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How walkable is Walker's paradise?

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Abstract

This article tests the extent to which a measure of walkable access is a good proxy for the quality of the walking environment. Based on existing findings on inequalities of walkability, we ask whether this relation varies between neighborhoods with low and high incomes. Walk Score is used to measure walkable access while the State of Place Index is applied to synthesize the qualitative urban form dimensions collected as part of the Irvine Minnesota Inventory. Simple bivariate correlations and difference-in-means tests assess the relationship and difference in average scores between the two. We draw on an existing sample of 115 walkable neighborhoods in the Washington, DC metro area that Mariela Alfonzo and colleagues had collected for previous research and that we augmented to include additional low-income neighborhoods. Our results reveal a strong and positive overall association between walkable access (Walk Score) and walkability (State of Place). However, this association masks problems with the quality of the walking environment that are significantly larger in low-income neighborhoods (even those with very good walkable access), especially regarding connectivity, personal safety, and the presence of litter and graffiti. As a proxy for walkability, Walk Score's walkable access measure is, therefore, not equally strong across all neighborhoods but declines with income. In this sense, Walker's Paradise is more walkable in higher than low-income neighborhoods.

Keywords

accessibility, built environment, design methods

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Introduction

A growing body of evidence has been quantifying the benefits of walking for the physical health of individuals, the sustainability of communities, and the economic well-being of neighborhoods. Recent book titles reflect the grand visions and hopes associated with walkable cities in this context: *The Option of Urbanism: Investing in a New American Dream* (Leinberger, 2009), *Walkable City: How Downtown can Save America* (Speck, 2012), and *The Metropolitan Revolution: How Cities and Metros Are Fixing our Broken Politics and Fragile Economy* (Katz, 2013). Furthermore, a host of institutions, initiatives, and web applications now exist to help motivate increased walking: There is now an *International Charter for Walking*, conferences on walking (*Walk21*), nonprofit campaigns, and initiatives to get people to walk, such as *America Walks* (and its initiative *Steps to a Walkable Community*), or *Every Body Walk!*

Simultaneously, demand for living in communities that are friendly to walking has been booming in recent years. Moving to a "Walker's Paradise"—a community with well connected and pedestrian-friendly streets, mixed land uses, easy bike and transit access, diverse residents, and a rich set of destinations—has become an attractive alternative to suburbia for many. Meeting the demand for walkable communities has even been characterized as part of the "future of American power" (Doherty, 2013).

As we will show later, recent evidence points to a positive relationship between the propensity to walk and characteristics of the built environment such as walkable proximity to amenities and pedestrian-friendliness of the built environment (like safety, sidewalks, and aesthetics). At the same time, pedestrian-friendliness and safety are often compromised in low-income neighborhoods.

Commensurate with this demand and evidence, planners and planning research have focused on factors related to increasing the walkability of the built environment through strategies such as retrofitting suburbia, upzoning, mixed-use development and densification, and complete streets (Talen, 2015). These efforts spurred an interest in baseline measurements of how walkable urban neighborhoods actually are. As expected, some dimensions of walkable neighborhoods are easier to assess than others: For instance, the number of amenities within walking distance is easier to define and measure at scale than qualitative aspects of the walking environment.

As a result, a number of large scale, web-based and automated measures of access to amenities within walking distance exist. In this context, Walk Score has gained enormous popularity as the main indicator of how walkable a neighborhood is since the Walkscore.com was founded in 2007. According to the company's website, as of September 2015, over 20 million online Walk Scores have been provided to realtors, apartment and home seekers, developers, and other stakeholders every day. More than 30,000 websites have integrated Walk Scores, and the company has expanded from the U.S. to Canada and Australia.

What makes the score attractive is that it can be accessed in standardized format for every address in these three countries, is free for small numbers of addresses and relatively affordable for larger volumes, is updated automatically as the underlying databases of housing units and amenities change, and includes street network distance to amenities (instead of straight-line distance). Other public and freely available sources of amenity access exist, such as the Smart Location Database developed by the U.S. Environmental Protection Agency (Ramsey and Thomas, 2012).

In contrast, most qualitative indicators of walkability (such as the presence of sidewalks or the aesthetics of the walking environment) do not yet exist in standardized electronic

format and are cumbersome and expensive to collect manually through walkability audits (Day et al., 2006). It is much more time and resource intensive to assess the extent to which the built environment is pedestrian friendly than it is to measure walkable access to amenities. Hence, even though Walk Score is designed as a measure of walkable access, the score is often used as an indicator of how walkable a city or neighborhood is, thereby conflating access to amenities with the quality of the walking environment.

In this context, we test how good a proxy for the quality of the walking environment Walk Score really is and whether the proxy's effectiveness is correlated with income. This is relevant for the design of new research as well as for planning efforts to increase the quality of the walking environment. Walkable access measures cannot diagnose which specific dimensions of urban design are in need of improvement like walkable audits can. Nevertheless, more information about the conditions under which they can proxy as a baseline measure for the quality of the walking environment more generally helps us understand the conditions under which it makes sense to use walkable access measures.

The purpose of this research is to shed light on these questions: How walkable is Walker's Paradise, really? And, more broadly, how walkable are neighborhoods with high Walk Scores—in terms of qualitative aspects of the walking environment? As Walk Score is increasingly being used, it is relevant to know whether it serves as a proxy for walkability more generally, beyond walkable access. Is this a legitimate use of the measure?

We are particularly interested in how the relationship between Walk Score and walkability varies between richer and poorer neighborhoods. We would expect that Walk Score and the quality of the pedestrian environment might be more congruent in more affluent areas, while the quality of the walking experience is worse in less affluent areas due to lower levels of investment in these neighborhoods. This is related to the fact that measures of walkable access cannot differentiate between high- and low-quality amenities (such as a full-service grocery store and a corner convenience store). And they do not contain information about the existence of sidewalks, the quality of streetscapes, the level of personal safety, or other features associated with pedestrian comfort. If Walk Score's access measure is a good proxy for the quality of the pedestrian environment in amenity-rich, higher income neighborhoods, is Walk Score also a good proxy in neighborhoods with lower incomes?

This article addresses these questions by statistically comparing Walk Scores to qualitative dimensions of walkability using the urban form dimensions of the State of Place (SOP) Index developed by Mariela Alfonzo as part of her start-up company for samples of neighborhoods in the Washington, DC, Metropolitan area (Alfonzo, 2012). The SOP Index synthesizes one of the most comprehensive set of indicators of the quality of the walking environment that is available (the Irvine-Minnesota Inventory [IMI] with 162 indicators). It classifies walkability along 10 dimensions (Table 1): Urban Form, density, proximity to amenities, connectivity, parks, pedestrian friendliness, personal safety, traffic safety, aesthetics, and recreation. The index is well tested and has been applied in academic research and contract work by Mariela Alfonzo and colleagues for over 10 years (Alfonzo et al., 2005, 2014; Boarnet et al., 2006, 2011; Day et al., 2005a, 2005b, 2006).

Even though the SOP Index is proprietary and Mariela Alfonzo has conducted contract work applying it through her company, the indicators of the IMI are publicly available, well documented and applied in other research (Alfonzo et al., 2005; Day et al., 2005a, 2005b). Hence, the data inputs for the SOP Index can be generated by anyone based on existing research and tools. The data can be synthesized in different ways. We rely on the SOP Index to do so since it is based on multiple years of development, testing, and publications that Dr. Alfonzo was part of and that make it more robust than ad hoc efforts to synthesize the 162 indicators. Another reason why we chose to use it as the measure to quantify walkability

Table 1. State of State of Place Urban Design Dimensions.

State of Place Urban Design Dimensions	Description/Example Items
Density	Measure of compactness based on building concentrations and height
Proximity to destinations	Quantity and quality of proximal non-residential land uses; mixed use
Connectivity	Ease of access within and across blocks
Form	Streetscape quality; how buildings meet the street
Parks and Public Spaces	Presence, quality, and accessibility of parks & public spaces
Pedestrian & Bicyclist Amenities	Features that facilitate pedestrian & bicyclist comfort; e.g. sidewalk widths, street furniture, bike racks
Personal Safety	Features that impact perceptions of safety; e.g. graffiti, litter, windows with bars, broken windows
Traffic Safety	Features that make walking and bicycling safer from motorist traffic; e.g., speed limits, traffic calming features
Aesthetics	Attractiveness and maintenance
Recreational Facilities	Gym/fitness facilities, Outdoor recreational uses

in this article is because of the opportunity to re-analyze existing sample data from previous research that represented substantial investments in multiple years of manual data collection (Leinberger and Alfonzo, 2012).

Existing Research

Explanations of walking behavior are often grounded in utility theory whereby people choose those travel options that are most useful to them (Ben-Akiva and Lerman, 1985). Planning theory (see below) has added explanations about how the design of a more walkable built environment can facilitate people's propensity for walking (and, conversely, people who have a preference for walking will also self-select into more walkable neighborhoods). Key dimensions of the walkability of a place are the accessibility of amenities by foot and a range of qualitative indicators such as the existence of sidewalks, the aesthetics of the walking environment, pedestrian comfort, as well as other factors such as personal and traffic safety.

Research and planning efforts are increasingly focusing on walkable access to amenities, the quality of the pedestrian environment, and walking itself. Over 400 articles have recently been published on topics related to walkable access and walkability (for reviews of this literature, see, for instance, Brownson et al., 2009; Ding and Gebel, 2012; Dunton et al., 2009; Durand et al., 2011; Ewing and Cervero, 2010; Feng et al., 2010; Heath et al, 2006; Saelens and Handy, 2008; Talen and Koschinsky, 2013).

A growing body of research provides evidence for the role the built environment and socio-economic factors play in facilitating or inhibiting more walking. For instance, in a study by Weinberger and Sweet (2012), the walkable access measure Walk Score was validated as a useful proxy for both pedestrian friendly environments and walking. They found that Walk Score generated ''robust and transferrable results'' as an indicator of people's propensity to walk. As a result, they recommend that planners use Walk Score's access measure as a consistent and cost-effective proxy for walking behavior. Duncan et al. (2011), Carr et al. (2010), and Carr et al. (2011) also found evidence of statistically significant

correlations between Walk Score and other measures of neighborhood walkability. Brown et al. (2013) documented a significant 19% increase in the chance of purposive walking and a 12% increase in the chance of meeting physical activity recommendations of recent Cuban immigrants for every 10-point increase in Walk Score. Manaugh and El-Geneidy (2011)'s results also showed strong correlations between higher Walk Scores and higher walking behavior.

However, when differentiating transport and recreational walking in a national study, Tuckel and Milczarski (2015) find that Walk Score only correlates positively with walking for transport, not with recreational or total walking. On the other hand, perceived neighborhood walkability proxied well for all three types of walking. Hirsch et al. (2013, 2014) also found an association between Walk Score and transport walking but not recreational walking.

Measuring walkability and walkable access

Theoretical and empirical work on the quality of the built environment, as it relates to the experience of walking (walkability) has advanced significantly over the past two decades as well (e.g., Farr, 2008; Jabareen, 2006; Van der Ryn and Calthorpe, 2008). Although the criteria to define walkability vary between authors, the prominent 5Ds often form a common core set of criteria (diversity of land uses, density, design, distance to transit, and destination accessibility; Ewing and Cervero, 2010).

Several examples illustrate the kinds of variables involved in the attempt to measure walkability. Arrifin and Zahari (2013) define walkability as "a measure of how friendly an area is to walking. It takes into account the quality of the pedestrian facilities, roadway conditions, land use patterns, community support, security and comfort for walking." In "Designing the Walkable City," Southworth (2005) identifies six criteria for successful pedestrian networks: 1) connectivity, 2) linkage with other modes, 3) fine grained land use patterns, 4) safety, 5) quality of path, and 6) path context.

In her book "Made for Walking: Density and Neighborhood Form," Campoli (2012) identifies five indicators of walkable urban form: 1) Connections between sidewalks and footpaths, 2) human-scale, aesthetic tissue, 3) housing and population density, 4) safe and pedestrian-friendly streetscapes, and 5) streets lined by trees and green space. To define walk appeal, Mouzon (2010) uses measurable criteria such as view changes, street enclosures, window view, shelter, goals in middle distance, and well-designed side streets. Immeasurable criteria include people on the street, lovable things along the way, magic of the city, safety, nature, and sound. Boarnet et al. (2011) found that sidewalks, street crossings, traffic, and destinations have stronger association with walking while aesthetic-related aspects such as nature elements, street furniture, and architectural treatments are less important for walking.

Walkable access to amenities, which is what Walk Score measures, is a topic with longstanding application in urban geography and planning. The prerequisites for pedestrian access to amenities often include higher density levels of housing and nearby amenities, mixed-use zoning, increased intersection density (shorter blocks), and often also higher socio-demographic diversity.

Destinations are considered accessible for pedestrians if they can be reached within a certain distance. These distances vary in different contexts. For instance, a standard used in the U.S. (and by Walk Score) is 0.25 miles or a 5-minute walk (Walk Score, 2015) and 100 intersections per square mile since smaller block sizes are associated with increased pedestrian safety (Institute of Transportation Engineers and Congress for

New Urbanism, 2010; New York City Department of Transportation, 2012). These metrics are derived from travel surveys of average walking speeds (Cerin, Leslie, Toit, Owen, and Frank, 2007; Iacono et al., 2010; Lee and Moudon, 2006). This distance can be measured either as straight-line distance or network distance (following street lines). In addition, more flexible minimum walking distances have been proposed depending on the context of walkability, e.g. 2 miles for London, three-fourth mile for U.S. main streets or one tenth of a mile for U.S. suburbs (Mouzon, 2010). The more destinations of different types (e.g. grocery stores, parks, schools, retail) can be reached, the more accessible a location.

As mentioned, Walk Score.com is the most popular web applications to measure walkable access. Walking behavior is not included in Walk Score, which measures distance-based access, not pedestrian walking behavior. However, to account for urban form that is friendly to pedestrians, Walk Score includes penalties for low intersection density and long block length—measures that researchers have identified as barriers to walking (e.g., Berrigan et al., 2010). Other applications have added some qualitative indicators of the walking environment to measures of walkable access, such as Maponics' Walkability service and Walkonomics' Walkobot, or combine walkable access to specific services, such as health services (WalkYourPlace; Steiniger et al., 2013). Major web-based navigation and mapping services such as *Google Maps* and *Bing* now also include walking directions.

The attempt to operationalize these walkability factors has been a major policy effort advanced by organizations like the *Walkable and Livable Communities Institute* (www.walklive.org) and Smart Growth America's *National Complete Streets Coalition* (www.smartgrowthamerica.org). Another important effort has been the Federal Highway Administration's recently approved *Designing Walkable Urban Thoroughfares* manual, developed as a joint effort between the Institute for Transportation Engineers and the Congress for New Urbanism (2010).

Factors compromising walkability

One of the challenges is that walkable access to amenities, walkability and walking do not always align. For instance, a neighborhood with amenities in walking distance is not necessarily walkable if the quality of the walking environment is not pedestrian friendly, e.g. if there are no sidewalks. Even if a given neighborhood offers access to a variety of local amenities, people might not necessarily walk because of unsafe traffic conditions, personal safety concerns, or other constraints. And when people are walking in neighborhoods with good access to amenities, the amenities they can reach could still be of poor quality. Factors that can inhibit walking include unsafe walking conditions (Smart Growth America, 2014), weather conditions (de Montigny et al., 2012), and pollution (American Lung Association, 2013) and a lack of traffic safety (Fleury, 2013).

The question of greatest interest in this article is whether the positive relationship between walkability, walkable access, and walking described earlier is compromised in low-income neighborhoods where residents are more likely to be "captive walkers" with no alternative transportation options to walking. The aim of this article is to test if potential compromising factors in low-income neighborhoods are missed when walkable access measures are used as proxies for walkability as if the relationship holds constant across all neighborhoods. It is part of the literature described below that analyzes urban form dimensions from a social equity perspective.

First, the fact that researchers found positive correlations between Walk Scores and crime (Carr et al., 2010) suggests that factors that compromise walkability are not proxied well by Walk Score's access measure. Crime and safety concerns, including attack dogs

(Cutts et al., 2009) inhibit people's likelihood to walk (Bennett et al., 2007; Carr et al., 2010). Other research finds that residents in urban low-income housing, especially women, walk less in unsafe environments (Bennett et al., 2007). A national survey found that crime ranks as the fifth most important barrier to walking among African American and Hispanic respondents (compared to 15th for white respondents) (Fleury, 2013); 43% of households with lower incomes (who are more likely to have health problems such as diabetes or obesity) reported walking less now than five years ago compared to 28% of higher income households (Fleury, 2013).

Second, since Walk Score is not highly sensitive to the quality of a particular amenity, poor neighborhoods with high Walk Scores may not necessarily have a higher quality of services translating to a qualitatively better neighborhood environment. For instance, a national study found that low-income neighborhoods have less access to chain supermarkets than middle-income neighborhoods (Powell et al., 2007). African American and lower income neighborhoods have less access to chain supermarkets but greater access to small grocery and convenience stores with lower quality food (Franco et al., 2008; Powell et al., 2007; Small and Mcdermott, 2006).

Access to recreational facilities and physical activity has also been found to be worse in minority and low-income neighborhoods (Gordon-Larsen et al., 2006; Moore et al., 2008). Lovasi et al. (2009) found that higher population density, more mixed land use, and greater transit access are more consistently correlated to a lower BMI within groups with more education, higher incomes who are non-Hispanic and white. Oreskovic et al. (2009) discovered that children living in lower income neighborhoods tend to have less access to built environment features that promote physical activity such as open space or nearby schools and subway stations. However, proximity to fast food is more consistently associated with obesity among children living in low-income neighborhoods.

Kelly et al. (2007) evaluated the relationships between poverty rate, race, and the street-scale environmental features, such as sidewalk quality, and physical disorder, including abandoned buildings, vacant lots, trash, graffiti, and broken windows. They found that block groups with the highest poverty rates tend to include more street segments with physical disorder characteristics.

Data and methodology

The methodology described in this section allows us to assess which urban design dimensions are most and least correlated with walkable access (Walk Score) and whether these correlations are constant across neighborhood income levels or not. It also tests the hypothesis that the quality of urban design dimensions is lower in lower income neighborhoods and quantifies the extent of potential quality differentials.

In an effort to shed further light on the question in how far walkable access measures can proxy for walkability, we compare Walk Score's measure of walkable access to a set of qualitative micro-scale urban design indicators about the walking environment: The SOP Index, a proprietary index developed by Mariela Alfonzo and applied in contract work through her company and in her academic research (see References). We assess whether the relationship between Walk Score and walkability as measured by the SOP Index and its components (see Table 1) differs between higher and lower income neighborhoods both in terms of correlations and average scores.

What complicates this comparison is the fact that lower income neighborhoods often have lower walkable access than higher income areas. For instance, in this sample, the average Walk Score in very low-income areas is 47 compared to 75 in higher income neighborhoods;

even in areas with walkable access (Walk Score of 70+), low-income neighborhoods within these areas have lower average scores of 81 vs. 87 (Table 2). This confounding of income and access levels makes it hard to distinguish whether differences between Walk Scores and SOP Index/component scores are due to income or walkable access levels. To address this problem, we also add a comparison between low and higher income areas that is limited to the subset of neighborhoods with walkable access (Walk Score of 70 or above).

We compute the correlation between Walk Scores and the SOP Index/dimensions using Pearson's bivariate correlation and report the associated significance levels for all groups mentioned earlier. We rely on bivariate correlations since multivariate correlations are too collinear due to the close interrelations between the 10 dimensions of the SOP Index. To determine if the average scores of the SOP design dimensions and the overall index differ by income level of an area, we also report the average SOP component and index scores for all neighborhoods and the two income groups (very low and higher as well as low and higher with walkable access). A difference-in-means test (t test) is used to test if the difference in scores between income groups is statistically significant or not.

This analysis is conducted for neighborhood samples in the Washington, DC, metro area that were collected for previous research (Leinberger and Alfonzo, 2012; Metropolitan Washington Council of Governments, 2013) and extended for this analysis to increase the number of neighborhoods with higher shares of low-income housing and African American residents (see State of Place section).

Table 2 summarizes the average unstandardized scores of the urban design dimensions and the SOP Index as well as bivariate Pearson correlations and significance tests between Walk Scores and the SOP Index and its dimensions for the three groups of neighborhoods. To test for differences in the Walk Score-walkability relationship between low- and high-income neighborhoods, we draw on the tract-level median household income variable from the 2006–2010 American Community Survey. We use the tract-level values to classify sample neighborhoods into one of two groups: A very low-income group if the tract's median income is below 50% of the national median household income, i.e. below $31,828, and a higher income group if it is above this national median (we use the 2008–2012 median income level of $53,046). These groups are designed to highlight concentrations in the bottom and top income categories in the sample while maintaining similar sample sizes within a group. Since there were almost no very low-income neighborhoods in the sample of neighborhoods with good walking accessibility, we used a higher threshold of 80% of median area income ($42,437) that corresponds to standard definitions of low-income areas.[1]

Walk Score—Measuring walkable access to amenities

We rely on "street smart" walk scores from Walkscore.com, which include walking distances along streets to amenities (rather than straight-line distances) and measures of pedestrian friendliness (intersection density and average block length). Scores are based on walking distance to nine amenity categories: grocery stores, restaurants, shopping places, coffee stores, banks, parks, schools, book stores, and entertainment, which are weighted (e.g. grocery stores weigh more than banks and the more amenities in the same category the less they are weighted). Scores are adjusted using a distance decay function where amenity counts lose weight with more distance from an address, starting from .25 miles (5 minute-walk) to 1 mile (20-minute walk) and up to a limit of 1.5 miles (30-minute walk). The amenity scores are standardized to range between 0 and 100. The score is adjusted by penalties for low intersection density and long block lengths. Our data were purchased in

Table 2. Correlations: Walk Score and State of Place Index for all neighborhoods and by income.

	Form problem	Density	Prox	Connect problem	Parks	Peds	Safety	Traffic safe	Aesthetics	Trash graff	Aesth_ Total	Rec	SOP Index	
All neighborhoods														
Average score	0.50	−0.24	−0.03	0.17	0.01	−0.13	−0.38	−0.19	0.81	0.53	0.28	0.01	−1.34	WS = 58
Pearson correlation	−0.54	0.60	0.25	−0.25	0.25	0.47	0.16	0.41	0.44	−0.43	0.51	−0.10	0.60	All neighborhoods
Sig. (2-tailed)	.000	.000	.006	.007	.006	.000	.082	.000	.000	.000	.000	.287	.000	*N* = 115
Very low and higher income neighborhoods[a]														
Average score	1.51	−1.18	−1.04	0.57	−0.33	−1.99	−3.01	−1.41	−1.66	2.32	−3.98	−0.01	−15.04	WS = 47
Pearson correlation	−0.18	0.39	0.001	−0.32	0.22	0.29	0.02	0.36	0.06	0.02	0.02	−0.28	0.31	Very low income
Sig. (2-tailed)	0.334	0.034	0.997	0.085	0.235	0.114	0.933	0.053	0.772	0.936	0.936	0.129	0.093	*N* = 30
Average score	−2.07	0.90	0.62	−0.13	0.48	2.38	1.65	1.74	3.40	−1.66	5.05	0.05	15.08	WS = 75
Pearson correlation	−0.49	0.69	0.58	−0.43	0.21	0.63	−0.34	0.63	0.59	−0.31	0.59	−0.14	0.76	Higher income
Sig. (2-tailed)	0.004	0.000	0.000	0.012	0.236	0.000	0.052	0.000	0.000	0.072	0.000	0.430	0.000	*N* =34
Difference in means (*t*-test)	**−4.47**	**5.61**	**1.85**	**−1.69**	**1.95**	**4.01**	**6.62**	**3.16**	**5.86**	**−5.85**	**7.43**	0.48	**7.297**	5.2105
Sig (1-tailed)	0.000	0.000	0.035	0.049	0.028	0.000	0.000	0.001	0.000	0.000	0.000	0.318	0.000	0.000
Low and higher income neighborhoods with walkable amenity access[b]														
Average score	−0.72	0.20	1.20	0.28	0.11	0.74	−1.46	0.46	2.29	0.16	2.13	0.02	3.85	WS = 81
Pearson correlation	−0.65	0.79	0.43	−0.48	0.62	0.59	0.11	0.46	0.60	−0.52	0.63	0.13	0.74	Acc. low income
Sig. (2-tailed)	0.003	0.000	0.076	0.046	0.006	0.011	0.658	0.057	0.008	0.028	0.005	0.599	0.001	*N* =18
Average score	−3.25	1.41	1.88	−0.53	0.59	3.84	1.42	3.04	4.64	−2.05	6.69	−0.02	22.64	WS = 87
Pearson correlation	−0.58	0.63	0.48	−0.33	0.24	0.35	−0.35	0.44	0.41	−0.36	0.53	−0.05	0.64	Acc. higher income
Sig. (2-tailed)	0.003	0.001	0.018	0.121	0.265	0.093	0.098	0.033	0.048	0.085	0.008	0.799	0.001	*N* =24
Difference. in means (*t*-test)	**2.54**	**−2.14**	−0.51	**1.69**	−0.66	**−2.78**	**−4.28**	**−3.07**	**−1.82**	**2.44**	**−2.40**	0.31	**−3.15**	**−1.98**
Sig (1-tailed)	0.009	0.021	0.306	0.052	0.257	0.004	0.000	0.002	0.039	0.011	0.013	0.378	0.002	0.027

[a]Very low income (<50% of national median HH income in 2008–2012: $53,046) and higher income (above national median HH income in 2008–2012: $53,046).
[b]Walkable Amenity Access (Walk Score ≥ 70); low income (<80% of national median HH income in 2008–2012: $53,046); higher income as in 'a' above.
Average scores are colored (■ = positive correlation; ■ = negative) if the associated difference-in-means test is significant at the 0.05 level.

February 2012 for the address that corresponded most closely to the 2010 Census block group centroid.

Five intervals used by Walk Score help interpret the score: 0–24 *Car-Dependent* (almost all errands require a car); 25–49 *Car-Dependent* (a few amenities within walking distance); 50–69 *Somewhat Walkable* (some amenities within walking distance); 70–89 *Very Walkable* (most errands can be accomplished on foot); 90–100 *Walker's Paradise* (daily errands do not require a car). We classify neighborhoods with a Walk Score of 70–100 as those with good walkable access and others (with scores of 0–69) as not. This decision is based on ground-truthing of the differences between the somewhat and very walkable categories.[2] We determined that the "somewhat walkable" category was too mixed in terms of areas with good and poor walkable access to amenities and therefore chose the more conservative option of "very walkable" or above.

Two key measurement challenges include the quality of amenities and the choice of amenities. For instance, Walk Score does not factor in the *quality* of amenities. This is relevant because the same amenity access score in a richer and poorer community is likely to provide access to very different levels of quality of amenities. For instance, stores can be classified as grocery stores in both cases but represent a fully stocked supermarket in one case and a gas-station corner store with primarily junk food in the other case. More walkable access to the latter could actually contribute to a decrease rather than increase in health. Walk Score also prioritizes more affluent consumption amenities such as coffee shops, restaurants, and bars in its scoring system while jobs, day care or health care services are not included. Our comparison with the SOP measures listed below seeks to assess the extent to which Walk Score's access measure is a good proxy for walkability, especially in poor communities.

SOP—Measuring the quality of the walkable environment

Walkability data were collected using the IMI (Boarnet et al., 2006; Day et al., 2006) and analyzed using the SOP Index. The IMI is intended to be an objective, reliable audit tool that measures 162 micro-scale built environment features linked to physical activity, such as the presence of sidewalks, crosswalks, street trees, benches, lighting, land uses, and maintenance. Developed in 2005, the IMI has been widely used in the urban planning, design, and public health fields. It uses the street segment (or both facing sides of a block) as its unit of analysis.

The SOP Index, a proprietary algorithm, was co-developed by one of the authors of this article (Mariela Alfonzo) in response to the need for a systematic analytical framework for processing and aggregating the IMI data into a useful, comprehensive built environment metric. Drawing from the results of a meta-analysis of 13 literature reviews and 29 original studies evaluating the link between the built environment and physical activity, 10 urban design dimensions were identified as key components empirically linked to people's decisions to walk (Saelens & Handy, 2008) (see Table 1). A Delphi panel with expertise spanning public health, behavioral psychology, urban planning, urban design, and geographic information systems then categorized each of the 162 IMI audit items into one or more of the 10 urban design dimensions. From that, syntax was derived to aggregate each of the audit items into their corresponding dimensions.

To create the SOP Index itself, scores for each of the audit items, which were scaled either dichotomously (e.g. "Is there outdoor lighting on the block? Yes = 1; No = 0") or ordinaly (e.g. "Are there outdoor dining areas (e.g. cafes, outdoor tables at coffee shops or plazas, etc.) located on the block? Some/a lot = 2; Few = 1; None = 0), were converted into Z-scores and then summed for each dimension. Since its initial development, the algorithm has been

refined and is now composed of a series of interactions between the individual audit items (if, then statements and multiplication of scores for individual audit items), rather than a simple summation of them. Finally, the SOP Index is normalized into a score from 0 to 100, with 100 representing the highest observed score within the existing database of nearly 4000 segments, spanning a continuum of walkability, including blocks within urban, suburban, exurban and rural settings. The SOP Index is calculated for each segment (block) and then aggregated at the neighborhood level; a "sub-index," also a normalized score from 0-100, is calculated for each urban design dimension (see Table 1; Table 2 is based on non-normalized scores).

This article combined three samples of neighborhoods: Built environment data was drawn from two previous studies conducted in the Washington DC metro region for which IMI data had been collected (Leinberger and Alfonzo, 2012; Metropolitan Washington Council of Governments, 2013). Since the data collected for these studies represent a tremendous investment in terms of time and other resources, we wanted to utilize the opportunity to address other research questions with it. Additional IMI data were collected for this article to increase the representation of neighborhoods with a high percentage of subsidized, low-income housing, African-American residents and low home values. IMI data were collected for street segment samples in four such neighborhoods in the Washington DC metro area.

In the first study that data were drawn from (Leinberger and Alfonzo, 2012), IMI data for 66 of the 116 neighborhoods were selected using a random stratified sampling scheme. The study aimed to create an operational definition for a "walkable urban place" and identify neighborhoods that subsequently fit that description. To do so, researchers first cast a "broad net" to identify places that could potentially "qualify" as walkable urban places, informed by a comprehensive review of existing research and a Delphi Panel survey of experts. A total of 202 neighborhoods in the Washington DC Metro region were identified as potential "candidates;" selected neighborhoods had access to a Metro station or had an existing plan (e.g. special district overlay) that aimed to increase walkability, density, or mixed uses that was not restricted to small area road corridor based plans *and* were not located in Census designated rural blocks. Given project constraints, data could be collected for only a subset of these neighborhoods.

To identify this subset of walkable urban places, Walk Scores were generated for the 202 neighborhoods to establish a continuum of walkability from which to sample. Neighborhoods were divided into five strata (levels) of walkability based on the average and standard deviation of their Walk Scores. Random representative samples were chosen from each strata; 100% of neighborhoods with Walk Scores above 2.5 times the standard deviation, i.e. a ranking of 90.6 or more, were included. This decision reflected the overall aim of the original study to create a comprehensive listing of all neighborhoods that fit the operational definition of walkable urban places. That study also supplied data for two additional neighborhoods that were not part of the random stratified sample.

In the second study that data were drawn from (Metropolitan Washington Council of Governments, 2013), an additional 43 neighborhoods were selected as part of a purposive sample. This project aimed to create walkability scores for a select sample of neighborhoods that had been identified as "Activity Centers," or areas that served an important economic development function for the Washington DC region.

Finally, as part of a third sample, IMI data for an additional four neighborhoods were collected specifically for this study to bolster the number of neighborhoods with high concentrations of African-American residents, federally assisted housing and low home values. The final combined sample from the three sources with complete data included 115 neighborhoods (Figure 1).

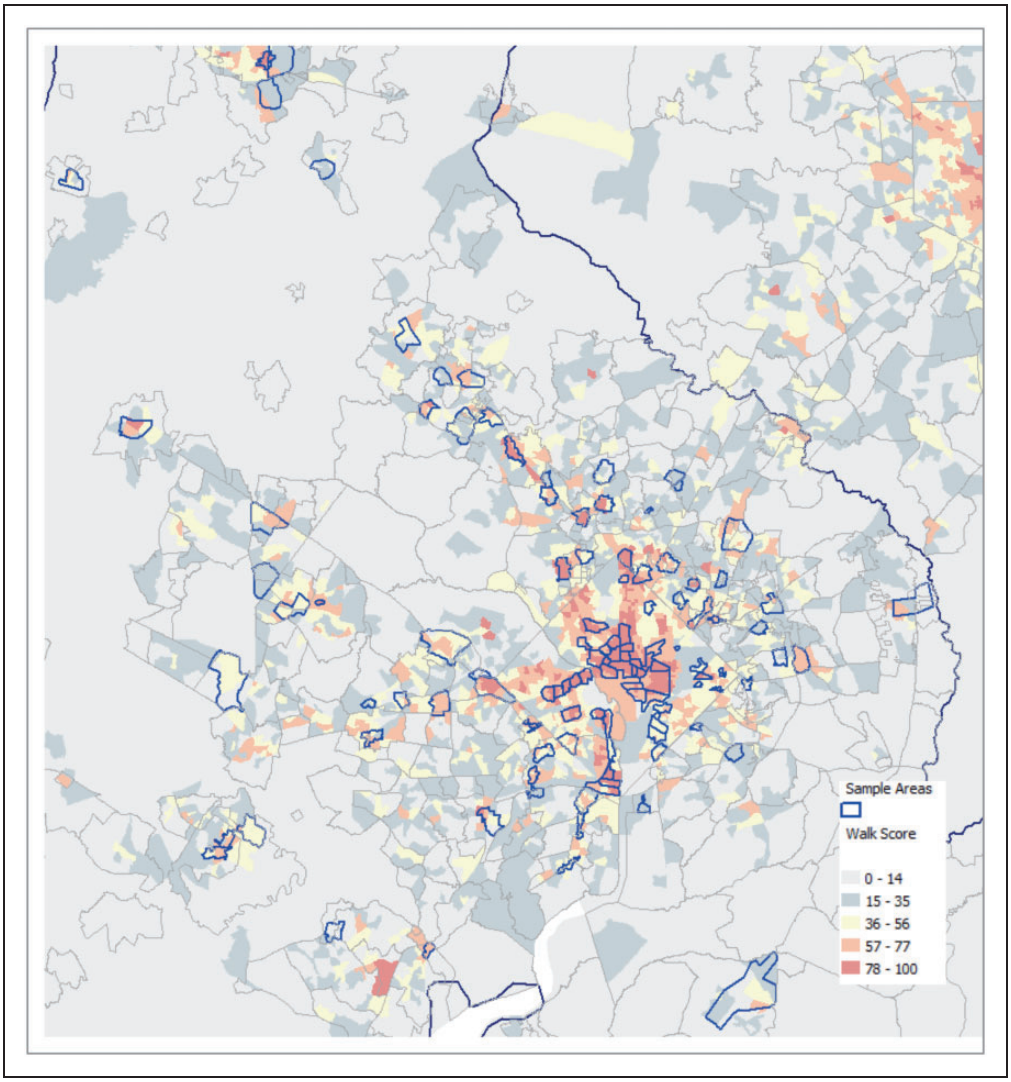

Figure 1. Map of Walk Scores and IMI sample areas in Washington, DC Metro Area.

All IMI data were collected by trained raters, as called for by the IMI training protocol. Raters received a 2-hour in-class and a 2-hour on-site training session; they then collected data on five test segments, which were tested for reliability. Raters included George Washington University undergraduate geography students who participated as part of a service learning partnership, Metro DC area planners, and three independent contractors.

IMI data were collected for a sample of segments within each neighborhood since it takes 8-10 minutes to collect the data for each segment. The same sampling scheme was implemented for all neighborhoods: On average, 25 percent of street segments within a neighborhood were collected – a minimum of 10 segments and maximum of 50 segments for each site. Since it takes more time to sample larger areas, smaller samples were drawn from larger places: 20% of segments were sampled within neighborhoods larger than 400 acres; 25% of segments for neighborhoods within 250-400 acres; 30% of segments for

neighborhoods smaller than 250 acres; and 35% of segments for neighborhoods with fewer than 75 segments. A minimum of 10 segments and a maximum of 50 segments were sampled from each neighborhood. The goal here was to collect segment data for an analysis of all neighborhoods combined instead of collecting data that would be representative at the neighborhood level.

The sampling scheme reflected that used in the Leinberger and Alfonzo (2012) study from which the initial sample of neighborhoods was derived; the scheme was derived based on the sampling strategy suggested by original developers of the IMI (Alfonzo et al., 2005). A sampling scheme was implemented to ensure that a comparable number of blocks were selected per neighborhood to ensure the feasibility of the timing of the data collection process, which was primarily conducted by students in a service learning class; each student team was responsible for collecting data for an equal number of neighborhoods. On average, it took raters 8-10 minutes to collect data for one segment. Data were collected using a paper version of the IMI and were subsequently entered into a spreadsheet. More details about the methodology can be found in the methods section and appendix of Leinberger and Alfonzo (2012).

Since the sample was drawn from walkable urban places, the analysis results are not designed to be generalized to places with low levels of walkable access to amenities. And since the samples were all drawn from the same Washington, D.C. metro area, it is unclear whether they speak for other metro areas. However, it is encouraging that emerging research comparable to ours (Pearce, 2015) finds very similar results for other cities (in this case San Francisco and Detroit), as is shown in the next section.

Findings

The analysis of findings in Table 2 reveals a strong and positive overall association between walkable access (Walk Score) and walkability (SOP). However, this association masks problems with the quality of the walking environment that are significantly larger in low-income neighborhoods, especially regarding connectivity, personal safety, and the presence of litter and graffiti. As a proxy for walkability, walkable access as measured by Walk Score is thus more reflective of Walker's Paradise in higher- than low-income neighborhoods but not across the board.

Across all sample neighborhoods, Walk Score was strongly (0.6) and significantly correlated with the SOP Index. Interestingly, this correlation is identical to others in the literature. For instance, Pearce (2015: 47) found a correlation of 0.62 between Walk Score and a walkability audit called an Urban Quality Assessment Tool in downtown neighborhoods that ranged from 0.58 in car-dependent Detroit to 0.83 in pedestrian-friendly San Francisco.

For all neighborhoods, all ten dimensions were significantly correlated with Walk Score except for personal safety and recreational facilities. The fact that personal safety is not captured in Walk Score is an interesting gap that the Walk Score company recognizes and is attempting to address by adding crime per capita to its scoring system (as of September 2014). The relationship could also be insignificant due to the countervailing high crime safety scores in low-income neighborhoods and low crime scores in high-income neighborhoods, as shown below.

The dimension associated with recreational facilities is the only one without a significant relationship to Walk Score in any of the groups we analyzed. This is interesting since Walk Score indeed does not include these facilities in its amenity categories. However, since gyms and fitness facilities as well as outdoor recreational uses that are part of this dimension

represent important destinations to improve physical health, this is a category worth considering for inclusion in Walk Score or other amenity access measures.

Of the bivariate correlations for the respective ten dimensions and Walk Score, density is the only one that is as strong (0.6) and significant as the correlation between Walk Score and the overall SOP index. The other strong correlations are form problems, such as interruptions to streetscape continuity (−0.54) and aesthetics (attractiveness vs. presence of litter and graffiti). Features that facilitate pedestrian and bicyclist comfort and traffic safety are moderately correlated with Walk Score (0.47 and 0.41). The three dimensions that were only weakly correlated with Walk Score across all neighborhoods are the presence, quality and accessibility of parks as well as the quantity and quality of nearby destinations and barriers to connectivity (we discuss this finding later since it masks differences between low and high-income areas).

However, a closer inspection of the results by income reveals that this relationship is primarily characteristic of higher-income neighborhoods (0.76 significant correlation). In contrast, the relationship between walkable access and walkability is weak and insignificant in low-income neighborhoods overall. This reflects a lower average Walk Score in low-income neighborhoods (47 compared to 75 in higher income areas). However, even when the sample is restricted to neighborhoods with good walkable access (a Walk Score of 70+) where a strong positive correlation characterizes both income categories, the average SOP Index score is significantly smaller in low income than higher-income areas (3.85 vs. 22.64), reflecting problems with the quality of the walking environment in these neighborhoods.

A review of the ten urban design components (Table 1) sheds light on what these problems are and highlights the dynamics that drive these overall findings. When looking at all neighborhoods, the urban design components have the expected sign: Problems of form, connectivity, and aesthetics are negatively correlated with Walk Score while the other dimensions have positive statistical associations. As for the overall SOP Index, the correlations between walkable access and walkability were much stronger and more likely to be significant in higher income neighborhoods while only density and traffic safety are significantly (and negatively) related to walk Scores in very low-income areas. This is presumably related to stronger correlations in areas with higher levels of walkable access, which are more likely to be in high-income areas. When isolating neighborhoods with good walkable access, the relationship between Walk Score and SOP component scores is indeed as strong if not stronger in low-income as in higher-income neighborhoods.

However, a comparison by income category reveals that, as hypothesized, very low-income neighborhoods are faced with poorer quality of urban form across all dimensions (except for recreation, which is insignificant across the board). Table 2 shows that, without exception, very low and higher-income neighborhoods have scores on the opposite end of the spectrum: Very low income areas have positive scores for problems such as form and connection as well as for the presence of trash and graffiti while higher-income areas have negative scores in all of these categories. In contrast, all of the dimensions with positive scores in higher-income areas have negative scores in very low-income neighborhoods, i.e. for density, proximity, parks, pedestrian friendliness, personal and traffic safety, attractiveness and overall aesthetics of an area. These differences are statistically significant for all of these dimensions.

When we restrict the same analysis to neighborhoods with walkable access, this pattern nevertheless persists in low-income neighborhoods for problems with connectivity, personal safety, trash and graffiti. In other words, even though low-income neighborhoods are classified as having good walkable access by Walk Score, this classification masks

problems with the quality of the walking environment that are not present in higher-income neighborhoods with walkable access. Further, even for those dimensions where a negative score in low-income neighborhood turns positive in low-income neighborhoods with good walkable access, the size of this score is much smaller (up to 3-4 times) in low-income areas. The difference in the SOP Index between 3.85 and 22.64 in low and high-income areas is also reflected in significant differences in total aesthetics (2.13 vs. 6.69), traffic safety (0.46 v. 3.04), and pedestrian friendliness (0.74 vs. 3.84).

Discussion and Conclusion

How walkable are high Walk Score neighborhoods, then? Walk Score serves as a good proxy for quality urban design features related to walkability for neighborhoods with relatively high Walk Scores (above 70) in high-income areas. However, the relationship between Walk Score and walkability is decidedly weaker for neighborhoods with relatively low Walk Scores and with lower incomes: As income and Walk Score levels drop, so does walkability. Especially personal safety, aesthetics (absence of trash and graffiti) and street connectivity are more likely to be jeopardized in low-income areas with good walkable access. Thus the congruence between Walk Score and walkability does not hold across all neighborhoods equally. In other words, Walk Score's accuracy as a proxy for walkability declines with income.

This finding is relevant since a vast number of cities and the majority of neighborhoods in U.S. cities ranked by Walk Score have relatively low Walk Scores. The average Walk Score of the 141 cities the rating covers is 47, the median is 44.5, and the mode is 38.9. Scores range from 87.6 to 18; only 9.2% of these cities have a Walk Score above 70, the criteria used in this study to differentiate between relatively high and low access. In Madison, WI (the US city with a Walk Score closest to the city average), with a Walk Score of 47.4, the average Walk Score for a neighborhood is 41.3; 87.8% of neighborhoods ranked have a Walk Score of less than 70. New York City, the city with the highest Walk Score, is an outlier: the average Walk Score for a neighborhood there is 79.1; 26.2% of neighborhoods ranked have a Walk Score of less than 70.

Figures 2-4 provide three examples from our sample neighborhoods where Walk Score fails to capture the micro-scale built environment features known to impact people's decisions to walk that are incorporated in the SOP Index. In these examples Walk Score overestimates how walkable a neighborhood is compared to the SOP Index. Figure 2 shows a block in Langley Park, MD with a high Walk Score of 79. It is part of our Gateway Arts District sample with a SOP Index indicating very poor walkability with a score of 14.4 (out of 100).[3] This reflects, for example, interruptions in streetscape continuity, poor pedestrian comfort, and a lack of traffic safety. Figure 3 depicts an intersection in Largo Town Center, MD with an almost walkable Walk Score of 68, which contrasts with a much lower SOP Index of 30 for the area reflecting car-centric roads. Figure 4 depicts an intersection in Gateway Arts, MD, which has a moderate Walk Score of 54 but a much lower State of Place index (6.1 out of 100) indicating a strong lack of walkability, including no sidewalks, as shown in the Google Street View image.

Our results suggest that Walk Score tends to overestimate the quality of the walking environment in neighborhoods with low incomes. This is because Walk Score does not capture "on the ground" features such as physical incivilities (or characteristics that impact perceptions of safety), aesthetics, traffic safety features, pedestrian amenities, etc., all of which impact walkability. One interpretation is that Walk Score is "biased" toward higher income neighborhoods. Another interpretation is that lower income neighborhoods

Figure 2. Google street view of Langley Park, MD.

Figure 3. Google street view of Largo Town Center, MD.

remain plagued by walkability risk factors, and that the differentiation with Walk Score serves to highlight that paradox. Floyd et al.'s (2009) recommendation that existing built environment measures should do a better job at reflecting inequalities is germane to our study's results. Larger gaps between pedestrian-based access and walkability measures in low-income and lower-access neighborhoods should motivate increased attention to the continued poor neighborhood quality of places that otherwise seem to provide geographic access.

Figure 4. Google street view of Gateway Arts, MD.

As a practical matter, policy makers using Walk Score should note the variability of its accuracy as a proxy for walkability in different types of neighborhoods. In particular, policies that currently use Walk Score as a benchmark or criteria for funding should consider the context within which Walk Score is being used.

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The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Mariela Alfonzo is the founder of the urban data analytics platform State of Place that is part of her start-up company Urban Imprint. In this context, she has applied the State of Place Index commercially. She is also a Research Assistant Professor at the New York University's School of Engineering where she is conducting research on walkability. To limit conflicts of interest, Julia Koschinsky and Sungduck Lee analyzed the data collected by Mariela Alfonzo and created the tables of results.

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Notes

1. The 50% and 80% thresholds correspond to established income limits by the U.S. Department of Housing and Urban Development. The median incomes associated with the tract centroids inside a sample neighborhood are averaged to generate a median income for each sample neighborhood. These data can have high margins of error, especially in more urban, diverse and low-income areas (Folch, Arribas-Bel, Koschinsky and Spielman, 2014). The margin of error associated with the median income estimates can lead to the false inclusion or exclusion of neighborhoods near the national median. However, this only matters at the margins of the threshold and since the middle-income group is excluded, the misclassification error only occurs between low and middle income or between high and middle income but not between the two groups we focus on, i.e., low and high-income neighborhoods.
2. We used this website for this assessment where we link street views to walkable categories at the neighborhood level for all metropolitan areas: http://walkableneighborhoods.org/explore/cbsa/
3. We normalize the scores for State of Place Index by finding the minimum and maximum of the range of index values, adding the minimum (−1*min) to all scores, and then dividing by the total range (−1*min + max) to obtain the percentage score. The average SOP scores in Table 2 are not standardized.

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