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Unpacking Walkability: Testing the Influence of Urban Design Features on Perceptions of Walking Environment Attractiveness

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Abstract *The potential environmental and health benefits of active transportation modes (e.g. walking and cycling) have led to considerable research on the influence of the built environment on travel. This paper presents the findings of a study combining environmental audits and a survey-based respondent mapping tool to test the influence of micro-scale built environment characteristics, including 'green street' storm water management features, on resident perceptions of walking environment attractiveness. Results suggest that this method is sensitive enough to unpack a concept like walkability into individual component characteristics. Findings from an ordinary least squares (OLS) regression model indicate that in a predominantly single-family residential context well-designed green street facilities, as well as other features such as parks, separation from vehicle traffic, and pedestrian network connectivity can significantly contribute to walking environment attractiveness.*

Introduction

The unique potential for active travel modes, such as walking and cycling, to address both environmental and public health concerns, has resulted in a growing body of research across multiple fields on how the built environment influences travel behaviour (for reviews of over 200 such studies, see Saelens *et al.*, 2003; Ewing & Cervero, 2010). As the most widely available form of both transportation and physical activity, walking has been the focus of many of these studies (for a review, see Saelens & Handy, 2008). In addition to obvious environmental benefits compared to driving, walking has also been linked to numerous health benefits, ranging from lower body mass index (Frank *et al.*, 2006), particularly in children (Rosenberg *et al.*, 2006), and improved cardiovascular health (Manson *et al.*, 2002). Among older adults, research has shown links between walking and improved longevity (Hakim *et al.*, 1998), cognitive function (Weuve *et al.*, 2004) and quality of life (Strawbridge *et al.*, 1996; Leveille *et al.*, 1999).

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Most studies relating the built environment to walking have focused on the amount of walking as the outcome variable. This is logical, as the policy objective is usually to increase walking. However, from an urban design perspective, success should not simply be measured by the number or duration of walking trips, but also by the quality of those trips in terms of user experience. As the literature makes clear, quality walking environments are one of several broad factors influencing walking behaviour, along with demographic characteristics, attitudes and the presence of desirable destinations. Therefore, better understanding how micro-scale built environment characteristics influence user perceptions of quality could potentially lead to both improved user experience and more walking.

This paper makes two unique contributions. First, it describes and tests a research method that uses survey-based respondent mapping and environmental audits to explore how individual features of the micro-scale built environment—i.e. the physical characteristics of street segments or blocks—contribute to perceptions of walking environment attractiveness. Second, in the test case presented, this method (adapted from Borst *et al.*, 2008) is used to investigate how ‘green street’ sustainable storm water management features, as well as other built environment characteristics, contributed to user perceptions of walking environments in a mostly single-family residential neighbourhood in Portland, Oregon. Green streets are becoming an increasingly popular tool for cities to address storm water management, yet the research literature on residents’ responses to these innovations is very sparse (Dill *et al.*, 2010).

Background

Walkability is a multi-faceted concept that includes several elements of the built environment. Moudon *et al.* (2006) operationalized walkability as comprising three elements: origin/destination, area and route. Similarly, Southworth (2005) identified six attributes of walkability: connectivity; linkages to other modes; fine-grained and varied land use patterns; safety; quality of path; and path context (e.g. visual interest, landscaping, spatial definition, etc.). At the micro-scale, then, the relevant built environment elements of walkability are route characteristics relating to safety, quality and context.

To explain how built environment elements influence behaviour, Ewing & Handy (2009) proposed a conceptual framework by which physical characteristics elicit user reactions (e.g. sense of safety, comfort and level of interest) that contribute to an overall perception of walkability and, ultimately, walking behaviour. Alfonzo’s (2005) hierarchy of walking needs, however, suggests that elements most often associated with the micro-scale built environment—safety, comfort and pleasurability—influence decisions to walk only after more basic needs of feasibility (e.g. an individual’s ability) and accessibility (e.g. somewhere to go) are met.

Alfonzo’s hierarchy hypothesis appears supported by empirical evidence showing that micro-scale characteristics tend to have relatively minor influence on travel behaviour compared to macro characteristics such as destination proximity, density and connectivity (Cervero & Kockelman, 1997; Saelens & Handy, 2008). Cervero & Kockelman concluded that “micro-design elements are too ‘micro’ to exert any fundamental influences on travel behavior” (p. 220). Still, from the handful of studies testing micro-scale built environment variables, there does appear to be some influence on walking.

Gallimore *et al.* (2011) tested whether fifth graders with objectively more walkable routes to school were more likely to walk in two mostly residential neighbourhoods. Results indicated that four of the factors from the Irvine-Minnesota built environment assessment (Boarnet *et al.*, 2006), including the two most related to micro-scale built environment, were correlated with higher rates of walking to school. Agrawal *et al.* (2008) showed that among a sample of commuters walking to rail transit stations, safety and aesthetic characteristics influenced route choice decisions, but were secondary to the directness of the route. Foltête & Piombini (2007) tested the relative influence of accessibility and micro-scale built environment characteristics on observed pedestrian frequency in Lille, France. Using a hierarchical modelling approach, they found that although accessibility was the primary determinant of pedestrian frequency, the addition of micro-scale built environment variables more than doubled the predictive power of their model.

A more common approach has been to examine relationships between neighbourhood-level built environment measures and walking. This has been done with user-reported perceptions of neighbourhood-level walking environments (Ball *et al.*, 2001; King *et al.*, 2006; Rhodes *et al.*, 2007) and with comparisons between researcher-defined pedestrian-oriented and auto-oriented neighbourhoods (Cervero & Radisch, 1996; Handy, 1996; Hess *et al.*, 1999). Neighbourhood-level walkability assessment, however, may overlook the influence of more subtle differences in micro-scale walking environments (Zhu & Lee, 2008; Gallimore *et al.*, 2011). This is problematic from an urban design perspective because it is often precisely these micro-scale design features that are of interest.

Focusing on perceptions instead of travel behaviour outcomes, Ewing & Handy (2009) used visual assessment surveys to test for correlations between perceptions of walkability and nine commonly used perceptual urban design qualities (coherence, complexity, enclosure, human scale, imageability, linkage, legibility, tidiness and transparency) on perceived walkability. In their study, an expert panel of design professionals and researchers rated walking environments for overall walkability based on video clips. Trained students then quantified the presence of the nine urban design qualities in each video clip. More than 95% of the variation in the expert panel ratings of walkability was explained by the students' assessment of just five of the variables: human scale, transparency, tidiness, enclosure and imageability. A stated limitation of this study was that experts, rather than users, determined the subjective walkability scores.

Despite evidence that micro-scale built environment characteristics influence walking and perceptions of walkability, there is little empirical evidence suggesting which specific micro-scale built environment variables are influential for either walking or perceptions of walkability. In their review of environmental audits for walking and bicycling, Moudon & Lee (2003) found that despite "empirical support for associations between classes of variables and walking and cycling behaviors", little is known about the effect of single variables (p. 33).

To address this knowledge gap, Borst *et al.* (2008) developed a method for testing the influence of individual built environment features using environmental audits and survey-based respondent mapping. Data collected using this method indicated positive associations between older adults' (aged 65 and older) perceptions of attractiveness for walking and such physical characteristics as trees, front gardens, parks, benches, marked crosswalks, transit stops and certain land uses in a Dutch city. Traffic volumes, vacant buildings, litter and high-rise buildings were negatively associated with street segment attractiveness in a regression model that predicted approximately 32% of the variance in perceived attractiveness.

This method, which was adapted for use in the present study, has parallels to conjoint analysis, a tool used by market researchers to examine how individual features of a product contribute to consumer preference for one product over others (Green *et al.*, 2001). Conjoint analysis has received limited attention within the fields of urban design and planning (for an urban design example, see Katoshevski & Timmermans, 2001).

Research Design

Green Streets

The research presented in this paper was part of a larger study, supported by the US Environmental Protection Agency, to examine the potential benefits of green street infrastructure on active transportation and active ageing (Dill *et al.*, 2010). The City of Portland has embraced green streets as a key tool in its efforts to reduce the amount of storm water runoff entering its sewer system. Green street facilities consist of vegetated catchment basins that capture runoff from nearby streets and sidewalks so that it can more naturally filter into the ground instead of running directly into overloaded sewer systems that can overflow into area streams and rivers. As of 2010, the City had installed over 500 individual green street facilities along approximately 20 000 feet of street frontage (Dill *et al.*, 2010). An additional $50 million is allocated for the City's 'Grey to Green' program, which will fund additional green street facilities as well as stream restorations, green roofs and the planting of 50 000 street trees.

Two distinct varieties of green street facilities were built in the study area between 2006 and 2008. One type of green street consists of concrete catchment basins located at the ends of blocks, which are planted with attractive ferns, grasses and rushes that extend vertically beyond the concrete rim and are easily seen by passing pedestrians (Figure 1). In addition, narrower basins typically extend the length of these blocks and are planted with lawn and young street trees (seen at top right of Figure 1). Here this variety of green street treatment is referred to as 'deluxe' in relation to the second type, which has been labelled 'basic'. This second, 'basic' type of green street resembles a standard lawn-covered planting strip, planted with young street trees and sloping on either side to form a basin to catch water running off the street through a perforated kerb (Figure 2). To the casual observer, the basic green street design may not register as being different than standard planting strips. Because the two types of green streets are so different in appearance, the decision was made to evaluate them as two separate design variables in order to test for differences in how each type influences perceptions of attractiveness for walking.

Study Area

The study area comprised four sub-areas, two of which included concentrations of green street features and two adjacent control areas matched for socio-demographic and physical characteristics. The study area lies completely within the Lents neighbourhood of Portland, Oregon and forms a nearly

Figure 1. 'Deluxe' green street feature along 92nd Ave.

Figure 2. 'Basic' green street feature near 104th Ave.

contiguous area of mostly residential parcels surrounding the Lents business district. The Lents neighbourhood covers approximately 4.5 square miles and is centred approximately 7 miles southeast of downtown Portland. The median family income for the neighbourhood was $41 647 in 2009, which was 17% below Portland's median family income. Nearly a quarter of adults in Lents have only a high school education versus 14% of adults citywide. According to a 2005 City of Portland survey, Lents residents also reported feeling significantly less safe in their neighbourhood due to crime than did residents in the rest of the city. Finally, about half of the homes in Lents were built after 1950, giving the neighbourhood a more suburban feel than some closer in Portland neighbourhoods.

Walkability Audits

The first stage of data collection was a systematic inventory of physical characteristics for each street segment in the study area. The research team developed an audit tool that combined elements from previously developed instruments (Michael *et al.*, 2006; Clifton *et al.*, 2007). The final audit instrument contained 50 items ranging from sidewalk condition and width to the level of building and public space maintenance. In addition, two subjective ratings were included: one assessing attractiveness for walking and the other perceived safety for walking. A team of 12 volunteers conducted the audits. Volunteers were required to attend 4 hours of in-class training and 4 hours of field training prior to data collection. Audits were conducted between February and April 2010. Reliability tests conducted on 10% of audited segments showed a high degree of reliability, with percentage agreement on individual items ranging from 0.677 to 0.986. This level of agreement was similar to levels reported in previous walkability audits (Michael *et al.*, 2006; Clifton *et al.*, 2007).

Survey-based Respondent Mapping

The measure of attractiveness used as the dependent variable in this analysis was derived from a survey-based respondent mapping exercise in which study area residents were given a map of their respective sub-area and asked to indicate with a small circle the street segments where they liked walking and an 'X' where they did not like walking. The map exercise was included as part of a longer survey sent to 2163 households in the Lents neighbourhood. The map was printed in black and white on a standard $8\frac{1}{2}$ x 11 sheet of paper at a scale of approximately 1 inch = 200 feet. Street names and major neighbourhood features such as parks, schools, light rail stations and bus stops were labelled, but commercial destinations such as shops and restaurants were not. A key distinction between the study by Borst *et al.* (2008) and the one here is that this one did not ask about specific routes or trips. The approach was meant to capture information on general attractiveness of walking environments whether experienced during utilitarian or leisure walking.

Analysis

Because the focus was on micro-scale walking environments, the units of analysis were individual street segments. The dependent variable for the analysis was calculated by aggregating all ratings for a segment and dividing the number of positive ratings by the total number of ratings for that segment. This attractiveness score represents the proportion of ratings for a segment that were positive. Attractiveness scores were calculated only for segments that had at least three ratings so that each score was a composite of multiple respondents. Unlike Borst *et al.* (2008), who assigned a neutral score to segments that received no ratings, this study treated unrated segments as missing data and excluded them from analysis. A total of 56 segments with two or fewer ratings were excluded, leaving 321 scored segments to analyze.

A total of 60 built environment and traffic variables were used for analysis. All but three were derived from data collected through the walkability audit. The additional variables included a dummy variable indicating whether a segment had a high volume of traffic according to recent City of Portland counts and a dummy variable for each type of green street design, taken from a City of Portland GIS file and confirmed through field visits.

Bivariate correlations for each variable were calculated and an ordinary least squares (OLS) regression model was tested to evaluate the individual influences of built environment characteristics on attractiveness for walking. The regression model was specified based on examination of the bivariate correlation matrix and the goal of testing the influence of green streets. One challenge of testing the influence of green street infrastructure is that these facilities often include pedestrian-oriented design features that are present elsewhere, independent of green streets. For example, green street installations typically include some type of buffer between the sidewalk and traffic and often incorporate curb-extensions or bulb outs that simultaneously capture storm water runoff and shorten the distance for pedestrians crossing the street. In order to isolate the unique effects of green street infrastructure and not simply the cumulative effects of these associated features, the following control variables were included in the model regardless of their statistical significance: kerb ramps, kerb extensions, sidewalks, trees and sidewalk setbacks from the kerb. With the exception of these control variables, non-significant variables were excluded from the model one at a time using a backward elimination approach.

Findings

Descriptive Statistics

Completed surveys were received from 748 individuals in 572 households, with a household response rate of 26.4%. Overall, 27% of survey respondents reported walking less than once per week and 46% reported having walked in the neighbourhood for recreation in the last month. Just over 10% of respondents lived in zero-car households and 15% did not have a driver's license. The average aggregated segment attractiveness score was 0.63 (on scale ranging from 0 to 1). Approximately 90% of survey respondents completed the map exercise. A higher percentage of respondents aged 65 and older skipped the map exercise (14% versus 8%).

Bivariate Correlations

A total of 33 variables had significant ($p < 0.05$) or marginally significant ($p < 0.10$) bivariate correlations with segment attractiveness scores (Table 1). These correlations were simply a jumping off point for further analysis and, as such,

Table 1. Bivariate correlations with street segment attractiveness scores

	r	Sig.
Street characteristics		
Bus stop	0.22	<0.01
Maximum lanes to cross	−0.35	<0.01
Minimum lanes to cross	−0.38	<0.01
On arterial	−0.45	<0.01
On-street (kerb) parking	0.19	<0.01
Over 20,000 total ADT	−0.35	<0.01
Adjacent land use		
Access through parking lot	−0.14	0.01
Building setback 20 + feet	−0.16	0.01
Front porches	0.10	0.07
Most yards well maintained	0.10	0.06
Off street parking spaces (#)	−0.22	<0.01
Park adjacent	0.12	0.02
Retail type: auto oriented	−0.15	0.01
Retail types: drive-thru	−0.14	0.01
Retail types: strip mall	−0.10	0.06
Pedestrian environment		
Buffers (landscape)	−0.14	0.01
Connectivity	0.32	<0.01
Kerb cuts	0.11	0.06
Free from obstructions	0.11	0.05
Green street treatments	0.16	<0.01
Off street path	0.18	<0.01
Poor public maintenance	−0.16	<0.01
Poor sidewalk condition	−0.19	<0.01
Sidewalk or paved trail	0.15	0.01
Sidewalk setback 5 + feet	−0.14	0.01
Trees	0.11	0.04
Safety interventions		
Marked crosswalks (#)	−0.27	<0.01
Ped warning sign	−0.16	<0.01
Pedestrian signal	−0.26	<0.01
Speed bumps	0.10	0.08
Stop sign	0.27	<0.01
Traffic light	−0.33	<0.01

should not be used to draw conclusions. A few observations are worth mentioning, however, in part as a caution against reading too much into correlations that do not control for more complex relationships. First, many features thought of as beneficial to pedestrians, such as crosswalks, pedestrian signals and traffic lights, were negatively correlated with attractiveness for walking. This is probably because such features are often placed deliberately in locations with a high degree of pedestrian-auto conflict. Second, landscaped buffers and sidewalk setbacks were unexpectedly negatively correlated with attractiveness. This is also probably explained because they tend to be concentrated along arterial streets with wider rights-of-way, faster speeds and higher traffic volumes.

OLS Regression Model

The OLS regression model (Table 2) predicted approximately 41% of the variation in segment attractiveness scores. The deluxe green street installations were one of the strongest predictors of attractiveness for walking. Controlling for other variables in the model, segments with deluxe green street features had attractiveness scores 0.34 higher (on a 0 to 1 scale). Basic green streets did not have a significant effect. Arterial streets lowered a segment's attractiveness score 0.32 while an adjacent park increased the attractiveness score of a segment by 0.34. Each additional connection to another pedestrian link also increased attractiveness for walking by 0.03. Separation of the walking environment from traffic in the form of sidewalk setbacks and on-street parking were both significant and increased attractiveness scores 0.12. Convenience stores had a negative influence on attractiveness for walking, with scores for segments with a convenience store 0.19 lower than those without.

Table 2. OLS regression model predicting street segment attractiveness scores

	Coeff.	T	Sig.
Roadway characteristics			
Arterial	−0.317	−7.649	<0.001
On-street parking	0.116	2.213	0.028
Walking environment characteristics			
Pedestrian network connectivity	0.034	3.336	<0.001
Sidewalk setback > 5 feet kerb	0.121	3.151	0.002
Enclosure	−0.088	−2.707	0.007
Adjacent land use characteristics			
Building setback > 20 feet	−0.071	−2.102	0.036
Convenience store	−0.188	−2.041	0.042
Park adjacent	0.337	4.084	<0.001
Green streets			
Green streets - Basic	0.053	0.722	0.471
Green streets - Deluxe	0.338	3.691	<0.001
Green street controls			
Sidewalks	−0.079	−0.894	0.372
Kerb extensions	0.026	0.261	0.794
Kerb ramps	0.002	0.081	0.935
Trees	−0.028	−0.859	0.391

Summary statistics: Adjusted R-square = 0.412; N = 321.

Discussion

Green Streets

The finding that deluxe green street installations were associated with higher segment attractiveness scores suggests that in addition to retaining and filtering storm water, well-designed green streets can contribute to more attractive walking environments. The insignificance in the model of the more rudimentary type of green street facilities indicates that for green streets to improve walkability, they must have distinct, high-quality (and probably more costly) design elements, such as an attractive mix of ground-level and vertical plants.

Other Built Environment Characteristics

Being on an arterial street had the strongest influence (negative) on a segment's attractiveness score. This echoes previous empirical findings of Agrawal *et al.* (2008). Separation of the walking environment from lanes of traffic was clearly associated with higher attractiveness scores, both for sidewalk setbacks from the kerb and the presence of on-street parking, which provides a visible and physical buffer between pedestrians and vehicle traffic. This mirrors previous empirical evidence regarding pedestrian safety (Dumbaugh, 2005) and supports the Institute for Transportation Engineers' (2010) recommendation of buffers for walkable urban street designs.

A high degree of enclosure is thought to make a streetscape more desirable to users by creating the feeling of a room rather than an open expanse (Nasar, 1994; Ewing & Handy, 2009). Initially there was surprise that the model indicated a negative effect of enclosure on attractiveness for walking, especially given that a separate variable indicating whether buildings were set back 20 feet or more from the sidewalk was significant and decreased segment attractiveness for walking (enclosure remained significant and negative in the model both with and without the inclusion of the building setback variable). These findings appear contradictory, but it is thought they could reflect the desirability of 'open but bounded space', as described by Nasar (1998). Another explanation is that traditional ideals of enclosure as a positive urban design characteristic may not hold up in the context of a predominantly residential, lower-income neighbourhood with relatively low perceptions of safety. Enclosure of the type one might find in a mixed-use town centre or neo-traditional residential neighbourhood was rare in this study area. Enclosure in this context was more likely to be in the form of a wooden fence, a row of overgrown arborvitae or the blank sidewall of a commercial building. A shortcoming of the audit instrument was that it did not capture more complete information on the nature of the enclosure that would allow for further elaboratation.

The finding that convenience stores have a negative influence on attractiveness for walking is not surprising considering that they are often located for maximum drive-by visibility and easy access for vehicle traffic. However, it also highlights a limitation of applying a quantitative research method to highly qualitative questions of user experience. It is not known, for example, whether negative associations with convenience stores stem instead from uneasiness about loitering or other activities that might take place there. Follow-up qualitative research could help to answer these questions.

Differences in User-derived versus Researcher-derived Perceptions

A final statistical test revealed that trained volunteer auditors' subjective 'attractive for walking' ratings were only moderately correlated ($r = 0.33$) with user ratings for the same segments. This suggests that subjective assessments of walking environments by research teams may not be reliable substitutes for user-generated assessments.

Limitations

Several potential shortcomings of this data collection method are acknowledged. First, using a binary rating of segment attractiveness is potentially limiting, as it may not capture subtle variation in individual preference and, in the absence of a neutral option, probably biases aggregate scores toward extreme values. A multi-point scale would have generated richer data, but this level of detail would have been far more burdensome for respondents who were potentially rating dozens of segments. Furthermore, as in the choice-based rationale behind conjoint analysis, there is rich interpretive value in examining the variation in binary outcomes aggregated from multiple respondents.

In addition, because respondents were not explicitly instructed to rate street segments based on attributes of the physical environment, it is possible that considerations not tested for in the model (e.g. routes to popular destinations, unfriendly neighbours or past negative experiences) influenced ratings. More specific instructions for the map exercise could have addressed this concern and may be appropriate for future applications of this method. A mixed-method study with a qualitative follow-up component could have made it possible to make more detailed conclusions about the nature of the reported relationships.

Conclusion

By coupling survey-based respondent mapping with detailed audits of the physical environment it was possible to successfully unpack the individual built environment components that contributed to user perceptions of attractiveness for walking. The findings indicate that well-designed green streets, separation from vehicle traffic, pedestrian network connectivity, parks and 'bounded openness' contribute to attractiveness of walking environments. Segments on arterial streets and those having convenience stores are associated with lower walking attractiveness scores. Of course, the methodology was only applied in a single context—a mostly single-family residential neighbourhood—and testing in other environments is necessary before broader conclusions can be drawn.

Despite acknowledged limitations, the method appears to have both the predictive power and sensitivity necessary to examine subtle differences across an array of built environment and design features, including two types of green street facilities. By focusing on micro-scale walking environments and drawing on user-derived data, this approach could be useful for urban designers and planners wanting to better understand how particular design features influence user perceptions of walkability.

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