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NEIGHBORHOOD DESIGN AND HEALTH: Characteristics of the Built Environment and Health-Related Outcomes for Residents of Detroit Neighborhoods

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Abstract

Obesity and associated health risks (cardiovascular disease, diabetes, dietary cancers, and stroke) in the American population have risen dramatically during the past quarter century. It has become clear that there is a need to create 'healthy' built environments – neighborhoods that are conducive to walking and other physical activities. To address these goals the Healthy Environments Partnership's Lean & Green in Motown (LGM) project brings together an interdisciplinary a team of researchers from the University of Michigan (UM) School of Public Health, UM Taubman College of Architecture + Urban Planning, University of Chicago at Illinois, Detroit Department of Health and Wellness Promotion, Brightmoor Community Center, Detroit Hispanic Development Corporation, Friends of Parkside, Henry Ford Health System and Warren Conner Development Coalition. One of the aims of this project is to explore the interrelationships between characteristics of the built environment, physical activities, and health measures of residents in three Detroit neighborhoods: referred to as Eastside, Northwest and Southwest. Street network characteristics (integration, connectivity) were derived for each neighborhood using computer-based space syntax methods applied to the GIS dataset of resident address locations. Data were also collected on ¼ mile and ½ mile

density, land use mix (Entropy), and neighborhood typologies based upon categorical measures of housing unit density and land use. These measures are then examined in relationship to reported localized physical activity (both leisure and transportation related walking), controlling for socio-demographic status and other factors.

Physical activity and other health outcomes were measured using data from the 2008 Healthy Environments Partnership (HEP) community survey. The HEP survey is 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 was a stratified two-stage probability sample of occupied housing units, designed to collect longitudinal data through interviews of adults 25 years of age and older across the three Detroit neighborhoods, The study design allowed for comparisons of residents of similar demographics across geographic areas of the city. The survey was conducted in August 2008-July 2009 with 461 completed interviews. For our analysis we fitted 3 level multivariate linear HLM models, using the following set of covariates: age, gender, race/ethnicity, education, length of residence in neighborhood, length of time in labor force, and income. Findings suggest that residents of neighborhoods that are better connected to other areas of the city (higher integration) report higher levels of physical activity as compared to residents who live in neighborhoods with lower global connectivity. Similarly, people living in neighborhoods with higher (local) connectivity report higher localized leisure time physical activity as well as physical activity overall as compared to those in less well-connected neighborhoods. A neighborhood typology measure that combined more traditional urban planning measures of density and land use mix was marginally and positively associated with localized physical activity. Specifically, people living in neighborhoods characterized by both higher density (measured at the ½ mile) and higher land use mix report higher levels of localized physical activity, both physical activity overall (p=.099), and physical activity for transportation (p=.072). This study advances the field by extending more traditional planning studies to include syntactic characteristics of the neighborhood built environment. In particular the research suggests the importance of considering combined effects of multiple measures of the built environment in understanding their independent and joint relationships to physical activity.

INTRODUCTION

The prevalence of obesity and 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 in addition to promoting improved dietary patterns, there is a need to create 'healthy' built environments – neighborhoods that are conducive to walking and other physical activities. To address these goals the Healthy Environments Partnership's Lean & Green in Motown (LGM) project brings together an interdisciplinary group from the University of Michigan (UM) School of Public Health, UM Tauman College of Architecture + Urban Planning, University of Chicago at Illinois, Detroit Department of Health and Wellness Promotion, Brightmoor Community Center, Detroit Hispanic Development Corporation, Friends of Parkside, Henry Ford Health System and Warren Conner Development Coalition. One of the aims of this project is to explore the interrelationships between characteristics of the built environment, physical activities and health measures of residents in three Detroit Michigan (US) neighborhoods: Eastside, Northwest and Southwest.

This paper examines the interrelationships between selected characteristics of the built environment and reported physical activity. We explore the contributions of street network characteristics (connectivity, integration) and the more traditional planning measures of density and land use. We also include a measure reflecting the combined effects of density and land use in what we characterize as a neighborhood typology or 'bundle' of community design features. Our findings suggest significant associations between a set of these environmental characteristics and localized physical activity.

BACKGROUND

Environmental design and physical activity. Multidisciplinary researchers in public health, urban planning, and policy have examined the link between environmental factors and physical activity (Handy, 1996c; Lee, 2004a; Moudon & Lee, 2003; Pikora et al., 2003; Saelens et al., 2003b). A review of numerous studies suggests three broad sets of factors associated with physical activity: sociodemographic, psychosocial, and built environment (King et al., 2000; Lee & Moudon, 2004b; Pikora et al., 2003; Saelens et al., 2003a; Sallis et al., 1997; Stokols, 1992).

Research has demonstrated that walking is the most common type of physical activity and that most walking occurs on neighborhood streets close to residents' homes (Brownson et al., 2001). Other studies suggest that neighborhood walking constitutes most of the physical activity that is associated with characteristics of urban form (Frank & Pivo, 1994; Frank et al., 2008; Lee & Moudon, 2006b; Saelens et al., 2003b). Given the positive effects of physical activity on health outcomes, understanding the characteristics of 'walkable' neighborhoods has become an important topic of current research.

Evidence has accumulated in the urban planning and transportation literature that people walk and bike more when they live in neighborhoods with greater population density, mix of land uses, and higher street connectivity (Brownson et al., 2004; Frank et al., 2005a; Saelens et al., 2003b). Versions of the three environmental dimensions were adopted as the key preconditions of New Urbanist communities. Proponents of New Urbanism suggest that compact, mix use, and pedestrian-oriented development may change how Americans travel (Calthorpe & Poticha, 1993; Duany et al., 2000; Katz, 1993).

The development of more specific objective and statistical measures of land use mix, residential density, and street connectivity[1] were explored by Frank and Pivo (1994). Cervero and Kockel man (1997) explored a similar set of three environment variables which they labeled 'the three D's': density, diversity, and design. These variables were found to correlate with frequency of walking for a sample of San Francisco residents[2]. The 3D's have become shorthand for the three environmental dimensions: population density (*Density* of residential units, households, population), the mix of land uses (*Diversity* of land uses - residential, commercial, institutional, etc), and layout of the streets (*Design* of the street system - connectivity, street intersections). A complementary l i ne of research puts the emphasis on destinations, suggesting that local destinations attract people and in turn facilitate walking.

Other factors such as the presence of sidewalks (Moudon et al., 2006c), street trees (Lee & Moudon, 2006a), hills (Lee & Moudon, 2006a), and other urban design qualities (Ewing et al., 2006) have also yielded associations with physical activity outcomes, although these relationships are less consistent than those

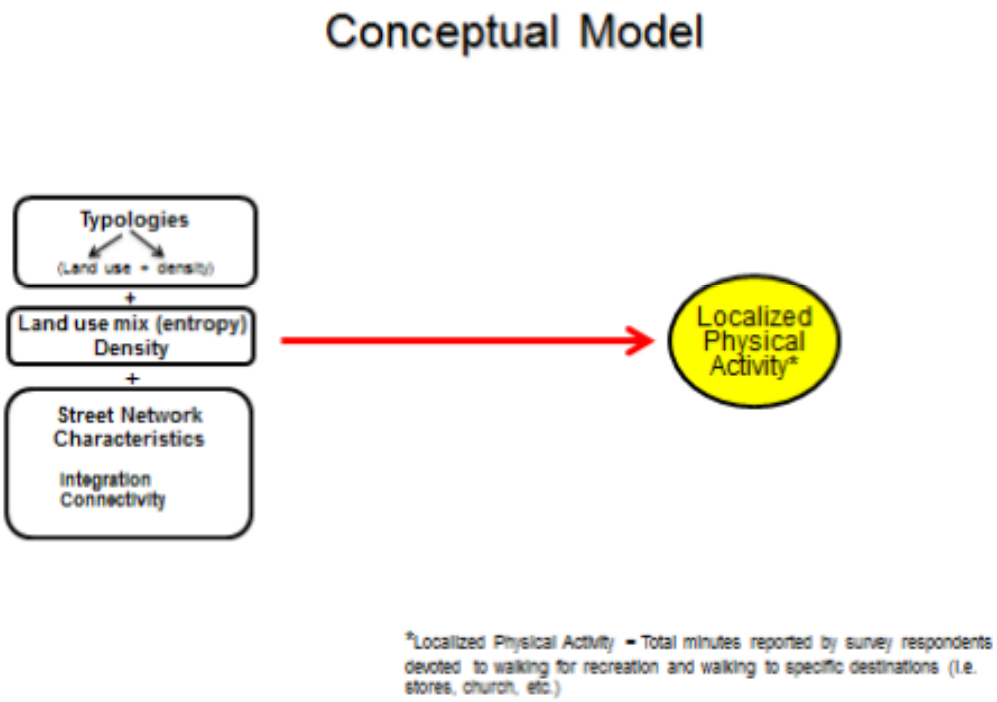
[1] A measure based on mean calculations of street segments and intersections, see also Handy (2003).

[2] This study also demonstrated that the 3D's are associated with mode choice. They suggest that compact, mix use, and pedestrian friendly environments reduce vehicle trips and encourage non-motorized travel.

found using density, land use mix, and street layout.

Measurements of the 3D's were further refined over the years by Frank and Engelke (2005b) and Frank et al. (2005b; 2004; 2006; 2005a) into rigorous objective measures of the built environment. Frank et al. (2008) demonstrated the relative predictive strength of each of these measures, with density showing the strongest relationship to walking, followed by connectivity and then land use mix. The research also explored the combined effects of these three measures working together; results indicate that street connectivity was related to walking only in the highest density neighborhoods.

In this paper, we explore the interrelationships between several environmental characteristics and reported localized physical activity among residents in three Detroit neighborhoods. We employ measures of density and l and use mix, as well as measures of street network characteristics (local connectivity and global integration), and examine their associations with physical activity (see Figure 1 below).



METHODOLOGY

Street network characteristics (integration and connectivity) were derived using computer-based space syntax methods applied to the GIS dataset of resident address locations. Data were also collected on 1/4 mile and 1/2 mile housing unit density, land use mix (Entropy Score), and neighborhood typologies based upon categorical measures of density and land use. These measures are then examined in relationship to reported localized physical activity (both leisure and transportation-related walking), controlling for factors such as socio-demographic status.

Physical Activity. Physical activity and other health outcomes were measured using data from the 2008 Healthy Environments Partnership (HEP) community survey. The HEP survey is 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 to collect longitudinal data through interviews of adults age >=25 years across three areas of Detroit, allowing for comparisons of residents of similar demographics across geographic areas of the city. The survey was conducted in August 2008-July 2009 with a final sample of 461 completed interviews.

Physical activity was assessed in the survey through the use of the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003). Measures included: Physical Activity (MET minutes) Transportation; Physical Activity (MET minutes) Leisure; Physical Activity Overall (MET minutes) Transportation + Leisure. 'MET minutes' is a measure of the volume of activity weighted by its energy requirements defined in M ETs to yield a score in MET–minutes. METs are multiples of the resting metabolic rate and a MET-minute is computed by multiplying the M ET score of an activity by the minutes performed. MET-minute scores are equivalent to kilocalories for a 60 kilogram person. Kilocalories may be computed from MET-minutes using the following equation: MET-min x (weight in kilograms'60 kilograms). The measures used in this study represent MET-minutes' week.

Street Network Characteristics. 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 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 street intersection types, the number of street 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 the parts to the whole, and the association between these properties and patterns of space use, has made space syntax a fruitful method for use in a 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, 1996; 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).

Street network characteristics were calculated at the city level using computer-based space syntax methods (Syntax2D) applied to the GIS dataset of resident address locations in each of the three Detroit neighborhoods --Eastside (2.5x2.5 miles), Northwest (3x3 miles), and Southwest (2x3 miles). Two aspects of *street network characteristics* were calculated for each respondent's street segment: street network connectivity and street network integration. The analysis assumes the 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 local or immediate neighborhood. *Integration* represents the extent to which a street segment is more or less accessible from all other parts of the city. Each respondent was assigned the mean value of the network characteristics for the 1/4 mile radius from the respondent's block; and the mean value for the 1/2 mile radius from the respondent's block.

Neighborhood Typologies. Based on the theoretical significance of sets of variables from several previous studies, and an analysis of the environmental characteristics of the Detroit study neighborhoods, we identified a set of proposed micro-neighborhood types or 'bundles' of neighborhood characteristics to be assessed as potential factors affecting 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 defined as the respondent's 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 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 (less than 4 units per acre); medium density (4 to <6 units per acre); and higher density (6 or more units per acre). Some rooks had significant proportions of vacant land; this characteristic is reflected in our density measures.[3] To address the characteristics of land use, we classified our micro neighborhoods into three categories based on the degree to which the l and-use classification was mixed: a homogeneous or single land-use type; two land-use types; or a mixed land-use with more than two types.

These descriptors of residential density and l and use were used to create our basic set of nine neighborhood types (see examples in Table 2 below). Each respondent was assigned the categorical typology value that reflected the residential density and land use characteristics of the rook surrounding the resident's block.

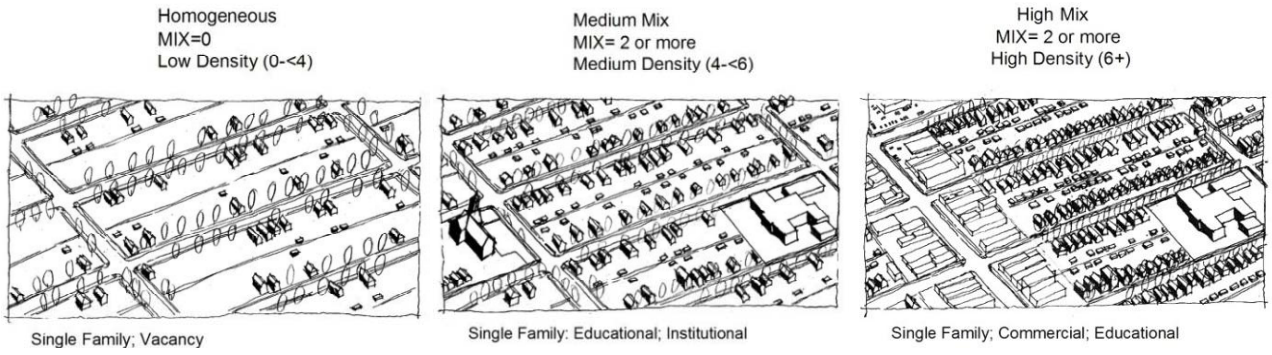


Figure 1. Examples of Neighborhood Typologies: Low density/low mix (left), medium density/medium mix (center), high density/high mix (right).

[3] It should be noted that these density ranges are based on the overall density patterns in the three study neighborhoods. The characterization and definition of high, medium and low density neighborhoods would likely be different in other cities where density patterns are higher (i .e. Chicago, New York, London, etc.).

For our analysis we fitted 3 level multivariate linear HLM models including weighted descriptive statistics at the individual and neighborhood level. Level 1 control variables for each respondent included age, sex, race/ethnicity, education, household income, length of residence in neighborhood, and whether the respondent was currently in the labor force. Level 2 variables (at the neighborhood level) include percent of population below the poverty level.

FINDINGS

Results suggest that neighborhood (local) connectivity and city level (global) integration are positively associated with localized physical activity. Specifically, we found that people living in neighborhoods that were more connected to the surrounding city (global integration) reported higher levels of localized physical activity overall (p=.001), localized physical activity for transportation (p=.008), and localized physical activity for leisure (p=.001) compared to neighborhoods that were less connected. Similarly, people living in neighborhoods with higher connectivity, reported higher localized physical activity overall (p=.015) and with localized leisure physical activity (p=.017).

In other words, people living in neighborhoods that are better connected to the rest of the city (higher integration) report higher levels of physical activity as compared to residents who live in neighborhoods with lower global connectivity. Similarly, people living in neighborhoods with higher (local) connectivity report higher localized leisure time physical activity as well as physical activity overall as compared to those in less well-connected neighborhoods.

The traditional planning measures of density and land use mix (Entropy) were negatively associated with localized physical activity. We found that people living in neighborhoods with higher land use mix (Entropy measured at the 1/2 mile) reported lower levels of localized physical activity overall (p=.012) and localized physical activity for leisure (p=.01 1). Similarly, people living in neighborhoods with higher density (measured at the 1/4 mile) reported lower levels of localized physical activity overall (p=.019), localized leisure time physical activity (p=.001), and localized physical activity for transportation (p=.044).

In other words, people living in neighborhoods with higher density report lower levels of physical activity overall and lower levels of leisure time physical activity as compared to those living in neighborhoods with lower density neighborhoods. Similarly, we found that people living in neighborhoods with a greater mix of land uses reported lower levels of localized physical activity overall, and localized leisure time and transportation physical activity than those living in neighborhoods with fewer land uses.

We discovered more positive effects from our neighborhood typology measure that combines categorical measures of density and land use mix. Results indicate that people living in neighborhoods characterized by both higher density (measured at the 1/2 mile) and higher land use mix report higher levels of localized physical activity, both physical activity overall (p=.099), and physical activity for transportation (p=.072). These findings suggest the importance of the combined effects of density and l and use mix on physical activity in these Detroit neighborhoods. We are currently engaged in exploring the differential effects of the single variables of density and land use mix and our categorized typologies.

	Localized Overall Physical activity	Localized Transportation Physical Activity	Localized Leisure Physical activity
Street Network Characteristics			
Street network connectivity	+ (p=.015)	not significant	+ (p=.017)
Street network integration	+ (p=.001)	+ (p=.008)	+ (p=.001)
Urban planning measures			
Density at the ¼ mile radius	- (p=.019)	- (p=.048)	- (p=.001)
Land use mix (Entropy) at the ½ mile radius	- (p=.012)	not significant	- (p=.011)
Neighborhood Typologies			
Density and land use mix at the ½ mile radius	+ (p=.099)	+ (p=.072)	not significant

Table 2. Summary table of findings of street network characteristics, urban planning measures, and neighborhood typologies and their associations with localized overall physical activity, localized transportation physical activity, and localized leisure physical activity.

CONCLUSIONS

This study advances the field by finding significant associations between the syntactic characteristics of the design of these urban neighborhoods and physical activity. This investigation differs from previous studies in space syntax looking at the observed street presence of people by emphasizing reported physical activity as outcome measures. Urban neighborhoods that are well connected both locally and in the larger urban area, and those that are higher in density with a heterogeneous land-use mix, were found to be associated with higher levels of localized physical activity. Contributions of this research 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.

This investigation suggests an interesting result when compared to the findings of Frank et al. (2008). Frank and his colleagues demonstrated the relative independent predictive strength of density, connectivity and land use mix in relationship to walking behavior. Our research suggests that as independent variables density and land use mix have negative associations with physical activity. However, Frank's research also explored the combined effects of the three measures (density, connectivity, and land use mix) working together. Their results indicate that street connectivity was related to walking only in the highest density neighborhoods. We also report interaction effects, finding higher localized physical activity in neighborhoods characterized by both higher density and a mixed land use. So we see the importance of examining the interactions between these key variables (note that Frank's measure of connectivity is somewhat different from the measure used in this study).

It is also important to examine differential effects across measures and contexts. Pertinent issues include the measurement of particular variables, the area to which the measure is applied (for example, rook, 1/4 mile, 1/2 mile), and how these measures perform in combination (such as density and land use). It is also reasonable to expect that outcomes may differ depending upon the socio-demographic characteristics of the neighborhoods being evaluated.

In future analyses we will examine the combined role of these environmental characteristics in augmenting the predictive power of our neighborhood typologies for physical activity and health outcomes in our three Detroit neighborhoods. Neighborhood typologies can provide urban designers and planners with 'image-able' sets of environmental characteristics to be applied in creating healthy neighborhood environments.

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