks, the "amenity" mindset combined with a fear that cities would potentially be liable for incidents taking place on poorly maintained sidewalk led to a national trend to shift responsibility away from cities and onto property owners (Ehrenfeucht and Loukaitou-Sideris 2007, Loukaitou-Sideris and Ehrenfeucht 2009, Ehrenfeucht and Loukaitou-Sideris 2010, Hicks 2014).

The cost of construction or repair of a sidewalk can be considerable. According to an online site connecting homeowners with trade companies, the average cost of sidewalk repair can vary from \$5 to \$15 per square foot. The National Association of City Transportation Officials (NACTO 2013) Urban Street Design Guide requires an absolute minimum 5 foot width, which equates to a \$500 to \$1,500 price tag for only a 20 foot long section. These numbers can spike when drainage considerations become an issue and can become a considerable burden if the responsibility is on the homeowner.

This combination of issues evokes the question: does variation in municipal sidewalk responsibility policy relate to the supply and quality of sidewalks in cities? Furthermore, are there significant sidewalk disparities based on income, race, or ethnicity in neighborhoods across a city?

Despite these well-known policy differences, and the potential for equity issues, the relevant research remains relatively limited. A thesis by Manning investigated 100 streets in Fremont, California – a city that places responsibility on the abutting property owner – and found little difference based upon income (Manning 2014). A study conducted by del Pilar Rodriguez and Rowangould in a city with the same policy – Albuquerque, New Mexico – conducted field based observations in 100 block groups, resulting in no evidence of disparity between quality of sidewalks and income (del Pilar Rodriguez and Rowangould 2017). A more recent study by Bise et. al. looked into race and sidewalks in a small Mississippi town with a similar sidewalk policy and showed relatively equal sidewalk access for white and black residents but considerably better sidewalk quality in whiter neighborhoods (Bise, Rodgers et al. 2018). While these are all good papers, they also focus on relatively small sample sizes and, in some cases, non-random site selection. All of the above studies also concentrate solely on locations where the cities place the responsibility for sidewalks on the adjacent property owner, and this strand of research has yet to adequately compare outcomes related to differing municipal policies.

One of the main reasons behind the small sample sizes in the above studies is the lack of comprehensive sidewalk data. Fortunately, cities are now beginning to collect planimetric spatial data from high resolution aerial imagery. Such remotely sensed data means that we can move beyond a simple binary assessment of sidewalk presence and begin to systematically consider factors such as sidewalk width, consistency, and connectivity for entire cities. This level of data is particularly important in cities such as Denver that often relied upon "Hollywood" sidewalks, which are only 18” wide with sloped curbs that, although they are often counted as a sidewalk, do not meet Americans with Disabilities (ADA) accessibility standards.

Walking is once again considered fundamental to urban areas (NACTO 2013). Unfortunately, our sidewalk infrastructure and the policies related to the funding and maintenance of that sidewalk network have yet to catch up with this perspective. The goal in this research project is to conduct a comprehensive spatial analysis of the sidewalk infrastructure of four cities: two cities that take on the responsibility of sidewalks, and two that put that responsibility onto the abutting property owners. As discussed above, we will ask the question as to whether variation in sidewalk maintenance policy impacts how sidewalks are being supplied and maintained in cities as well as if there are differences in the provision and condition of sidewalks based on income, race, or ethnicity in neighborhoods across these cities. In attempting to answer these questions, we will account for sidewalk supply as well as quality, state of disrepair, urban design, street design, and connectivity as well as potentially confounding factors such as land use (as we would expect wider sidewalks in areas with more commercial land uses or near schools). We will also consider disparities with linkages to important destinations – including transit stops – as well as the impact of these differences on safety outcomes. Beyond the direct policy implications of this research, this work will also speak to environmental justice as well as ADA accessibility.

Research Objectives

This study will utilize Geographic Information Systems (GIS) to analyze sidewalks at the Census block group scale for four US cities. More specifically, the objectives of this study are to:

1. Investigate municipal sidewalk policies over time as well as data availability in order to select the four study cities
2. Collect sidewalk and built environment data
3. Gather socio-demographic and socio-economic data
4. Collect pedestrian counts and safety data
5. Advance knowledge by carrying out analyses to answer our research questions
6. Advance policy and practice with respect to building safer and more equitable cities
7. Advance education through the training of students
8. Build an evidence base by disseminating findings through publications and presentations

Research Methods

These efforts will initiate with a thorough literature review of research related to sidewalk infrastructure policy, provision, and maintenance. The next step will involve site selection, which will be based, in part, on the presence of secondary sidewalk data based on remote sensing. In our preliminary investigation, we acquired potentially useful sidewalk data from Denver, CO, Raleigh, NC, Virginia Beach, VA, Seattle, WA, and Austin, TX. We intend to first delve into the history of municipal sidewalk policies for these cities and the accuracy/applicability of their data before focusing in on four study cities: two with side maintenance responsibility held by the city; and two where that responsibility lies with the property owner.

This study design envisions a spatial Census block group-level analysis of the built environment to determine if municipal policy associates with the quality and availability of sidewalks with respect to socio-demographic and/or socio-economic differences. Our preliminary work with the planimetric sidewalk data suggests that we will be able to develop sidewalk metrics heretofore unseen at the scale of a major US city. However, sidewalk data, particularly when it is derived from remote sensing sources, can be a tricky proposition. Thus, we plan to expend significant effort in verifying that our metrics correspond with what we are seeing and what road users would experience in the field. This will include comparing our GIS-based sidewalk measures with a sample of micro-scale built environment data that we will collect using an urban design measurement guide developed and rigorously corroborated by Ewing and Clemente (Ewing and Clemente 2013).

Upon completing our sidewalk and built environment data collection efforts, we will move on to collecting American Community Survey (ACS) for our cities at the Block Group level and begin exploring income, racial, and ethnic disparities. For this work, we will employ the Kruskal-Wallis H test, which is similar to a t-test or ANOVA but does not require normal distributions and also allows for the comparison of more than two groups simultaneously (Laerd Statistics n.d., UCLA Statistical Consulting Group n.d.). This research project will also consider confounding factors such as land use as well as access to important destinations and transit stops. This work will require a significant data collection effort but will facilitate a comprehensive equity analysis.

A related question we hope to answer with this research is whether any of the disparities we may find in sidewalk provision and quality associate with differences in pedestrian safety outcomes. To answer this question, we will initially conduct a crash cluster analysis that analyzes the spatial relationship among pedestrian crashes in order to identify statistically significant crash clusters. The Hotspot Analysis GIS tool, created by ESRI and available in ArcMap, scrutinizes the data to develop both high and low values spatial clusters. In other words, it identifies statistically significant hot spots and cold spots.

Each crash is considered a single, equally-weighted incident, and the Hotspot Analysis tool aggregates clustered crashes into a mean centroid point. It then outputs the Getis-Ord Gi* (pronounced G-i-star) statistic, which serves as a confidence interval for the identified clusters and indicates the statistical significance of the cluster, as such (ESRI n.d.):

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \overline{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j} \right)^2 \right]}{n-1}}}$$

where: G_i^* = Getis-Ord Local Statistic
$w_{i,j}$ = Spatial Weight between Feature i and j
x_j = Attribute Value for Feature j
n = Total Number of Features

$$\overline{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \left(\overline{X}\right)^2}$$

Using ArcMap's Directional Distribution tool, we will focus on clusters that reach 95% confidence and use those clusters to develop deviational ellipses. Standard deviational ellipses measure crash dispersion and orientation around the mean center of the cluster. The axes of the ellipses are defined using the standard deviation of the distance between the mean center and the x- and y-coordinates (Schneider, Ryznar et al. 2004, ESRI n.d.):

$$C = \begin{pmatrix} var(x) & cov(x,y) \\ cov(y,x) & var(y) \end{pmatrix} = \frac{1}{n}\begin{pmatrix} \sum_{i=1}^{n} \tilde{x}_i^2 & \sum_{i=1}^{n} \tilde{x}_i \tilde{y}_i \\ \sum_{i=1}^{n} \tilde{x}_i \tilde{y}_i & \sum_{i=1}^{n} \tilde{y}_i^2 \end{pmatrix}$$

where: C = Standard Deviational Ellipse
x, y = Coordinate for the Feature
$\{\bar{x}, \bar{y}\}$ = Mean Center for the Feature
n = Total Number of Features

$$var(x) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2 = \frac{1}{n}\sum_{i=1}^{n} \tilde{x}_i^2$$

$$cov(x,y) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})\,(y_i - \bar{y}) = \frac{1}{n}\sum_{i=1}^{n} \tilde{x}_i \tilde{y}_i$$

$$var(y) = \frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})^2 = \frac{1}{n}\sum_{i=1}^{n} \tilde{y}_i^2$$

The sample covariate matrix can then be factored into standard form and represented by eigenvectors with standard deviations as follows:

$$\sigma_{1,2} = \left(\frac{\left(\sum_{i=1}^{n} \tilde{x}_i^2 + \sum_{i=1}^{n} \tilde{y}_i^2\right) \pm \sqrt{\left(\sum_{i=1}^{n} \tilde{x}_i^2 - \sum_{i=1}^{n} \tilde{y}_i^2\right)^2 + 4\left(\sum_{i=1}^{n} \tilde{x}_i \tilde{y}_i\right)^2}}{2n} \right)^{0.5}$$

Because crash data tends to be over-dispersed, we will then use a multilevel negative binomial model with pedestrian crashes or pedestrian fatality counts as the dependent variable. With spatial research, our data is multilevel because it consists of crashes at the neighborhood level that can be clustered into a second level of geography at the city level. A multilevel hierarchical model essentially links a pair of statistical models to account for this multilevel relationship and the interaction between levels (Healy 2001). This helps account for spatial autocorrelation and the possibility that people living in the same city share the characteristics of that city, which would violate the independence assumption of an ordinary least squares regression (Ewing, Schmid et al. 2003). Not taking this into account may underestimate the standard errors of regression coefficients (Ewing, Schmid et al. 2003).

Take, for instance, the following sample hierarchical structure:
Level 1: Between-Neighborhood Disparities
Level 2: Between-City Differences

Level 1 includes safety outcomes, our dependent variable, as well as socio-economic/socio-demographic data and our built environment data. This can be modeled as a function of the between-neighborhood characteristics plus stochastic random error (Ewing, Schmid et al. 2003).

$$Y_{ji} = \beta_{0j} + \beta_{1j}x_{ij} + r_{ij} \qquad\qquad r_{ij} \sim N(0, \sigma^2)$$

where Y_{ji} is the outcome for neighborhood i in city j, and x_{ij} is a fixed covariate. β_{0j} represents the mean level of the outcome in city j, and β_{1j} represents the effect of the neighborhood-level variable on the outcome in city j.

With level 2, the city-specific intercept and coefficients are modeled in terms of city characteristics plus random error (Ewing, Schmid et al. 2003). A random effects level 2 model would allow for the intercept and slope to vary across cities and connect to the level 1 random coefficients model as follows:

$$\beta_{0j} = \gamma_{00} + u_{0j} \qquad\qquad \begin{pmatrix} u_{0j} \\ u_{1j} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \tau_{00} & \tau_{01} \\ \tau_{01} & \tau_{11} \end{pmatrix}\right)$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

where γ_{00} represents the overall average outcome level (at $x_{ij} = 0$), and γ_{10} is the average effect of neighborhood variables on safety. The final variables used in the models will be chosen to maximize model significance via the AIC value.

Using the above methods, we will investigate the statistical relationship between sidewalks and safety measures while accounting for other relevant variables that speak to equity including race, ethnicity, and income.

Expected Outcomes

In cities that place the responsibility of sidewalk repair and maintenance on the adjacent property owner, we hypothesize greater disparities in sidewalk supply and quality than in places where that responsibility falls on the city. If that proves to be the case, there are clear environmental justice concerns and policy implications. If not, then we will seek to understand the details of how these programs are able to maintain equity despite a sidewalk maintenance policy that would seem to make that outcome difficult. Our safety models will shed light on the importance of any disparities we find and begin to speak to issues of accessibility, health, environmental justice, and liability. The expected outcomes of this work will also include:

1. Findings with respect to the hypotheses and research questions
2. Manuscripts for presentation/publication at TRB and other peer-reviewed journals
3. Presentations to academic and policy audiences
4. A new module regarding environmental justice and transportation equity for a graduate-level sustainable transportation course at the University of Colorado Denver

Relevance to Strategic Goals

This project links to nearly all of the FAST Act strategic goals with the top two being preserving the existing transportation system and promoting safety.

Educational Benefits

This study will be integrated into Dr. Marshall's "Sustainable Transportation Systems" graduate course through a case study approach that will present research materials to the students and provide the opportunity for students to get involved in data collection and analysis as part of their term projects. The course is based in the Civil Engineering Department but cross-listed in Urban and Regional Planning as well as Public Administration. The GIS data will also be made available to students in the Master's of Engineering GIS program for use in term projects or master's reports. As a result, this project will influence students from a variety of disciplines that comprise our future transportation professionals.

Technology Transfer

In terms of dissemination, the intent is to target both academic and practitioner audiences. For academic audiences, we will produce conference presentations and peer-reviewed journal papers. To share findings of this project with broader audiences in mind, we will make sure these results are disseminated via newsletter and/or popular press articles and presented at more practitioner-oriented conferences. We also will seek to coordinate with City Council members and non-profit groups such as WalkDenver with the goal of linking our results to policy.

Work Plan

The proposed scope of work is scheduled for a one-year timeframe that will begin with a look into the existing literature and historical municipal codes regarding municipal sidewalk maintenance polies. During this time, we will also be collecting and evaluating extensive sidewalk data, built environment data, as well as socio-economic and socio-demographic data. In month 4, we will finalize our city selection. The goal is to have two cities with a policy that places the sidewalk onus on the abutting property owner and two where the city maintains that responsibility. Months 6 through 9 will be dedicated to data analysis. We will then draft manuscripts and presentation materials in months 10 through 12. Over the course of the project, this work will be incorporated into lessons for a teaching module within graduate-level sustainable transportation course.

Task	Timeline
Literature review	Months 1 – 2
Sidewalk data collection and evaluation	Months 2 – 5
Municipal code research and secondary data evaluation	Months 2 – 5
Select cities for analysis	Month 3
Analyze data	Months 6 – 9
Incorporate lessons into transportation classes	Months 6 – 10
Draft paper and presentation materials	Months 10 – 12

Project Cost

Total Project Costs:	$258,313.20
MPC Funds Requested:	$129,156.60
Matching Funds:	$129,156.60
Source of Matching Funds:	University of Colorado Denver

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