Contributions of Accessibility and Visibility Characteristics to Neighborhood Typologies and their Predictions of Physical Activity and Health

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Keywords
environmental typology; physical activity; health outcomes; space syntax

Abstract

In recent years, numerous studies have examined the effects of the built environment on physical activity and health outcomes. While much of this research has focused on discrete environmental measures, such as housing density, land use, or the presence or absence of sidewalks, recent studies have addressed the combined effects of 'bundles' of environmental measures.

As part of a program of research aimed at understanding neighborhood effects on the physical activity and health of residents in three Detroit MI (USA) neighborhoods, this paper describes the process of creating micro-neighborhood types and their hypothesized affects on local physical activity and health outcomes. In particular, we consider the additive predictive significance of incorporating into our micro-neighborhood types measures of street network characteristics (connectivity and accessibility) and objective measures that capture aspects of design quality (based on visibility measures) along walking paths.

Based on the theoretical significance of sets of variables from previous studies, and an analysis of the environmental characteristics of our study neighborhoods, we propose nine 'bundles' of neighborhood characteristics or micro-neighborhood types to be assessed as potential factors *affecting our outcome variables of physical activity and health. Our intent was to identify a reasonable number (<10) of neighborhood types that shared readily observable differences that could be easily adopted by planners and designers.*

Patterns of residential density and land use were examined across all study neighborhoods and used to create our basic set of nine types. For the purposes of our data analysis, we further divide our typologies into sub-categories to examine the impact of different types of land uses and their projected multiplying effects as enhancers or deterrents to destination walking. Using aerial photographs and syntax analysis, we consider measures of street network characteristics (connectivity and accessibility), and the role of objective measures that capture aspects of design quality (based on measures of visibility: visual access, visual control and visual interest) along walking paths.

Contributions of this study include the identification of critical 'bundles' of physical environmental characteristics that play a role in the creation of neighborhoods that support physical activity. Our current analyses are quite suggestive in postulating the contribution of syntax measures in capturing aspects of the design quality (path characteristics) and ease of reaching destinations (network characteristics) that shape respondents' perceptions of their environment and contribute to physical activity outcomes. In future analyses we will examine the role of these characteristics in augmenting the predictive power of our neighborhood typologies.

1. Introduction

The prevalence of obesity and its associated health risks (cardiovascular disease, diabetes, dietary cancers, and stroke) in the American population has risen dramatically over the past 20 years. It has become clear that there is a need to create 'healthy' environments – neighborhoods that are conducive to walking and other physical activity and that support healthy diets. To address these goals the Lean & Green in Motown (LGM) project brings together an interdisciplinary group of researchers from the University of Michigan School of Public Health, UM Taubman College of Architecture + Urban Planning, University of Chicago at Illinois, and the Henry Ford Health System Center for Multicultural Health, with representatives from eastside, northwest and southwest Detroit MI (USA) communities.

In recent years, numerous studies have examined the effects of the built environment on physical activity and health outcomes. While much of this research has focused on discrete environmental measures, such as housing density, land use, or the presence or absence of sidewalks, recent studies have addressed the combined effects of 'bundles' of environmental measures. It has been posited that while urban designers and planners work with individual environmental attributes, in practice they typically consider them in combination with one another.

One of the aims of the LGM project is to explore the interrelationships between characteristics of the built environment and the physical activity behavior and health measures of the residents in three Detroit neighborhoods. This paper presents the theoretical and methodological approach we have used in a process to create nine neighborhood typologies or 'bundles' of community design features, and the exploration of the effects of these typologies on local physical activity, walking behavior and selected health outcomes. In particular, we consider the additive predictive significance of incorporating into our micro-neighborhood types measures of street network characteristics (connectivity and accessibility) and objective measures that capture aspects of design quality (based on visibility measures) along walking paths.

Based on the theoretical significance of sets of variables from previous studies, and an analysis of the environmental characteristics of our study neighborhoods, we propose nine 'bundles' of neighborhood characteristics or micro-neighborhood types to be assessed as potential factors affecting our outcome variables of physical activity and health. Our intent was to identify a reasonable number (<10) of neighborhood types that shared readily observable differences that could be easily adopted by planners and designers.

Patterns of residential density (derived from census data) and land use (derived from land use maps) were examined across all study neighborhoods and used to create our basic set of nine types. For the purposes of our data analysis, we further divide our typologies into sub-categories to examine the impact of different types of land uses and their projected multiplying effects as enhancers or deterrents to destination walking.

We then examined the contribution of syntactic characteristics that might augment our typologies as predictors of physical activity. Using aerial photographs and syntax analysis, we consider measures of street network characteristics (connectivity and accessibility), and objective measures that capture aspects of design quality along walking paths (based on measures of visibility: visual access, visual control and visual interest).

Contributions of this investigation include the identification of critical 'bundles' of physical environmental characteristics that play a role in the creation of neighborhoods that support walking and other physical activity. Neighborhood typologies can provide urban designers and planners with 'imagable' sets of environmental characteristics for use in creating healthy neighborhood environments.

2. Research Relevant to the Construction of Typologies

There is general agreement that characteristics of the built environment shape travel demand, particularly with respect to automobile travel. However, the relationship to and environmental characteristics that might affect walking behavior are less clear (Boarnet and Crane, 2001). Although much of the early research has focused more on discrete environmental measures, such as housing density, land use mix, or the presence or absence of sidewalks, several recent studies have addressed the combined effects of groups or 'bundles' of environmental measures. It has been posited that while urban designers and planners work with individual environmental attributes, they typically consider them in combination with one another or as a bundle of attributes. Several recent papers are reviewed below that explore the assessment of groups of neighborhood characteristics and their contributions to walking behavior.

A significant contribution to this research field was the framework presented by Cervero and Kockelman (1997) that suggested the importance of the three D's: density, diversity, and design in affecting automobile trips and non-motorized travel. Their results indicated that density, land-use diversity, and pedestrian-oriented design affected trip rates and mode choice for residents of the San Francisco Bay area. They observe that these factors (density, diversity, and design) are interrelated and conclude that the combination of more compact, diverse and pedestrian-oriented development, those features reflected in new-urbanist development perspectives, can influence travel outcomes.

Following on the above work, Frank and Pivo (1994) and Frank et al. (2005) attempt to identify specific objectively measured aspects of the physical environment as measures of density, diversity and design. Objective measures of land-use mix, residential density, and street connectivity (intersection density) were developed. Areas that are higher density often tend to be highly connected and represent greater mixed use. To accommodate this high colinearity, these measures were combined into a 'walkability' index. Results indicated the positive relationship between physical activity and the three measures of the physical environment, and the significant effects of the combined walkability index in predicting participation in physical activity above and beyond the affects of socio-demographic data.

Lee and Moudon (2006) also recognize the problem of colinearity; however, they suggest that grouped measures that are characterized by composite indices, such as the walkability index, may be difficult for planners and designers to translate into development guidance or policy. They conclude that a focus on a small number of readily observable characteristics, such as specific destination land uses and distances to these uses, may be an equally or more effective means of characterizing 'walkable' environments for use in the development of planning policy and design practice. Lee and Moudon propose three D's (density, diversity, design) plus R (route distance, or the distance to land uses).

As part of the LGM program of research aimed at understanding neighborhood effects on the physical activity and health of residents in three Detroit neighborhoods, efforts have been made to characterize the micro-neighborhood of study participants. Below we describe the process used in creating micro-neighborhood types and their hypothesized affects on walking behavior and health outcomes. Following from the literature above, these types incorporate measures representing the three D's (density, diversity, design) plus R (route distance).

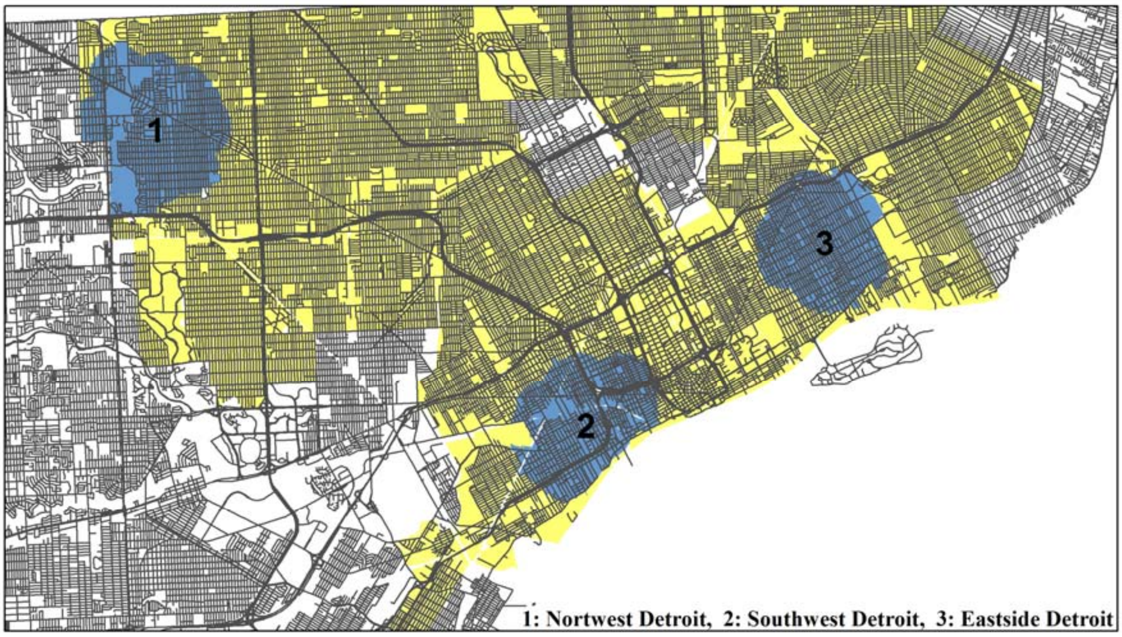


Figure 1
City of Detroit, Michigan, USA

3. Constructing the Typologies

Based on the theoretical significance of sets of variables from several previous studies, and an analysis of the environmental characteristics of our study neighborhoods, we have identified a set of proposed micro-neighborhood types or 'bundles' of neighborhood characteristics to be assessed as potential factors affecting of our outcome variables of physical activity and health. For the construction of our proposed typologies, characteristics of the environment were examined for each of our sample 'rooks' (a rook is a respondent block and the four blocks that surround it). Our intent was to identify a reasonable number (<10) of neighborhood types that shared readily observable differences (reflective of the three D's plus R) that might be easily adopted by planners and designers. This process is presented in two steps as described below.

First, patterns of residential density (derived from census data) and land use (derived from land use maps) were examined across all study rooks. Based on an examination of the range of density values, three categories of density are proposed: lower density (0 - <4 units per acre); medium density (4 - <6 units per acre); and higher density (6 units and greater per acre). Some rooks had significant proportions of vacant land; this characteristic is reflected in our density measures. To address the characteristics of land use, we have divided our typology into three categories based on land-use mix: homogeneous land-use type; two land-use types; more than two land-use types.

These descriptors of residential density and land use were used to create our basic set of nine types. These factors: residential density and land use mix reflect the first two of the three D's: density and diversity. In addition to the rook-level analysis, we will also look at these typological characteristics for an area that extends ¼ and ½ mile radius from each of our sample blocks.

For the purposes of our data analysis, we will further divide our typologies into sub-categories to examine the effects of looking specifically at different types of land uses and their projected impact as enhancers of destination walking or deterrents to walking. Specifically we propose that the presence of industrial land uses would be a deterrent to walking. This measure will augment our assessment of the diversity of land uses.

Second, we elaborated our proposed typologies with syntax measures that captured characteristics of neighborhood routes. Specifically, we suggest that measures of street network characteristics capture the ease of reaching destinations. Street network characteristics for this study included syntax measures of connectivity, local and global integration. And furthermore, we proposed that visibility measures capture aspects of the design quality of routes. Our visibility measures included syntax measures of *visual access* ('how far one can see'—defined by the longest radial), *visual control* ('how much can one see'—defined by the visual area, length of perimeter and occluded perimeter) and *visual interest* (mean change of these measures along a route).

Space syntax techniques applied in this research provide rigorous methods of measuring both global and local street network characteristics and relationships between them. "Space syntax" has contributed increasingly sophisticated ways for dealing with urban layouts as differentiated patterns of large-scale connections. This complements the emphasis on local attributes (such as the dimensional profile of street sections, the characterization of boundaries, or the attributes and qualities of individual open spaces) that is typical in many studies of urban space use (Whyte, 1980; Caliandro, 1986). Even when authors have emphasized the importance of configuration and overall connectivity to the culture and use of streets (Schumacher, 1986; Southworth and Owens, 1993; Southworth and Ben Joseph, 1995; Siksna, 1997) descriptive concepts remain either qualitative or limited to mostly local variables, such as the various types of intersection between street segments, or the number of intersections per unit area, or the size of urban blocks. The ability of "space syntax" to describe global configurational properties as well as the relationships of part to whole, and the association between these properties and patterns of space use, has made space syntax a fruitful method for use in a broad variety of fields.

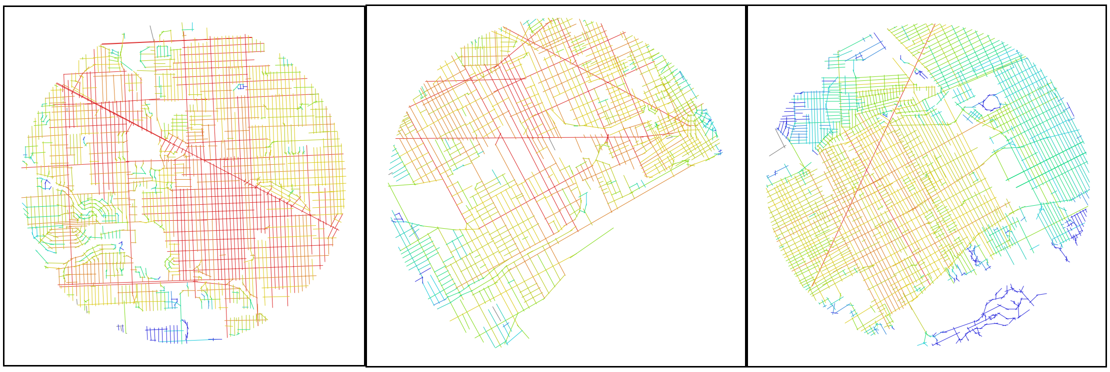
The techniques for the analysis of spatial form or "space syntax analysis" were developed by Bill Hillier and his colleagues at University College London (Hillier & Hanson, 1984). Syntax analysis techniques characterize spatial systems on the basis of the ways in which spaces are related to other spaces within a larger system. Syntactically, a system of spaces is more "integrated" if spaces can be easily reached from one another, or less integrated if one must travel through many other spaces to move from one space to another. Previous research has demonstrated the importance of such spatial characteristics as integration (a global measure) and connectivity (a local measure) in describing pedestrian movement rates in neighborhoods (Hillier, 1997; Hillier et al., 1987; Hillier et al., 1993). Desyllas and Duxbury (2001) found connectivity and visibility measures associated with higher pedestrian activity. These results have been replicated in studies of U.S. cities and other international cities (Kim and Sohn, 2002; Min, 1993; Peponis et al., 1989, 1997; Read, 1999).

Syntax measures (using Syntax2D) were derived for each of our three Detroit neighborhood study areas, Eastside, Northwest and Southwest. Street network characteristics were based upon a lines analysis for each neighborhood. Each respondent was assigned the network characteristics (see above) for the street outside their unit location; the mean values of those measures calculated for each respondent's "rook" (a rook is defined as the respondent's block and the surrounding contiguous blocks); the mean value for the ¼ mile radius from the respondent's block; and the mean value for the ½ mile radius. Visibility measures were developed for eye level visibility fields (see above) along neighborhood streets. This analysis was applied to maps developed from aerial photographs that included built structures, trees, and other potentially obstructive natural or man-made features. Each respondent was assigned the visibility values for the street outside their unit location, and the mean values of those measures calculated for the respondent's 'rook'.

4. Preliminary Results

One of the specific aims of the Lean & Green in Motown (LGM) project is to assess the independent and collective scientific contributions of the built environment for understanding the means by which the built environment influences behavioral and biological factors associated with obesity and related co-morbidities among African American, Hispanic and white residents of Detroit. Survey data used for this study were drawn from the Healthy Environments Partnership (HEP) community survey, one component of a community-based participatory research study involving academic, health care and community-based organizations in Detroit, Michigan (Schulz et al., 2005). The HEP survey is a stratified two-stage probability sample of occupied housing units, designed for 1000 completed interviews with adults age >25 years across three areas of Detroit, allowing for comparisons of residents of similar demographics across geographic areas of the city. The final sample consisted of 919 face-to-face interviews (Schulz et al., 2005).

Built environment measures were developed for each of the three Detroit neighborhood study areas, Eastside (2.5x2.5 miles), Northwest (3x3 miles), and Southwest (2x3 miles). *Street network characteristics* (accessibility, connectivity) and *path characteristics* (visual access, visual control, visual interest) were derived for each neighborhood area using computer-based space syntax methods (Syntax2D) applied to the GIS dataset of resident address locations.



Northwest Detroit | Southwest Detroit | Detroit Eastside

Figure 2

Integration- Three Detroit Neighborhoods

Two aspects of *street network characteristics* were calculated for each respondent's street segment: street network connectivity and street network accessibility. The analysis assumes the neighborhood street system is represented as a system of 'axial' line segments (Hillier, 1984). *Connectivity* measures the extent to which a street segment (or set of streets) is well connected within its immediate neighborhood. *Accessibility* (assessed by the measure integration) represents the extent to which a street segment is more or less accessible from all other parts of the neighborhood.

Path characteristics include a set of objective measures that are intended to capture aspects of design quality (based on visibility measures) along walking paths. Measures include: visual access (how far one can see), visual control (how much one can see), and visual interest (how varied is the visual information). The visibility measures included in this analysis are those that define 'how much one can see': *visual area, length of perimeter* and *occluded perimeter*. These measures are based on an analysis of two-dimensional eye-level fields of view (visual fields) along specified paths derived from aerial photographs (indicating both built structures and significant vegetative cover).

We are currently in the preliminary stages of our data analysis. At this stage, we have completed simple correlations to explore the relationship of street network and path characteristics to the physical activity and other social/psychological responses of neighborhood residents. These correlations are the first step in our analysis. In order to explore predictive effects and co-variance, our next step will be to construct multivariate models. Following these analyses, we will examine the contribution of these syntactic variables to the predictive effects of our nine neighborhood typologies (as described above).

Street Network Characteristics: On the basis of simple correlations, we will discuss a number of significant relationships. From the survey data, a number of scales were constructed. Two of these scales are of interest to us: "sense of community" (residents of this neighborhood know each other, watch out for each other, and so forth) and "safety stress" (how safe residents feel in their house or on their street from robbery, theft, and so forth). First, we found a positive relationship (although not strong) between the scale measure of respondents' "sense of community" and *connectivity*, and a negative relationship with *integration* (1/RRA). The more the local neighborhood is well-connected, the stronger the sense of community. The more it is integrated with other parts of the larger neighborhood area, the lower the sense of community. Second, we found a negative relationship between *integration* and safety stress. The more integrated one's street is to the larger neighborhood, the less a resident is concerned about safety. We also observe a near significant negative relationship between connectivity and safety stress. The more connected the local neighborhood, the lower the concern about safety. These relationships are significant and stronger for our Hispanic sub-group than for African-American and White subgroups. Although these two scales are related, it appears that greater connectivity supports sense of community at the local level. However, sense of community is reduced as there are more connections with the larger neighborhood area. Fear of crime is also reduced as the neighborhood is more connected to the larger area (potentially more accessible to observation or eyes on the street).

	Connectivity	p-value	Integration (1/RRA)	p-value
Sense of Community	0.080	.014*	-0.080	.015*
Safety Stress	-0.059	.076	-0.081	.013*
Safety Stress for Hispanics	-0.28032	.0001*	-0.348	<.0001*
Perception of Safety of Parks for Hispanics	-0.20521	.0092*	-0.228	.0037*
Physical Activity Scale for Income $35,000+ per Year	-	-	0.192	.0072*

Table 1
Street Network Characteristics ** =<.05 is significant*

We also found significant relationships between perceptions of the safety of parks and playgrounds for our Hispanic sub-group. The more connected the local neighborhood and the more integrated with the larger neighborhood area, the less the park is perceived to be safe. This may appear to be an unexpected result. However, we need to keep in mind that there is a relatively high concern for safety in the city of Detroit; and parks may be used for unsanctioned activity. For our Hispanic sub-group, if a park is in a well-connected local area and is well-integrated in a larger neighborhood area, it may be more easily accessible to outsiders. Related to the variable on safety stress, it may be that residents are less concerned about crime in more tightly knit local neighborhoods, but may feel that a park is more isolated and open to outsiders.

Our physical activity scale (combines many forms of activity) was found to be significant only for the highest income group ($35,000+ per year). For this group, there was a positive correlation between *integration* and physical activity. This may suggest that perceptions of safety affect one's exercise behavior at higher income levels. The more integrated one's neighborhood (ie. well connected to the larger neighborhood), the less likely residents are to be concerned about safety, and the more likely they are to engage in physical activity. For lower income groups, there may be many other factors affecting whether a respondent engages in physical activity.

Path Characteristics: We also have some interesting correlational results concerning path characteristics. Of course as with our other correlational analyses these are very tentative results and need further investigation to examine covariate effects. One of the important differences with these measures is that in contrast to the street network measures that characterize the local neighborhood (*connectivity*) and the larger neighborhood area (*integration*), the path characteristics for these analyses are measures that characterize the visual qualities of the street segments along a respondent's block and the contiguous blocks (the 'rook').

We found a positive correlation between *occluded perimeter* and safety stress; and a negative correlation between *length of perimeter* and safety stress. Occluded perimeter (non-real-wall perimeter) is an indicator of hidden areas, where potential undetected activity could occur. It makes sense that as the extent of occluded perimeter increases, respondents might feel higher safety stress. On the other hand, there was a negative correlation between *length of perimeter* and safety stress. Length of perimeter indicates the extent views are more irregular or 'spikey', potentially broken-up by objects such as buildings. Thus the results suggest as the views are more irregular, perceptions of safety stress decrease. More irregular views may be characteristic of streets with more houses (and thus perceptions of safety stress decrease) versus streets with pockets of vacancy. We are exploring other neighborhood characteristics that may be moderating this relationship.

	Occluded Perimeter	p-value	Length of Perimeter	p-value
Safety Stress	0.120	.0003*	-0.120	.0003*
Park Use	0.131	.025*	-0.135	.020*

Table 2
Path Characteristics ** =<.05 is significant*

Results from our analysis of park use were also difficult to interpret. Consistently we found that respondents visited parks more often if their street segment had higher *occluded perimeter*, and less often if their street segment had higher *length of perimeter*. These relationships appear to contradict what might be expected theoretically and what is shown by responses concerning safety stress; however, one needs to keep in mind that these path measures relate to the street segments adjacent to the respondent's block and contiguous blocks (the 'rook'). Perhaps if these are characteristics of their immediate neighborhood, residents are more likely to visit parks located elsewhere. Again, we are in the process of exploring other neighborhood characteristics that may be moderating these relationships.

In future analyses, we will be exploring the direct effects of our neighborhood typologies on walking and other physical activity, and how these typologies might be augmented by the inclusion of particular characteristics of street network and paths.

5. Conclusions

Contributions of this project will include the identification of critical 'bundles' of physical environmental characteristics that play a role in the creation of neighborhoods that support walking and other physical activity. Our current analyses are quite suggestive in postulating the contribution of syntax measures in capturing aspects of the design quality (path characteristics) and ease of reaching destinations (network characteristics) that shape respondents' perceptions of their environment and contribute to physical activity outcomes. In future analyses we will examine the role of these characteristics in augmenting the predictive power of our neighborhood typologies.

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