CONCEPTS OF SPACE AND PLACE

NEIGHBORHOOD ACCESS, PEDESTRIAN MOVEMENT, AND PHYSICAL ACTIVITY IN DETROIT: IMPLICATIONS FOR URBAN DESIGN AND RESEARCH

by

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"*The way to get at what goes on in the seemingly mysterious and perverse behavior of cities is, I think, to look closely, and with as little previous expectation as is possible, at the most ordinary scenes and events, and attempt to see what they mean and whether any threads of principle emerge among them*."

(Jacobs, 1961, p. 19)

DEDICATION

I dedicate this dissertation to the best parents one could ever ask for:

Dr. Louis and Veronica van der Westhuizen,

for your unconditional support, commitment, and hours on the phone

all the way from South Africa.

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ABSTRACT

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The physical environment plays a major role in facilitating people's activity patterns in residential settings. The ways in which people conceive of their neighborhood as a space and a place for activities has theoretical implications for exploring the relationships between environmental factors and pedestrian behavior and physical activity. An elaboration of existing theories of space and place combines these two constructs into a single framework useful for describing and studying the physical environment. It is suggested that patterns of place and configurational aspects of space both encourage walking and physical activity.

The empirical section of this dissertation investigates the relationships of destination, space syntax, and urban planning measures with *pedestrian movement* and *physical activity* outcomes. This work draws on data from the Healthy Environments Partnership (HEP), a research initiative that focuses on the contributions of the environment to health outcomes in three Detroit neighborhoods. Data were obtained from a household survey of 919 respondents, neighborhood observations, parcel level land use records, and the US census. The *physical activity* outcome data comes from the survey and is directly connected to neighborhood residents, while the neighborhood observations of *pedestrian movement* include both residents and visitors.

Multilevel and OLS regression analyses were used to test the relative predictive strength of the three types of environmental factors on two sets of outcomes: *pedestrian movement* (+ *sedentary behavior)* and *physical activity* (and *waist circumference*). *Psychosocial perceptions* were also analyzed as possible mediating factors. Findings show that the three types of measures are associated with *pedestrian movement,* with destination measures being the most related; fewer associations were found with *waist circumference* and *physical activity*. Perceptions of the psychosocial environment were not found to mediate the main effects.

New environmental measures developed for this research offer new ways to conceptualize the built environment. The findings related to psychosocial factors, the importance of destination measures, and the theoretical distinction made between physical activity and pedestrian movement may be useful constructs in the design process. This dissertation suggests that approaches emphasizing environmental patterns rather than discrete environmental variables should be considered in future research.

Chapter 1
INTRODUCTION

Residents, urban designers, and planners often consider neighborhood access as an important ingredient in the design of quality residential environments that may contribute to people's walking and physical activity outcomes. This dissertation examines whether the destination environment and spatial properties of streets contribute to the neighborhood access of pedestrians and resident populations in three areas in the city of Detroit. A framework of theories of space and theories of place guide an investigation into how place and space factors mutually reinforce perceived accessibility and neighborhood walking.

1.1. The significant role of urban planning, design, and health research in understanding healthy environments

Since the 1990s, numerous studies have examined the impact of the built environment on physical activity in an attempt to counteract the rising incidence of obesity, one of the major risk factors of cardiovascular disease. The impact of the physical environment on physical activity and health outcomes is well-documented (Boarnet et al., 2008; Boer et al., 2007; Cervero & Kockelman, 1997; Dannenberg et al., 2003; Giles-Corti & Donovan, 2003). In addition, widening health disparities between racial and socioeconomic groups, especially in regards to the occurrence of cardiovascular disease, leave some groups particularly vulnerable (Eyler et al., 2003; Frank et al., 2008; Israel et al., 2006; Schulz et al., 2005a). The nature of the physical environment seems to play a significant role in these outcomes (Boslaugh et al., 2006; Brownson et al., 2001; Estabrooks et al., 2003).

In response, architects and urban planners have become involved in multi-disciplinary research projects focusing on planning and design aspects that encourage physical activity and walking (Cervero & Kockelman, 1997; Day et al., 2006; Ewing & Cervero, 2001; Frank & Engelke, 2001; Lee & Moudon, 2006a; Rodriguez et al., 2006).

1.2. The importance of this dissertation research

Much of the theory examining the relationships between people and their surroundings falls into one of two categories, both of which bring important issues to the table. The first, represented by the place theories of David Canter, focuses the attention on meaningful thought processes to understand the goal-oriented interactions of people and their environments (Canter, 1977; Canter, 1986; Canter & Stringer, 1975a; Canter, 1988; Canter & Lee, 1974). The second category, represented by Bill Hillier and the space syntax community, focuses on the spatial properties of the built environment. Instead of investigating meanings or thought processes, they examine objective measures of the spatial environment (Hillier, 1996a, 1996b; Hillier, 1999; Hillier & Hanson, 1984; Hillier et al., 1993).There is of course no clear boundary between the two areas of research, but nonetheless it can seem as if the literature in this area takes an “either/or” approach. This dissertation attempts to conceptualize the two theoretical models as a single framework. This brings out the reinforcing qualities of ‘space’ and ‘place’ and enables the environmental effects to be more fully understood.

Applying this ‘both/and’ approach to urban design and planning can also be quite useful. Much of the research pertaining to walkability has focused on the three built environment factors of density, land use mix, and street connectivity as proposed by Cervero and Kockelman’s (1997) 3Ds thesis. One limitation of these studies is their consideration of discrete environmental factors without discerning the interrelationships between them.

The 3Ds are important in understanding the relationships between the built environment and physical activity/walking outcomes, but this dissertation suggests that destination factors, one dimension of 'place', and space syntax factors, a dimension of 'space', also have important contributions to make. Considering multiple design aspects such as layout, accessibility, and destinations avoids the isolation of individual environmental variables. It is hoped that this dissertation will encourage practitioners and researchers to broaden the focus of their design and inquiry to include multiple types of environmental factors, enabling them to consider the built environment as a cohesive whole.

This dissertation explores the role of destination factors as they relate to pedestrian movement outcomes, as discussed in earlier research that focused on self reported walking (Cerin et al., 2007; Handy, 1996c; Lee & Moudon, 2006a; Lee & Moudon, 2006b; McCormack et al., 2008; Moudon et al., 2006c). A greater understanding of destinations and how the design of street spaces connects people to destinations and groups of destinations may allow professionals and residents to characterize the built environment in more meaningful ways.

In addition to adding to the understanding of broad types of environmental factors, this study develops new measures of the physical environment. Previously-used measures of destinations, space syntax, and urban planning are also employed in this dissertation, but some of them only partially describe spatial or destination aspects. The following new measures will be introduced. D*estination reach* focuses on the distance to destinations in all directions and is proposed as a new measure that enhances those used by the space syntax community. *Distance to "main streets"* and *distance to "place chains"* are two measures that add to the syntax measure of *street network integration*.

The measures of *clustering* and *number of bundles* demonstrate the importance of the concepts of destination clusters in understanding the broader destination environment. See Chapter 5 for a full description of these new measures.

As discussed in more detail in section 4.9.1, walkability research often does not make a distinction between walking (pedestrian movement) and physical activity. The two concepts are related, and indeed, walking is one form of physical activity. However, it is suggested that it is important to distinguish between the two outcomes to better elucidate the effects of the built environment (Forsyth et al., 2008a). This dissertation adds to the literature by separating the two concepts in analysis and demonstrating that the built environment factors that are associated with pedestrian movement do not necessarily have a relationship with residents' physical activity outcomes. The pathways between the physical environment and walking have been more clearly shown in the literature (see Chapter 4, section 4.9.1), while more research needs to be done to examine the connections between environmental factors and overall physical activity.

The discussion of the role of psychosocial perceptions adds another important dimension. Perceptions have been variously examined in the literature as independent variables impacting physical activity outcomes (Cervero & Duncan, 2003; Handy, 2005), as outcomes of the design of the physical environment (Kim & Kaplan, 2004), or as factors mediating the relationship between the built environment and physical activity. Studies examining the possible mediation of perceptions have mainly focused on perceptions of the physical environment (Booth et al., 2000; Brown et al., 2007; Ewing et al., 2006; Humpel et al., 2004; Humpel et al., 2004a). This dissertation research also examines whether perceptions of the *psychosocial* environment play a mediating role.

In addition to having relevance to the urban design and planning community, this research also makes contributions useful to the field of public health. Research into the connections between the built environment and physical activity draws upon the expertise of both groups: urban designers and planners specialize in the built environment, whereas public health researchers have expertise in physical activity and health outcomes. Just as this dissertation offers the design/planning community a more nuanced understanding of the conceptual differences between physical activity and walking (one specialty of public health), it also offers an explanation of different types of built environment measures (the specialty of urban design) to the public health field. It is hoped that the descriptions of different groupings and measures of the physical environment will be useful as the multidisciplinary researchers and practitioners focus on ways to improve physical activity outcomes.

A final contribution of this dissertation is its focus on Detroit. Much of the research in the fields of walkability and urban design is in cities/neighborhoods quite different from the three study areas. The space syntax community, for instance, tends to focus on large cities with a high population density such as London (Hillier, 1996a; Hillier & Hanson, 1984; Hillier et al., 1993). Other research puts the attention on communities that follow New Urbanist ideals (Baran et al., 2008; Kim & Kaplan, 2004; Rodriguez et al., 2006). Although both these areas have important findings to share with the design and planning communities, it is also critical to investigate other types of communities. The average American is likely to live in an already existing spread-out suburban or urban area with a range of issues not always seen in large cities with high densities or neotraditional communities. The focus on low-density environments, extant neighborhoods, and areas with populations of varying race, ethnicity, and socioeconomic status is therefore relevant.

1.3. Structuring of the dissertation

Chapters 2 and 3 lay out the theoretical ideas that guided the development of the empirical study. The historical development of the understanding of person-environment relationships over the last century will briefly be reviewed[1]. The purpose of this section is to revisit and highlight a selection of studies that integrate theory, research, and practice while resisting the dualism of object (environment) and subject (humans). Titles from the 1960s and later, such as *Advances in Environment Behavior and Design: Toward the Integration of Theory, Methods, Research and Utilization* (Moore & Marans, 1987), have spurred rich discourse around these issues. These researchers tread within the gray area often referred to as the ‘interaction,’ ‘action,’ or ‘transaction’ dimension and they develop useful integrated frameworks by which the physical environment can be assessed, understood, and imagined. Chapter 3 of this section presents a theoretical framework building on the theories of space and place.

In subsequent chapters, research questions are framed around objective descriptions of destination measures and space syntax measures, which are then tested using both objectively-measured and self-reported outcome measures. The results of the study are presented in two chapters to reflect the two different outcomes included in the research questions. The findings mainly address issues that relate to the physical design of neighborhood environments, although reference is made to both planning and design processes. Finally, the empirical work establishes a basis for developing stronger theoretical frameworks for understanding the mental and physical processes that shape the urban landscape. The research questions below guide the empirical investigation.

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1 The review consists mainly of a selection of studies from environmental psychology, environment behavior, human geography, social psychology, anthropology, and architecture.

Research Question 1:

To what extent do destination measures have an association with pedestrian movement and physical activity?

Research Question 2:

What are the relative contributions of destination measures and space syntax measures to pedestrian movement and physical activity?

Research Question 3:

Are destination measures and space syntax measures more predictive of pedestrian movement and physical activity than commonly used urban planning built environment measures?

Research Question 4:

Do perceptions of the psychosocial environment mediate the associations between the built environment and physical activity?

Chapter 2
THEORIES OF SPACE AND PLACE AND THE ACTION DIMENSION

The investigation of the built environment, pedestrian movement, and physical activity in this dissertation started with a general exploration of how and why actions occur within the built environment. Significant research contributions have been made within the areas of social psychology, environmental psychology, environment behavior, anthropology, human geography, and architecture to study the relationship between people and environments. Researchers in these areas build important bodies of knowledge that can inform the design and planning decisions that shape the built environments in which people live. The purpose of this research is to emphasize the importance of planning and designing environments that support people from all walks of life to become more physically active and maintain more sustained physically healthy lifestyles. The goal of this chapter is to identify relevant theories that can guide an investigation into these issues.

2.1. Selected contributions to the understanding of person-environment relationships

Exploration into understanding how people and environments relate to one another has encouraged a review of the literature in person-environment relationships. A few significant contributions have been made in these areas of research that are relevant to this dissertation.

The research on the interaction between people and their surroundings suggests that these relationships are complex, resulting in different ways to theorize and measure the built environment and activities within the environment. A century of environmental research has been troubled by two opposing metaphysical realities: one emphasizing the deterministic forces of the environment on subjects (behaviorism) and the other emphasizing people as agents constructing their environmental reality (cognitive and symbolic processes) (Hillier & Leaman, 1973; Lee, 1976). It is necessary to first clarify these two metaphysical relationships in terms of prior research before further theorizing, measurement, analysis, and interpretation can occur. This can be done by highlighting a few important historical developments.

An early significant contribution was made by Kurt Lewin (1946), who introduced the concept of *life space.* His work established a direction in environmental research that opposed the earlier work of behaviorists such as Watson (1913) who proposed that the environment elicits a direct impact on human subjects; this radical behaviorism is also called *stimulus-response* theory. Lewin's work instead conceptualized the relationship between humans and environment as *transactional*. *Life space* suggested that it is the interaction between the inner forces of needs, values, and attitudes, and the outer forces of environmental conditions that influences behavior (Stokols, 1977).

Lewin considered ecological theories, emanating from Darwin's classic work *The Origin of Species*, to be of great importance in his work. His dedication to the ecological perspective raised the awareness that psychology is about 'true-life issues' resulting from 'real-life' circumstances (Bonnes et al., 2003). At the same time, Lewin also raised awareness of the importance of the physical environment by solidifying the idea that behavior is "conducted in space." Lewin's work laid the foundation for what later became the field of environmental cognition (discussed in further detail later in this chapter). His *life space* perspective, however, attracted criticism for neglecting the “objective” environment and focusing instead on how environments are perceived (Stokols, 1977).

Two of Lewin’s students, Roger Barker (1968) and Urie Bronfenbrenner (1979), further developed his work by trying to articulate his concept of *life space.* Barker’s idea of *behavior settings* suggests that recurrent behaviors establish a clear *program* within settings. Bronfenbrenner’s interpretation of *life space* raised the point that *transactions* between people and their socioecological settings develop over time (learning perspective) and at various perceptual scales (microsetting to macrosetting). At the end of the 1960’s at the City University of New York, a group consisting of H. Proshansky, W. Ittelson, and A. Rivlin took a similar, but more nuanced, approach by focusing on the relationship of human behavior/experience in the *physical setting* (Bonnes et al., 2003). Their handbook in environmental psychology *Man and his Physical Setting* (1967) included prominent studies in cognition and architectural and urban ecology that will be referred to throughout this dissertation.

An important influence on Kurt Lewin’s work was the Chicago school of human ecologists prominent since the 1920’s, including Robert Parks and Ernest Burgess. They viewed the city as an ecological *‘organism’* of social relationships and popularized the use of objective measurement at a city-wide scale as a powerful method of revealing collective urban patterns. During the 1970’s, Oscar Newman introduced his theory of “defensible space” as part of this school of thought. The Chicago school researchers developed objective measures of urban behavior using census units and demographic statistics in combination with spatial information. One of the contributions that sustains the Chicago School’s ongoing presence in the literature is their ability to describe the relevant sociological and contextual factors that shape people's communal reality. What remains a challenge for researchers using this approach is a substantive understanding of *why* people interrelate with their environments to produce these sociophysical patterns.

Irvin Altman's (1975; 1977; 1976) later work in the area of environment behavior attempted to reconcile the division between the research in the two areas of 'physical settings' and 'sociological ecologies' by proposing *social-unit* oriented approaches in addition to the dominant *behavior-oriented* approaches. *Social-unit analysis* focuses on behaviors associated with social units—which could include privacy, territoriality, or crowding—instead of trying to understand single behaviors. Altman observed that when communicating about social phenomena, researchers talk about *behavior* while practitioners talk about *place*: a building, community, or city. In order to avoid focusing on single behaviors, he suggests that the *social-unit* is similar to *place* in that it analyzes patterns of several levels of behavior (Altman, 1977). The term "place" refers to a coherent physical setting that collects a *program* (from Barker, 1968), that in turn implies certain social rules, regulations, and expected roles that facilitate *actions*. This idea was picked up by researchers such as David Canter who suggested that peoples' *actions* are facilitated by the role that they see themselves play within a *place* (Canter, 1977). Use of the term *action* instead of *behavior* is intended to put the emphasis on human as an active agent rather than a passive recipient of environmental stimuli (Canter, 1991).

It is useful to point out that there seems to be an ongoing return to ecological approaches in an attempt to avoid the dichotomy of 'person' and 'environment' and instead focus on understanding 'actions' in physical settings. Investigations that focus on the 'person' emphasize *why* people interact with the environment and investigations that focus on the ‘environment’ show *how* these interactions occur. These two dimensions also suggest different inquiries into understanding person/environment relationships. The reason for trying to balance an investigation into person and environment is that understanding of both the ‘*how’* and the ‘*why’* is important for doing research that reflects issues of everyday life. Approaches in perception and cognition of the environment became the main thrust after the introduction of seminal works such as Proshansky et al’s *Man and his Physical Settting* (1967). At this time, it was considered more important to understand ‘*why*’ actions occur, and researchers often preferred some combination of approaches in environmental cognition, phenomenology, and meaning.

2.2. Three approaches of describing the ‘actions’ of people in the built environment

A substantial body of research developed from an interest in the perceptual/cognitive processes (images, mental mappings, distance, and space perception) critical to understanding people’s relationships with their physical environments. These studies became referential for how people interpret, experience, and understand their surroundings. Contributors in environmental psychology such as Stea (1969) and Ittelson (1973) started writing about the differences between the perception of *objects*, the primary mode of inquiry in environmental perception during this time, and the perception of *environments*. This reminder of the importance of perception of the *environment* drew attention to how the person is part of an embedded contextual reality rather than a universal being affected by *objects*. This return to the ‘ecology’ of environmental relationships resulted in three approaches that developed in cognition, phenomenology, and meaning which are relevant for laying out the theoretical approach applied in this dissertation.

2.2.1. Cognitive approach: socio-spatial schema

The first approach focuses on the cognition of the environment. Terence Lee (1976; 1970a) proposed the "*socio-spatial schema*" to explore the connection between social space and physical space. He shows that the size and the composition of participants' cognitive schemas are consistent with both the physical territory that people identify with and the extent of their individual use patterns. Lee's concept of merging 'physical' with 'social' shows that meaningful localized areas serve as an important operative construct for realizing everyday activities. His work suggests that the interrelationship of physical and social spaces is manifested in the concept of 'neighborhood.' Lee further argues that social-physical patterns exist in people's minds in the form of meaningful 'mind' impressions *of* the urban landscape and that these impressions structure people's physical and spatial activity orbits. Lee extensively applied cognitive mapping and estimations in his research studies to gain insight into people's conceptions of their environment. His research emphasizes conceptions of the environment.

2.2.2. Phenomenological approach: sociospatial reference system

A related area of research in environmental psychology emphasizes the experiential relationships between people and their environments. Anne Buttimer offers a model of the shared transactions that occur between people and their experiential (phenomenological) environment (she calls this 'sharedness'). She suggests a "*sociospatial reference system*" that acts as a filter through which the physical environment is known, evaluated, and used. This reference system consists of people's shared perceptions, their aspirations to engage in activities, and their individual and collective understanding of the environment. (Buttimer, 1972).

She considers the concept of *action spaces*: the spaces of lived experience. Her approach attempts to connect people's habitual movement in space with their social activity patterns that are meaningful to them. Buttimer's work built upon earlier studies that investigated people's social activity patterns and movements in urban space (Cox and Golledge 1969; Adams 1969; Brown and Moore 1971 cited in Buttimer 1972). She uses methods such as respondent activity reports, attitudes, and perceptions to study people's learned patterns within the environment.

Buttimer's unique contribution is a reminder that the sociological context contributes greatly to an understanding of people's shared experiences and actions. She also suggests that experience, a topic that reached full fruition in the work of her student David Seamon, is critical to understanding how people develop habitual patterns that in turn guide a major part of their interactions with the environment. Her focus is primarily on the learned or experiential aspects of environmental relationships.

2.2.3. Meaning approach: patterns of meaning

A third perspective attempts to negotiate a middle-ground between the two approaches of *cognition* (mind) and *body* (experience) and puts varying emphasis on either dimension. Krampen (1987) and others suggest that human-environment transactions occur through *environmental meaning,* a perspective that draws from semiotics, the study of symbols and signs. The semiotics of architecture and space devised the separation of meaning into *form* and *content*, which is often interpreted in environmental research as physical aspects and symbolic aspects of the environment.

Some considered structures of *content* to be variant by context, and structures of *form* as universally stable, taking on additional cultural-specific meanings (Krampen, 1987). Hillier and Leaman (1973) are two researchers that have supported the *meaning* approach and applied it to properties of space. This approach developed later into space syntax theories (discussed in more detail in 2.5 of this chapter), which draw on objective descriptions of the environment to uncover covert laws of space and show consistencies in their prediction of social patterns (Hillier & Hanson, 1984). Similar to the Chicago school approach mentioned earlier, these objective descriptions reveal more about *how* the properties of space relate to social life than *why.* However, space syntax researchers have more recently shown interest in the cognitive and experiential importance of their physical observations (Hillier, 1999, 2003; Hillier, 2004; Hillier, 2008; Long et al., 2007; Penn, 2003; Penn et al., 2007; Penn & Turner, 2002; Seamon, 2007).

Other researchers seem less comfortable with how objective methods, such as space syntax, describe the relationship between environments and human actions as fixed. Instead, they view *form* and *content* as inseparably 'transactional.' Canter and others suggest that people organize meaningful experiences and perceptions into *systems of thought* in their minds. These *systems of thought* show consistencies but are never fixed: they change over time (Canter, 1988). The work of Canter draws heavily on cognition and environmental values to assess patterns of meaning that are shared among individuals (Canter, 1977; Canter, 1983; Canter & Stringer, 1975a; Canter & Tagg, 1975b; Canter, 1988; Canter & Lee, 1974). Other approaches for investigation these *systems of thought* include the free-sorting of environmental variables (Downing, 1992; Groat, 1982; Groat & Canter, 1979), cognitive mapping (Canter, 1977; Downs & Stea, 1977), and multidimensional scaling procedures (Canter & Tagg, 1975b; Groat, 1982).

The two directions taken within the *meaning*-approach are considered most relevant in this dissertation for the investigation of environmental relationships. Both approaches build from the foundations of structuralism, but they provide different ways to describe the environmental relationships.

The two broad constructs that will be emphasized in this research are space and place, each of which has been theorized independently. Although research tends to emphasize either space or place for the sake of measurement, there is consensus among both camps that the major dimensions of human-environment relationships include physical environments, people's conceptions, and their actions, albeit with varied degrees of importance placed on each. The following section will discuss how both 'space' and 'place' approaches significantly shape our understanding of the interaction between humans and environment, and how these constructs are applied in analysis.

2.3. Focusing on space and place

Two theories of 'space' and 'place' have particular value for conceptualizing the processes of environmental interaction and developing empirical measurements: Bill Hillier's "theory of natural movement" and David Canter's "theory of purposive place." Their approaches share the search for underlying patterns and structures that describe activities [and movement] in environments. Although both theories developed from structuralism, they have important differences.

As an environmental psychologist, Canter searches for conceptual patterns that originate within the mind of the individual. He suggests that reality is created through experience and meaning: what a person knows, does, and feels. The focus is not on people's individual predispositions, but rather on how individuals relate to their shared social roles in transaction with their environment (Canter, 1988). Canter considers people to act purposefully, engaging with environments to best support their activities: he associates this process with people's *environmental roles*. His definition of the physical environment is all-inclusive, referring to the physical realm as spatial properties and arrangements, features and elements, boundaries and territories, geographical units, and form and meaning qualities. He suggests that peoples' conceptions of the environment provide the best information about how the environment becomes meaningful in people's lives (Canter, 1977; Canter, 1986, 1991; Canter & Stringer, 1975a; Canter & Tagg, 1975b).

With a background in philosophy and mathematics, Hillier focuses instead on the notion that patterns of activity become possible as groups move through space. Unlike place theories, which often emphasize the level of the individual, the relationship in Hillier's "theory of natural movement" is at the level of society. Hillier comes from the position that social behavior follows a logic that is imbedded within the physical properties of space; this is called the "space syntax" approach (Hillier, 1996b). Hillier suggests that behavior is not determined directly by space, but that the way in which people conceive reality, and therefore act in the world, is inherently spatial. Social life takes advantage of the social potentialities in space. One main example is *copresence*, providing the raw materials for encounters and interaction. A great part of social life can be understood by studying the probabilistic consistencies that can be observed between space and social life (Hillier, 1996b; Hillier & Hanson, 1984). Space syntax methods primarily rely on objective diagrams to represent potentially meaningful description of space.

A review of each of the theories of space and place will be presented, focusing on their distinctive emphases on the three environmental dimensions: *physical*, *conceptions*, and *actions*. The goal of this discussion is to propose clear definitions of space and place that can be applied to the rest of the dissertation research.

2.4. A theory of place: purposive patterns

For place theorists, people's relationships with their physical surroundings are primarily understood through *meaning*. Place researchers are committed to uncovering why people behave in certain ways in their environments and to finding explicit descriptions of what people think of places. They put empirical emphasis on mind-processes, trying to describe how people construct *conceptual systems* about places (Appleyard, 1981; Canter, 1977; Lee, 1976; Lynch, 1960; Neisser et al., 1976).

Based on their goal-oriented-action patterns and their continued experiences within their physical surroundings, people are able to enter into a transaction with the environment through which they can meet their needs, preferences, and desires. This transactional process through which people purposefully interact with surroundings is called their shared environmental roles. Place theorists further believe that environmental information should be deduced from people's subjective responses *to* their environment (eg. mental maps, images, free associations, sorting tasks) rather than their objective descriptions *of* the physical environment.

One important example is Canter's "theory of purposive place," a comprehensive framework for describing the three main constituents of the human-environment relationship: *physical*, *conceptions*, and *actions* (see Figure 2-1). Canter is concerned with *conceptual systems* rather than behavioral systems, with the individual as the primary basis for actions (Canter, 1977). He suggests that human actions occur due to a combination of the context in which the individual thinks herself to be and the processes of perception and cognition through which the environment is filtered.

As discussed earlier, transactions exist between people's perceptions of their shared social roles and the organizational patterns that certain activities require. Canter uses the term *"action potentials"* to describe how people are predisposed to aspire to their particular *environmental roles*; in turn, their understanding of their *environmental roles* enables them to seek out environments that fit their action-associated patterns (Canter, 1988, p. 8).

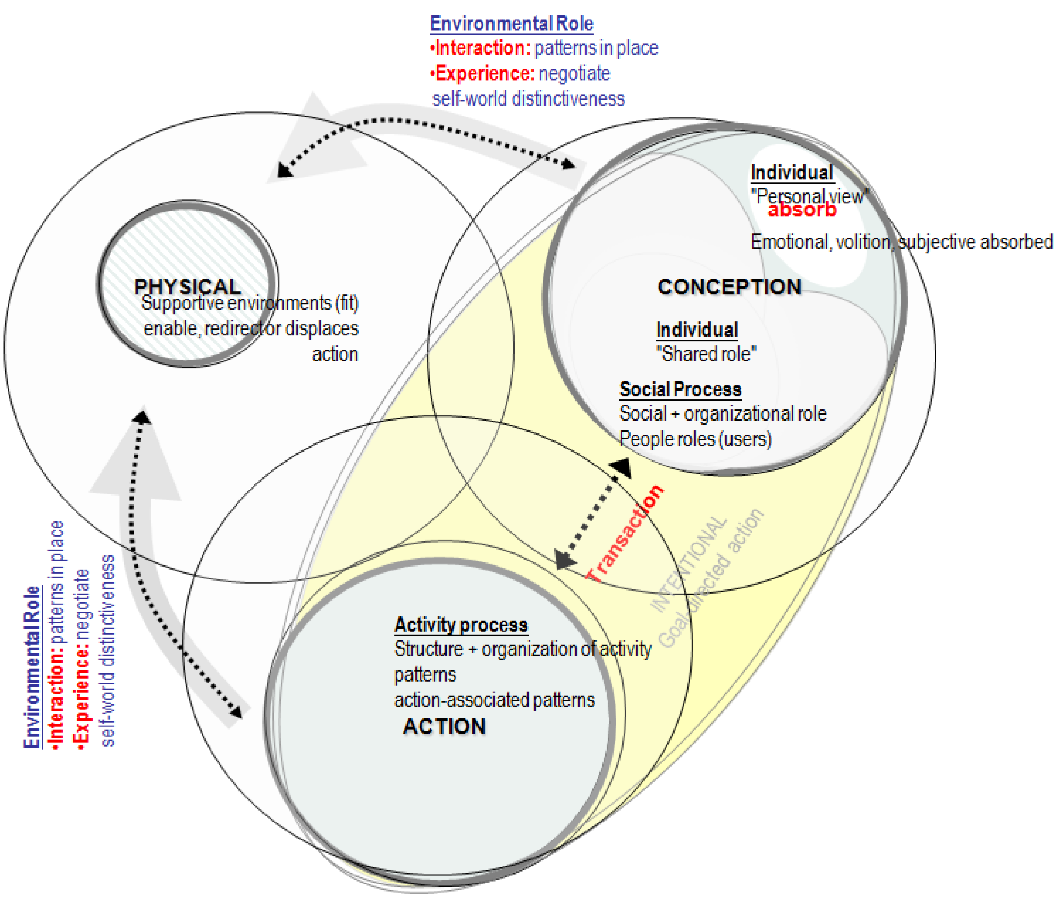

Figure 2-1 Analytical interpretation of David Canter's model of purposive place

Canter's transactional framework is along the same lines as Neisser's perceptual cycle, in which a coherent representation of the ideal place is constructed in the mind based on how people have integrated their previous experiences of places. This *mental image* is then cross-checked with knowledge of available locations, creating anticipations that then lead to actions. Throughout the activity process, the schema is selectively updated as a result of new experiences (Neisser et al., 1976, pp. 20-21). When environments are not able to fulfill their supportive role, action is disabled, redirected, or displaced. Therefore, Canter is suggesting that places are not just locations, but rather categorizations of experience and even experiences themselves. When people find an environment lacking, an experience is lost or altered. The physical environment thus plays a fundamental role in actualizing, perpetuating, and perhaps transforming the *environmental roles* necessary for *actions*.

Some theorists have been critical of Canter's method. Jonathan Sime (1985), for instance, suggests that the main limitation of Canter's application of the purposive place model is the explicit emphasis on people's *conceptions*. He points out that following Canter's approach deemphasizes measurement of the *physical* dimension beyond what is locked up in people's minds. Canter's background in psychology is important for understanding why less emphasis is put on the description of the *physical* dimension. Although not the first to suggest this, Sime observed that architects and planners create physical places and therefore need clearer descriptions of the implications of their decisions regarding physical environments (Lee, 1976; Sime, 1985).

Perhaps a more controversial critique of place theories has been leveled against the conflation of 'place' aspects and 'space' aspects. Place researchers do not distinguish between how meanings are constructed around *meaningful objects*—buildings, shops, public places, bridges, and rivers—and those aspects that result from the *properties of space*. This critique has been presented in a slightly different context discussing the difference between *spatiality* and *space* (Hillier, 2005).

What then defines a place? Rather, what situates a place? Is it the distinctive qualities of one place that attract people over other places, or is it the potential for copresence of people that creates place? This distinction is critical in both place and space approaches, yet it remains ambiguous. At this point in the discussion, a definition of place can be formulated that to some extent emphasizes the realm of conceptions and actions in the environmental framework. Canter's approach informs the following definition of 'place' that will be adopted for this research:

Place is the patterns that result from people's shared goal-oriented transactions with the environment

2.5. A theory of space: spatial configuration

The "theory of natural movement" is a widely recognized analytical spatial theory developed by the space syntax group (Hillier & Hanson, 1984). It posits that the city functions as an organic system, stimulating the *copresence* of people through the inherent properties of its spaces. Researchers apply this theory primarily to analyze urban conditions by looking at the syntactical properties of space. Space syntax analysis looks to the configurational aspects of physical space to explain patterns of human behavior by observing the reciprocal relationship between space and movement (Hillier, 1996a; Hillier et al., 1987; Hillier & Hanson, 1984; Hillier et al., 1993; Penn et al., 1998; Peponis et al., 1989; Read, 1999).

Without explicitly involving individual motivations or cognition, the "theory of natural movement" argues that the morphological aspects of urban form, often called the urban grid, are the primary generators of pedestrian movement. The more directly accessible spaces are relative to other spaces in a system, the more people will move through them (Hillier, 1996b). In contrast with Canter and the place theorists, Hillier seems less concerned with acknowledging the direct connection between social/cultural conceptions and movement and instead isolates the fundamental properties of space. He suggests that social information is embedded within physical space itself, and that behavior follows probabilistic patterns constrained by space (Hillier, 1996b; Hillier & Hanson, 1984).

In his article "Natural movement, or configuration and attraction in urban pedestrian environments," Hillier describes how spatial configuration has an observable effect on movement, while also providing the spatial conditions for place attractors, which in turn reinforce movement (see Figure 2-2). He suggests that place attractors themselves have a probabilistic tendency to locate in more accessible spaces, following the logic of spatial configuration. Finally, attractors and residential density are considered to have a multiplying effect on the preexisting impact of spatial configuration (Hillier, 1996b, p. 113; Hillier, 1999; Hillier et al., 1993, p. 13). The finer nuances of his theory can often be misinterpreted as deterministic, but they are carefully explained in articles with titles such as "The hidden geometry of the deformed grid: or, why space syntax works, when it looks as if it shouldn't" (Hillier, 1999).

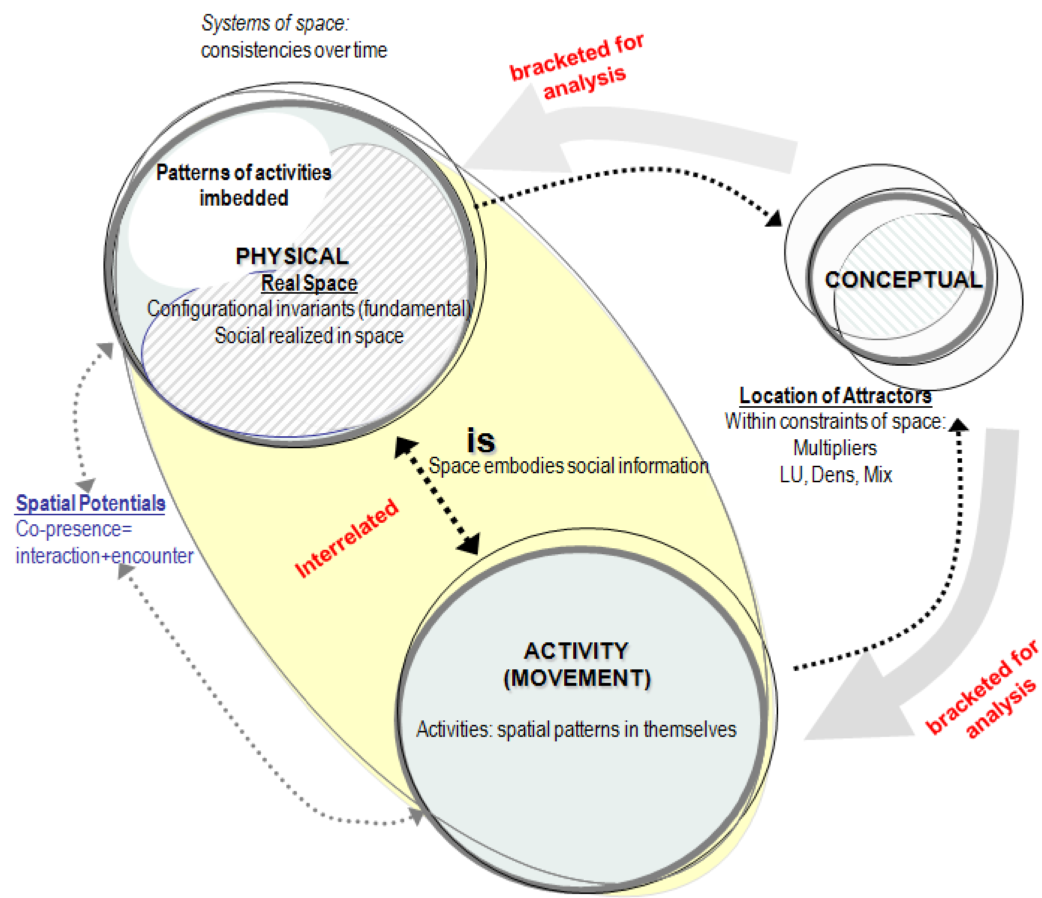

Figure 2-2 Analytical interpretation of Hillier's theory of natural movement

In space syntax, the description of space focuses specifically on topological characteristics. In other words, the importance is put on the property of spaces as they are configured in relation to each other, not on the metric distance between spaces. This is a critical distinction between space syntax and other spatial measures. At the level of cognition, this topological representation of space helps reveal a largely ignored mental capacity: the ability of humans to make inferences about the layout of space based on their configurational expectations (see Hillier's (2005) reference to Lakoff & Johnson).

Hillier points out one important caveat in his description of environmental behavior in that spatial behavior is not immediately determined by the configuration, but rather by people's configurational expectations of space (Hillier, 1996b, pp. 143-144). Consequently, in contrast with other spatial measures that are often static, space syntax allows for a dynamic description of urban space that captures human awareness of configurations that occur over multiple city scales (Hillier, 1996b, p. 114).

Hillier (2005) focuses on space because of his critique that previous research focused on the meaning of space—or what he calls the "spatiality of meaning"—and as a result reduced 'space' to a description of variant symbolic processes, rather than a description of real space itself. Furthermore, there is strong evidence that urban centers around the world follow the "natural movement" logic of space (Hillier, 1996a; Hillier et al., 1987; Hillier & Hanson, 1984; Hillier et al., 1993; Penn et al., 1998; Peponis et al., 1989; Read, 1999).

However, it has been proposed that natural movement patterns may be a necessary precondition but not always sufficient to explain activity in all urban conditions (Stahle et al., 2006). Since space syntax puts emphasis on the physical properties of space rather than the broad range of experiential dimensions of space, it may overlook meaningful social and cultural variations. In a different context, Canter & Stringer argue for a 'both and' approach from the position of *mind-processes*: "The perception of the environment derives as much from the structure of the stimuli in it as from the properties of the stimuli themselves" (Canter & Stringer, 1975a, p. 7).

By taking some interpretive freedom with Canter's suggestion that the structure of stimuli is [also] important for perception of the environment, it is reasonable to expect these stimuli to include both spatial and non-spatial properties. In space syntax, the focus is on perceptions of the configurational properties of space. One could then ask whether meaning-associated elements in the environment also follow configurational logics of their own. Do meaningful patterns have their own logic of space? Is there a configuration of place? Others have alluded to this (Alexander, 1977; Appleyard, 1976; Buttimer, 1972; Canter & Stringer, 1975a; Stahle et al., 2006).

Having reviewed the space syntax "theory of natural movement," a definition of space can be formulated that emphasizes the realms of *physical* and *actions* in the environmental framework presented above. Hillier's approach and space syntax theory inform the following definition of 'space' that will be adopted for this research:

Space is the patterns that both result from, and encourage copresence through, the relational and localized 'properties of space'

2.6. Conclusion: moving beyond space and place

Space syntax offers a tight definition of space through rigorous investigative methods. Place theories, on the other hand, offer an all-inclusive definition of place which emphasizes the importance of meaningful patterns and affords opportunities to apply measurement to a variety of physical characteristics. In this research, an attempt is made to apply useful aspects of both definitions to find empirical evidence that space and place are in fact mutually reinforcing dimensions of the relationship between people and environments.

By using definitions of both space and place, there is room to think about activity patterns that are observable and related to both meaning-related elements (which include space) and spatial elements in the urban environment. It also becomes possible to view both spatial elements and place elements to function according to configurational rules. It is therefore suggested that space and place are both concepts by which people likely structure their experiences in the environment.

It is also important to emphasize that the concepts of space and place are not fully independent constructs. One of the main theoretical positions in this dissertation hypothesizes that environmental attractors such as destinations create relational patterns that are both independent from, and co-dependent on, street network space. Rather than continuing down the road of 'either-or' in terms of these theoretical approaches, it seems compelling to attempt to, once again, reunite the constructs of space and place.

The research in urban cognition since the mid-1950s is a valuable source of extant literature to guide the development of further theory and measurement of space and place. The most prominent examples include Kevin Lynch's urban elements, Donald Appleyard's spatial and locational mental systems of the city of Guayana, and Ann Buttimer's and Terence Lee's variations on a socio-spatial schema. These and other cognitive systems of meaning will be discussed in the following chapter.

Chapter 3
EVIDENCE IN URBAN COGNITION AND PHENOMENOLOGICAL RESEARCH FOR THE CONCEPTS OF SPACE AND PLACE

This chapter describes some of the significant contributions in the research on urban cognition and environmental phenomenology that apply to the proposed framework of environmental relationships of the *physical*, *conceptions*, and *actions* which shape people's activities in neighborhood environments. The research presented in this chapter provides mostly empirical evidence for framing people's transaction with the built environment in terms of concepts of space and place. In the previous chapter, a theory of place and a theory of space were presented. The discussion in this chapter is an attempt to present support for *why* people rely on locational (place) and spatial elements in the way they conceive of the environment.

Some investigations during the 1960's and '70's saw space and place as interdependent constructs, after which research studies increasingly disassociated these terms for the sake of empirical measurement. Place theorists started focusing more on subjective experiences (phenomenological), whereas space theorists argued for the quantification of space (cognitive).

This chapter embarks on a brief survey of the research starting from the time of Jane Jacobs in order to get a better sense of how people use space and place elements to access the city. The review also provides the backdrop to speculate about the kinds of environmental measures that are appropriate for investigating how space and place may be important in how people move through the city. This review will set a platform for:

[1] reuniting space and place as interdependent constructs by referring to earlier research that looked at both of these concepts in combination, while searching the literature for thoughts on how each dimension facilitates access to the urban environment,

[2] relating 'action' to movement and experience,

[3] arguing that people are connected to meaningful territories and apply cognitive and experiential mental patterns to maintain their habitual movement within these areas, and

[4] highlighting that cognitive patterns of the arrangement of the physical environment exist in people's minds and that people conceive of their surroundings in terms of distance and configurational aspects.

3.1. Early research on accessibility and the built environment through the concepts of space and place

It would be hard to imagine the surge of discourses surrounding 'space' and 'place' without Jane Jacobs' 1961 classic book, *The Death and Life of Great American Cities*. In this book, she describes the nature of the livable city through the lens of her neighborhood, Greenwich Village. She sees the city as an organic unity of distinct but interdependent and overlapping parts: places such as neighborhoods, districts, streets, and venues. Her descriptions underpin how people experience city life through their deep connection to places and their embeddedness within a continuous spatial reality. She describes it as follows:

> "Most of us identify with a place in the city because we use it, and get to know it reasonably intimately. We take our two feet and move around in it and come to count on it. The only reason anyone does this much is that useful or interesting or convenient differences fairly nearby exert an attraction. Almost nobody travels

> willingly from sameness to sameness and repetition to repetition, even if the physical effort required is trivial. Differences, not duplications, make for cross-use and hence for a person's identification with an area greater than his immediate street network." (Jacobs, 1961, p. 169)

It is perhaps her first-hand description of everyday urban scenes that allows one to understand how spatial continuities, attractors, and everyday life needs of people coalesce to generate vibrant street spaces. People move through the networks of streets, are attracted to distinct places, and designate these areas as 'city', 'district', or 'neighborhood'. At the core of these environmental relationships is the seamless interplay of meaningful places and spatial properties that facilitates greater access of the physical environment.

The study of the way people conceive physical accessibility has its roots in research that tried to link urban features in the environment with perceptual processes of the mind. Kevin Lynch was one of the first to conduct empirical studies on the extent to which people's shared mental images of their city helped them access the city. After studying the mental maps of residents in three American cities, his findings supported his initial premise that people do not merely move, but they move with intent, consulting their mental images of their surroundings. He found that the extent to which people find their cities "imageable" depends on how clearly people recognize elements of the environment as belonging to the following simple categories: *paths*, *nodes*, *edges*, *districts*, and *landmarks* (Lynch, 1960). De Jonge (1962) replicated and corroborated Lynch's findings using three cities in the Netherlands.

Lynch (1960) further posits that space and place are almost inseparable. He demonstrates that meaningful urban elements reinforce the nature of spatial form, together contributing to the legibility of the city. Most participants in this study retrieved ‘*path’*, the element that describes the street networks in the city, most frequently from all the urban elements. However, Lynch considers the presence of landmark elements to be fundamental to how people visualize and move through the city, with the arrangement of spaces taking on a secondary role.

Another approach considers ‘*paths*’ to be equally important, with the ‘*landmark*’ functioning as a point-reference to clarify spatial orientation, whether it be *through-movement* within a city grid or *to-movement* in a constant direction towards a *landmark* such as a tower, hill, or dome. As Lynch himself suggests, the observer does not enter the *landmark*; it is exclusively a device to delineate spatial hierarchies.

Three additional elements—*nodes*, *districts*, and *edges*—also challenge the autonomy of space by representing the various facets that can be used to describe places. Although different in scale, both ‘*districts*’ and ‘*nodes*’ have locational qualities that result in people being either on the “inside” or the “outside”. The observer is situated “here” as opposed to “there,” and considerations of distance, connection, and boundaries become paramount. This is where *edges* come into play.

‘*Edges*’ are lateral borders dividing areas and spaces of the city into identifiable mental units. They are also used as references to estimate relative distances to locations that fall inside or beyond their boundaries. ‘*Edges*’ can be partly penetrable seams such as a busy street (Appleyard & Lintell, 1972), complete breaks in the continuity of the street pattern such as shores, railway lines, and highways (Canter & Tagg, 1975b; Lynch, 1960, pp. 47-48), or demarcate territories that fall beyond a walkable reach (Lee T., 1970a). In legible cities, the ‘*edge*’ always relates to the location, such as the neighborhood boundary and the house, or the edge of the downtown district and the shop.

A study by Appleyard (1976) in Ciudad Guayana used cognitive maps to investigate how inhabitants structure their city. Without the help of a public map, many residents had difficulty drawing their impression of the city. During this time, the city of Guayana was undergoing large scale restructuring, making it more likely that people made reference to their mental image of the city rather than a previously seen map. Although the respondents used a variety of ways to visualize familiar areas of the city, they most frequently employed *spatial elements* and *locational elements* in their diagrams (Figure 3-1). People are describing *spatial elements* when they refer to a type of mental street network or system of paths, and *locational elements* when they put more emphasis on the distribution of destination places rather than the connections between them. *Spatial elements* were by far the most common, by almost a three quarter majority. The question can then be asked why people favor these two kinds of elements and why they mostly employ *spatial elements* over *locational elements*.

A few observations may put these tendencies in context. First, Appleyard's measurements focused on the structuring of Cuidad Guayana as a whole, including the smaller communities of San Félix, Puerto Ordaz, Castillito, and El Roble. Since people's movement patterns often occurred across these different parts of the city, the overall spatial system became the benchmark from which people reported their impressions. (Referring to a substantial body of evidence, it will be argued later in Chapter 4 of this dissertation that the spatial characteristics of the street network in a city are a good predictor of pedestrian movement).

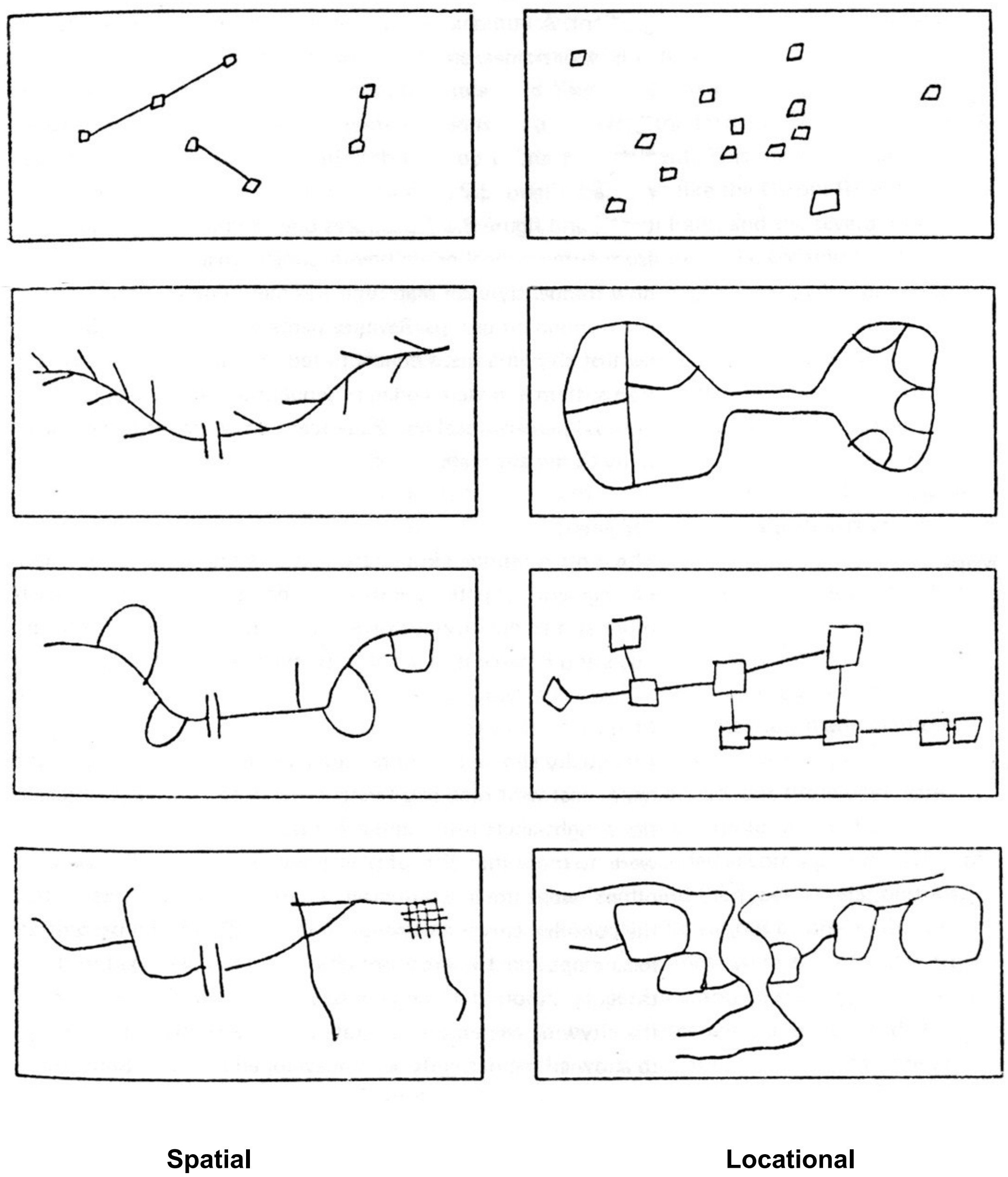

Figure 3-1 Cognitive maps by residents of Cuidad Guayana (Appleyard 1976, p.158)

A second reason that spatial elements were employed more often is that it did not make a difference whether urban features (buildings, signboards, towers, etc.) had distinctive forms, were highly used, or were of community significance; instead, it mattered only whether these features were visible at major decision points along the transportation routes of the city. This supports Lynch's notion that *landmarks* are orientation devices that add to a city's legibility by clarifying the most efficient spatial structure. Third, and perhaps the most pertinent in light of the previous observation, prominent buildings that were off the beaten track were not mentioned as frequently during Appleyard's interviews (1976).

Familiarity with the local environment also seems to play a vital role. In areas where spatial and locational features reinforced each other, such as significant urban features that corresponded with major decision points on the street network, locals and strangers held similar images of the city. In places where this correspondence was lacking, their reports diverged.

A general hypothesis can be formulated from the findings of the Lynch, De Jonge, and Appleyard lineage: the relational structure of familiar urban features may override the relational structure of street spaces if the spatial structure is less clear. This may explain why some interviewees in the mental mapping exercises focused on locational properties, viewing the city as an assemblage of distinct units (or *districts*), rather than a spatial interconnected whole. If the spatial layout is unclear, people find their way by reconstructing efficient patterns of accessibility that use the location of urban features such as destinations as points of reference.

A study by A. Lusk (2002) on rural, urban, and rail-trail greenways shows evidence that people prefer greenways that have destinations located at regular intervals. She used on-site semi-structured surveys and cognitive mapping exercises to investigate the contribution of prominent environmental features on preferences and use of greenways. She suggests that habitual walkers use familiar destinations as important mental markers along the path: people associate features, activities, and meanings with locations that they describe as important destinations. Lusk also reports that people tend to refer to similar characteristics of destinations, regardless of whether they were describing destinations on rural, urban, or rail-trail greenways. Although her work considers greenways and not urban streets, the consistency of her findings across different types of greenways suggests that destinations are important meaningful mental structuring devices of the physical environment.

In sum, a few important points need emphasis:

[1] Life in cities, especially pedestrian movement, favors unique combinations of place and space properties to make the environment legible,

[2] People use place and space factors as structuring devices to find their way through the urban environment, and

[3] It is conceivable that the dimensions of space and place operate independently, tightly or loosely related to each other.

3.2. A *home-ground* perspective of the built environment

The following discussion shows evidence that people conceive of their neighborhood as a type of *home-ground* turf that becomes a significant mental construct in organizing their daily life patterns. This has implications for how people conceive walking distances and how they structure their networks of familiar places. Research in cognition and phenomenology has introduced special focuses on localization: cognition shows how people organize their surroundings through their mental images of environments, and phenomenology shows how people build lasting emotional connections to their community by strengthening their local, social, and physical networks.

There is strong evidence from the literature in cognition and phenomenology that people develop meaningful connections with their immediate (local) experiential realms (Appleyard, 1976, 1981; Buttimer, 1972; Desyllas & Duxbury, 2001; Lee T., 1970a; Stahle et al., 2006). People intuitively organize their experiential environment through their engagements with their immediate surroundings: the here-and-the-now. Stahle et al. (2006), doing preliminary work in what they call Place syntax, speculate that "*people . . . live and move locally* and businesses move and attract globally" (p. 11)—emphasis added. They also suggest that people's movements are likely to be influenced by local destinations and the local properties of space. This capacity to focus locally is perhaps a heuristic mechanism by which people favor and invest in their localized places to sustain their daily life routines. As a result, people conceive of these psychological territories as a cohesive system that they call 'home' or 'neighborhood.' Through continued engagement, the local place becomes easily accessible, providing people with a level of comfort, familiarity, effortlessness, and predictability. The local therefore becomes a zone of support for people's aspirations and needs[2].

Similarly, Appleyard (1976) writes that the continued engagement with environments results in a concentration of urban knowledge around the location of a respondent's home, with decay of that knowledge correlating with the distance from *home-base*. He suggests that these local affiliations result from propinquity: social relationships that are maintained by the physical closeness of people to one another. This enables them to build strong connections in their immediate surroundings and concentrate their *life-worlds* locally. The act of walking has also been suggested to be help people feel connected to their local environments and focus their efforts locally (Solnit, 2000).

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2 Also see Wolpert (1965), Webber (1964), Horton & Reynolds (1976), and Brown & Moore (1970) mentioned in Downs et al. (1973) pp. 363-364.

3.3. Movement, action, experience

One area that has been less researched is the crucial connection between movement, action, and experience. To understand these connections, it is necessary to first revisit the human-environment relationship of *'action'* in order to understand the cognitive and experiential processes that occur when actions are taken in the environment.

Hillier clarifies a few preconditions for this term '*action*'. First, the relations of humans to their external environments are, in his view, primarily cognitive. A mental schema of the environment may be present, but knowledge of the environment does not consist of a static mental copy of the 'object' but rather consists of mental representations undergoing constant transformations through transactions with the environment. Second, these constant schema transformations occur through people's operations within the world, in other words through their actions. Third, people recognize 'objects' when they confirm their preconceived ideas about the world. In unforeseen situations, they accommodate new mental structures by differentiating them from or integrating them with previously known mental structures (Hillier et al., 1973).

Hillier's interactionary *'action*' dimension is quite similar to what David Canter calls *environmental transactions*. Canter adopts the term from an earlier cognitive model of "environmental transactions" by David Kaplan (1982), and suggests that action is intentional because it is only "by acting on our surroundings that we make sense of them" (Canter, 1988, p. 5). Ulrich Neisser also used this approach in his book *Cognition and Reality*. His model of the "perceptual cycle" recognizes the dynamic anticipatory role of cognition as it interacts with meaning, spatial position, and form within the environment. The construction of experience occurs through the ongoing "trans-actions"[3] that occur between people and places (Neisser et al., 1976).

Ulrich Neisser's "perpetual cycle" describes how action and movement have the same character. Action is a consequence of people's cognitive schemas directing them to follow through with their expectations. While people act, their internal schemas are compared with the external environmental information that becomes available to them. Neisser relies on Piaget's concept of "accommodation," suggesting that the perceiver *is* what she experienced in the past, and further *becomes* what she perceives in the present. The idea of perceiving "over time" is critical. Action unfolds through movement, for the perceiver is introduced to more information as she moves through space. This perception in motion is what allows learning to occur. The cognitive operation either reinforces the schema, causing it to become more coherent and automatic, or modifies the schema by adding alternate ways of following through with the intended action (Neisser et al., 1976).

'*Action*' is also experiential. As Jane Jacobs (1961) once suggested, people move from place difference to place difference, not sameness to sameness. As people aspire to take action according to their needs and preferences, they also become aware of the potentials for accessing their surroundings; in other words, their intentions are channeled through the heuristic of movement. People discover different gradients of accessibility in their surroundings (neighborhoods) through the movement of the *body*. These gradients of accessibility maintain patterns of movement that people come to rely on. For the theorists in phenomenology, these aspects of the schema that become automatic, often

3 This author takes liberty in the use of the word "transaction" in terms of Neisser's perceptual cycle.

referred to as the "*habitual*", are critical in the ongoing experience of place (Seamon, 1979). The *habitual* is also important in establishing a *home-ground* affiliation to local place. This maintains coherence and continuity in people's lives, reaffirms their belonging to a place, builds confidence through distinct experiences, and facilitates opportunities to engage with their most treasured places and people[4] (McMillan & Chavis, 1986).

Another important aspect to consider is whether the *home-ground* perspective is associated with a special mode of perceiving places that needs to be considered in the way that people move through the city. Appleyard suggests that there are, in fact, three different modes of perception relating to the built environment: *operational, responsive,* and *inferential.* The *operational* mode most clearly highlights the *home-ground* perspective, as it is a way of relating to the city that favors elements, which promote personal action and behavior. Elements that can seem inconsequential, such as street scenes, billboards, storefronts, and prominent buildings, may play into our mental conception of the city. These aspects are remembered because they are essential for completing tasks, trips, and finding places for activities, hence the term *operational* accessibility.

Operational perception is goal-oriented, seeking to improve accessibility to the city while minimizing the amount of cognitive and physical effort. As described earlier, Appleyard also believes that the mode of travel mediates environmental perception since the processing and retention of environmental elements is affected by aspects like speed of travel, relative position of views, and level of contact with surroundings and other people

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4 These aspects reflect the four dimensions of place identity introduced by Glynis Breakwell (cited and applied in environmental psychology research done by Twigger-Ross and Uzzell (1996)).

(Appleyard, 1976). In close contact with the surroundings and with limited ability to cover distances, pedestrian have certain restrictions, resulting in patterns of observed behavior that are potentially consistent with this form of movement. In the walkability literature, this mode is also called purposive or transportation walking and has been shown to be associated with consistent behavior patterns (Lee & Moudon, 2006a; McGinn et al., 2007b). The *operational* mode of perception demonstrates a possible connection between *action* and *movement*. (As thought provoking as the other two modes of perception may be, they are not central to the goals of this discussion. Their descriptions may be followed up in Appleyard, 1976. pp. 205-206).

3.4. Metric distance in urban environments

Central to localization is the concept of *distance*; people are situated in the area around where they live and it requires increased effort to move beyond their localized spaces. To gain an understanding of how the home as a central reference point in people's lives affects the way in which localized settings emerge, the aspect of distance needs to be explored. Lee (1970b) suggests that *home-ranges* are limited by metric distance decay, a term used in geography.

The issue of 'distance' raises the question: how far can/would people walk? Various studies have reported neighborhood walking distances for the average person to range from ¼ to ½ mile. The respondents in Lee's study of neighborhood socio-spatial schemas referred to an area smaller than ½ mile radius (Lee T., 1970a). It has also been shown that the distance to destinations depends on perceptions about the destinations (Cerin et al., 2007; Giles-Corti et al., 2005; Lusk, 2002; Moudon et al., 2006c). The question of 'distance' therefore becomes a question of the 'perception of distance'. How does the human mind construct [and distort] mental representations different from reality to allow the individual to reasonably work around the constraints that exist within the environment?

Research in urban cognition has favored object-oriented approaches to visual perception that include aspects such as metric distance, direction, and movement (Downs & Stea, 1973; Hillier & Iida, 2005; Ittelson, 1973; Ittelson, 1960). These approaches imply that the aspect of *to*-movement, moving to and from destinations, is the dominant mode of urban movement. To accurately estimate [or distort] distances, people not only anticipate the distance of the trip to a destination, but they also account for the overall travel effort and the ways around barriers that will allow for a successful round trip.

When considering pedestrian movement, the physical ability to move around on foot for only limited distances has important implications for how movement occurs in urban space, how mental imagery about environments is constructed, and how people identify what counts as their home territory.

3.5. Neighborhood boundaries, activity ranges, and shared social roles

In the following section, studies that consider *operational accessibility* (introduced in section 3.3) were consulted to understand the nature of the zones near where people live. There seems to be sufficient evidence that conceptions of place and space: [1] exist as a coherent mental representation in the mind, [2] are concrete enough for people to base their decisions to act upon it, and [3] are maintained and often re-imagined through people's continued habitual movements. The following discussion focuses on the implications of neighborhood territories on activity patterns and movement. The aspect of distance is also mentioned briefly.

Lynch's (1960) five elements suggest that people conceive of place as a shared territory, or 'district,' by using their mental representations. These mental representations may manifest as main streets, street corner hangouts, neighborhoods, or other mental assemblages loaded with meaning. Terence Lee clarified the notion of localized patterns with his concept of "sociospatial schemata" by building on Lynch's work (Lee, 1976; Lee T., 1970a). By comparing the neighborhood boundaries that people sketched on a map of their neighborhood with the location of acquaintances, shops, and amenities, Lee was able to show more precisely how people's sense of territorial ground coincides with their most favored locations. Over 30% of friend's houses, 50% of shops, and 60% of amenities were found to fall inside respondents' reported neighborhood boundaries.

Golledge and Zannaras (1973) tested Lee's claim that perceptions of the physical and the social are linked. They found that there is a high level of agreement between people's reports of the spatial extents of their social neighborhoods—proximate territories where acquaintances, friends, and family are—and the parts of their neighborhoods they feel attached to, but the two are not exactly equivalent. Lee (1970b) also found variation among individuals' patterns of actions, although some indication of consistencies was present.

Often, neighborhood boundaries are not clear and can be better described in terms of gradients or layers (Lynch, 1960). (Also see Lynch's description of 'edges' in section 3.1). An individual may also construct various 'neighborhood' patterns, each corresponding to a different aspect of their *life-space*. This led Lee (1970b) to speculate whether the idea of 'neighborhood' is even useful if the interest is people's localized activity ranges. He shows that there is a high correspondence between how people indicate their neighborhood boundaries and how they map out their localized activities and social relationships, suggesting something about how the social and the physical environment are linked.

One of the recurring critiques of urban planners' attempts to describe meaningful units of the local is that their descriptions are often too fixed; they follow physical demarcations on a map rather than fluid social processes. "Subdivisions", "planned units", or "block groups" are idealized and static ways in which the local is often conceived. As a result, there has been criticism of the idea of the local: some have gone so far as to argue that the modern urban dweller prefers mobility and anonymity rather than local affiliation (Wirth, 1938; Meyer, 1951; McClenahan, 1945; and Riemer, 1951; cited in Lee T., 1970a). (Lee (1970a) and Golledge & Zannaras (1973) provide a detailed review of the difficulties in securing a single definition for the elusive term "local").

As a result of his research, Lee challenges the idea of labeling activity ranges using static terms such as "neighborhoods," suggesting instead the terms "networks" or "chains of influence" (1970b). Along similar lines, Appleyard describes this *home-based* perception of the city as "islands of knowledge" that create a constellation-like form of known areas, with tentacles of known circulation systems connecting familiar hubs (Appleyard, 1976, p. 204) (see Figure 3-2). Roads serve as the framework, and people, buildings, and places become articulated as *figure*, standing out from the *ground* that subsides into insignificance (Lee T., 1970a, p. 354 and 366).

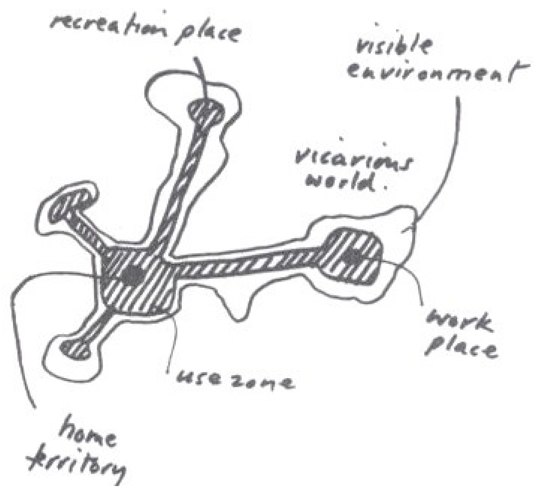

Figure 3-2 Diagram of the spatial form of urban knowledge (Appleyard, 1976, p. 204)

But if distance is most important at generating these networks of known areas, should not all activity ranges be predictably similar? One characteristic of the *home-ground* perspective is that it is perceptual in nature. First, *home-range* distances do not decay in a linear fashion; it is mediated through perceived distances that depend on the environmental feature(s) toward which it is directed. These perceived estimations are discussed in a study by Canter and Tagg (1975b). Second, it also extends beyond what is visible in the immediate surroundings, in other words it resembles a 'mental map' (Appleyard, 1976, 1981; Lynch, 1960, 1981). Third, there is a constant tension between the city beyond the individual's realm of experience and the familiar territories that have already been explored. Lee suggests that the process is likely bi-directional: expanding outwards from home and contracting inwards from the city (Lee T., 1970a, p. 354).

Although the outer bound of the *home-range* is capped by the travel effort associated with walking, a diversity of potential activity spaces and the "shrinking" of distances due to the familiarity of places[5] ensure that 'neighborhood' remains a flexible construct.

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5 Ittelson (1960), Lee (1970b), Canter & Tagg (1975b), and Nasar et al. (1985) show that more desirable places are estimated to be nearer.

Jane Jacobs describes the abstract concept of neighborhood territories as follows:

> "Street neighborhood networks…work best…[if they]…have no beginnings and ends setting them apart as distinct units. The size even differs for different people from the same spot, because some people range further, or hang around more, or extend their street acquaintance further than others. Indeed, a great part of the success of these neighborhoods of the streets depends on their overlapping and interweaving, turning the corners." (Jacobs, 1961, p. 156)

The Golledge and Zannaras (1973) study discussed earlier raises a concern with the way Lee defined social variables in his study. Lee asked participants to locate their acquaintances and friends as a way to approximate their social engagements. This measurement describes the "social" in a very narrow sense, missing out on a range of life experiences that occur in other activity spaces. On the other hand, Lee's study succeeded in demonstrating that a localized space of activity exists, both within people's minds and in their practice of everyday life (Lee T., 1970b).

Anne Buttimer's dimensions of environmental experience address the criticism that Lee's study lacks the "social." One of the first research studies to apply a *home-ground* perspective is her sensitive examination of residents' localized *activity ranges*—the spatial extents that residents' activities occupy. She quantified activity patterns for different groups of city dwellers and showed that activity orbits (or *ranges*) emerge because of the social significance they carry for people. These ranges included people's activity footprints of social participation as well as their engagements with their destination environments. She suggests that social groups often share sociospatial experiences that shape their networks of preferred and disliked places, interaction spaces, and avoided or inaccessible spaces (Buttimer, 1972, p. 307). Their purposive action patterns generate mental images and establish affective relationships with routes, nodes, and places unique to their activity ranges.

3.6. Alternative of configuration

Research in space syntax offers an alternative by focusing primarily on the configurational properties of space—how spaces relate to each other—while also [more recently] looking at the fundamental connections to modes of experience and cognition (Hillier, 1999, 2003; Hillier, 2004; Hillier, 2008; Long et al., 2007; Penn, 2003; Penn et al., 2007; Penn & Turner, 2002; Seamon, 2007).

Space syntax theories developed out of the concern that other measures of urban movement are too local, favoring measurement from a centralized position in space (Hillier, 1996b; Hillier, 2003; Hillier & Iida, 2005). They instead propose that humans rely on the perceptual ability to “read” spaces in relational terms in addition to metric terms. Findings from their measures of the configurational properties of space, especially their primary measure of urban space, *street network integration,* show remarkable consistencies with concentrations of pedestrian movement (Hillier et al., 1987; Hillier et al., 1993; Peponis et al., 1989).

More recently, there has been interest in also demonstrating the contribution of *through*-movement, closely associated with the configuration of cities. Peponis et al. (1997) suggest that movement *to* and *from* spaces is primarily related to land use (or destinations), whereas movement *through* spaces is primarily a function of configuration. He goes on to suggest that the liveliness of cities requires both components to be present and support one another (p. 345).

Using syntactical diagrams, researchers look for predictable patterns that result from the consistent ways in which people move through urban space. Their groundbreaking discoveries show that how spaces relate to each other is often more important than the metric distance of spaces in understanding urban movement (Hillier, 2003). Their methods are relational; in other words, they develop models of urban space that put every street (or space) in relationship with other streets.

Until recently, space syntax studies predominantly investigated world cities such as London, Tokyo, and Rome with higher and more equally spread population densities than most American cities. Only a few studies have considered how spatial properties support the *copresence* of people and places in lower-density urban settings (Peponis et al., 2007; Peponis et al., 2006; Peponis et al., 1997; Stahle et al., 2006). Recently, Peponis et al. (2007; 1997) have used space syntax measures to investigate how these spatial regularities apply to lower-density American cities. A few issues are critical in understanding the relationships between density, land use, and street network characteristics.

Peponis et al. (2007) suggest that street networks remain stable over long periods of time, whereas land uses and population densities tend to vary. The longevity of streets has important implications for the examination of all aspects of the city layout and how they interrelate with land uses and population densities in different contexts. It has also been posited elsewhere that the relational properties of space affect the location of attractor land uses (Hillier, 1996a, 1996b; Hillier et al., 1993)—also see the discussion in Chapter 2.

Space syntax studies show a significant correlation between higher integration and higher numbers of pedestrians (Hillier et al., 1987; Hillier et al., 1993; Peponis et al., 1989). This result has been tested on cities with regular and irregular street grids, business centers and residential districts, and in small towns and large metropolitan areas. A study by Peponis et al. (1997) in Atlanta suggests that how spatial configuration relates to movement can be different for vehicular as compared to pedestrian movement. They were particularly interested in Atlanta due to the high heterogeneity of spatial configuration values and geographic differentiation of land uses. They found that the integration of spaces in sub-areas show stronger positive correlations with vehicular movement than the integration over the entire metropolitan area. Pedestrian movement, on the other hand, increased as the integration over the entire city increased.

Because most space syntax research has been done in cities with high density, the question has been raised as to whether higher density of both populations and land uses covaries with the configurational hierarchy of spaces (streets) in a system of spaces (streets). Peponis et al. (2007) tested this idea in Atlanta, a city with much lower population density than its European counterparts. Preliminary results indicate that street configuration is more influential than land uses in affecting urban movement. However, their findings also show that the interaction between density and street networks may be different for different cities. Their findings show that a higher density of streets (street length per square kilometer) covaries with a higher density of residential buildings, especially after excluding the Atlanta downtown area from the analysis. However, they did not see a correspondence between the density of streets and the total square meters (or occurrence) of non-residential uses. They explain this finding by suggesting that some non-residential uses are attracted to small parcels and blocks in dense areas, while other non-residential uses are drawn to very large parcels and urban blocks (Peponis et al., 2007).

Another analysis in the same article tested the correlations between street network connectivity and the frequency of commercial and recreational uses that are likely to attract urban movement (pedestrian or vehicular). They report that a clear triangle emerged on the correlation plot, suggesting that highly connected[6] areas have large variation in frequencies of commercial and recreational uses (Peponis et al., 2007). This suggests that areas with an unequal population density and destination environment may perhaps generate a configurational logic that relates differently to space, perhaps a logic that refers to the locations of destinations (Stahle et al., 2006). In this case, a loose association exists between space and place, and land uses may enhance or distort the effects of space. Since there are a growing number of low-density suburban areas in the United States, understanding these interactions between spaces and places are critical.

3.7. Conclusion

This chapter presented evidence for understanding why the concepts of space and place are important. Findings from previous research were presented to demonstrate how people mentally organize their neighborhood areas and how they rely on these mental representations for their daily activities.

People's *activity-ranges* are biased by the locations of their homes, resulting in activity spaces that are dependent on *distance*. Distance estimation to locations may be a useful starting point to unravel some of the complex interactions between space and place and their contributions to 'actions' and 'movement'. An additional aspect of the spatial realm that has been shown to influence people's movement consists of the local and global *configuration* of spaces.

6 A new connectivity measure called metric reach was applied in this analysis. See Peponis et al. (2008) for a description of this measure.

Since aspects of both space and place combine to maximize accessibility of neighborhoods, environmental measurements should reflect this dialectical reality. The goal of the rest of the dissertation is to investigate empirical evidence for the theoretical notion that concepts of space and place are reinforcing dimensions of the accessibility of the built environment. A quantitative research study applying measures of place (destination measures) and space (space syntax measures) is presented next.

Chapter 4
LITERATURE REVIEW OF ENVIRONMENTAL FACTORS, PHYSICAL ACTIVITY, AND WALKING

4.1. Chapter overview

In support of the theories presented in the previous chapters, Chapter 4 reviews the long tradition of interdisciplinary research in social science and design that investigates the ways in which people rely on mental conceptions of space and place to access their neighborhood environments. The idea that mental patterns of the physical environment can be observed will have major implications for the application of objective environmental measures that are proposed to distill the associations between the built environment, pedestrian movement, and physical activity.

This chapter examines the development of research on environmental characteristics that are associated with the two main study outcome variables of physical activity and walking. Since the main focus of most research is the outcomes variables, literature reviews are often used to develop arguments for the importance of the outcomes and therefore the purpose of conducting the research. However, because the main purpose of this research is to identify and test characteristics of the built environment in greater detail, the focus is therefore on the independent rather than the dependent variables. In addition to focusing on environmental factors, this literature review is intended to support the relevant research questions that posit an association between the built environment and physical activity and walking.

First, an understanding of the relevant environmental characteristics and their various measurement approaches is necessary. This section identifies hypotheses presented by the current literature on the built environment and discusses the environmental measures that test these relationships. Because most of the literature in this section comes from the fields of architecture and urban design, where clear distinctions are not often made between the two concepts of physical activity and pedestrian movement, the two terms are at times used interchangeably. This first part includes sections 4.3-4.7, introduces research questions 1-3, and focuses on the independent variables.

The second part of the literature review focuses on the psychosocial factors that are also proposed to be associated with physical activity and walking outcomes. This section examines the literature for how psychosocial factors relate to both people's understanding of the built environment and their walking and physical activity behaviors. This second part (section 4.8) introduces research question 4 and focuses on the mediating variables.

Finally, a third section (4.9) examines the measurement of pedestrian movement and physical activity. This discussion elaborates on these outcomes both in terms of their conceptual differences and in terms of the strengths and limitations with their measurement. As mentioned earlier, the literature discussed prior to this section does not generally make a clear distinction between these two outcomes measures.

Overall, the research questions are framed to: [1] test destination measures for their relationships with *pedestrian movement* and overall *physical activity*, [2] compare the relative impact of destination measures on these outcomes with advanced spatial measures, [3] compare the relative impact of destination measures and spatial measures with mainstream measures in urban planning, and [4] determine if psychosocial perceptions play a mediating role in the relationships between the built environment and physical activity outcomes.

4.2. Research linking the built environment with walking and physical activity

Multidisciplinary researchers in public health, urban planning, and policy have long 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: [1] socio-demographic, [2] psychosocial, and [3] built environment (King et al., 2000; Lee & Moudon, 2004b; Pikora et al., 2003; Saelens et al., 2003a; Sallis et al., 1997; Stokols, 1992). See Figure 4-1.

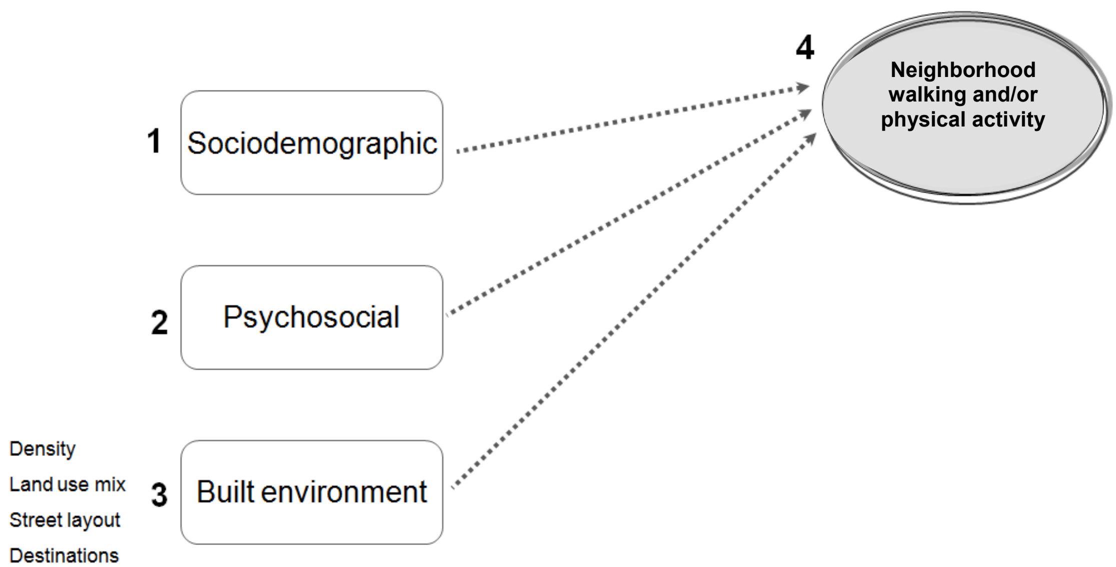


Figure 4-1 Factors that are associated with neighborhood physical activity and walking

This dissertation research focuses on the links between the built environment and *physical activity* outcomes such as neighborhood physical activity incurred from walking within the local neighborhood environment. Research studies suggest that walking is the most common type of physical activity and that most walking occurs in 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). The growing awareness that there are important links between the physical characteristics of the environment and walking has resulted in a wealth of research.

Current urban planning research on walkable neighborhoods has described the physical environment along the lines of three main characteristics: density (of residential units, households, population), land use mix (residential, commercial, institutional, etc.), and street layout (street connectivity, street intersections). A complementary line of research puts the emphasis on destinations, suggesting that local destinations attract people and in turn facilitate walking (see Figure 4-1). Recently, it has been suggested that the focus on destinations is a useful alternative to descriptions of the physical environments along the three characteristics that were mentioned above (Lee & Moudon, 2006b).

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 found using density, land use mix, and street layout. Destination characteristics have also shown consistent associations with physical activity outcomes, although these factors are not yet as widely recognized among urban planners and designers as density, land use mix, and street layout. In the next section, the three commonly-applied environmental characteristics will be discussed, after which the alternative of destination research is introduced.

4.3. The 3Ds: density, diversity, and design

A landmark study by Cervero and Kockelman (1997) suggested three important environment variables called the three D's: density, diversity, and design. So widespread in the field, the term 3Ds has become shorthand for the three environmental dimensions: population density (density), the mix of land uses (diversity), and layout of the streets (design). Their study demonstrated that these three characteristics facilitate the frequency of walking for a sample of San Francisco residents[7].

Evidence from other studies in the urban planning and transportation literature has accumulated 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 propose that compact, mix use, and pedestrian-oriented development may change how Americans travel (Calthorpe & Poticha, 1993; Duany et al., 2000; Katz, 1993) .

The Cervero and Kockelman (1997) 3Ds thesis clarified and pulled together a chain of response papers and cross citations that had been floating around during this time. However, the development of more specific objective and statistical measures of land use mix, residential density, and street connectivity had already been explored by Frank and Pivo (1994). Measurements of the 3Ds 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) also demonstrated the relative

7 This study also demonstrated that the 3Ds are associated with mode choice. They suggest that compact, mix use, and pedestrian-friendly environments reduce vehicle trips and encourage non-motorized travel.

predictive strength of each of these measures, with density showing the strongest relationship to walking, followed by connectivity and then land use mix. Moudon et al. (2007) also found that density is strongly related to walking.

Frank et al.'s (2008) article is relevant to this research for several reasons. The study was conducted with a sample of 13,065 white and non-white participants[8] in the city of Atlanta, an American city with low density urban environments[9] not too different from the areas in Detroit described in this research (more description of the specific study sample and context later). Participants in the 2008 study lived in study areas spread across the Atlanta metropolitan area. Self-reported responses from the 2006 Strategies for Metro Atlanta Regional Transportation and Air Quality (SMARTRAQ) were analyzed. A unique aspect of this study is that both walking and body mass index were analyzed as outcome measures. (In this dissertation research, this aspect of including multiple reported and objective outcome measures of physical activity will be addressed when research questions are discussed).

Frank et al. (2008) did find that walking was associated with the three environment characteristics, although only 9.9% of the surveyed respondents reported walking at least once over a two-day period. Interestingly, while walking showed significant relationships across the sample, body mass index showed only a few relationships when analyzed by socio-demographic subgroups. This study demonstrates [1] the relative predictive strength of density, street connectivity, and land use mix as mentioned above, and [2] the combined effects of these three measures working together to support walking. The article reports that street connectivity was related to walking only in the

8 White n=9317 and non-white n=3748.
9 Residential density tertile cut points are1.6 and 3.6 housing units per acre.

highest density neighborhoods. They also suggest a synergistic effect between land use and connectivity: areas with higher residential density and street connectivity also had the highest land use mix (p. 177).

The Frank et al. (2008) study demonstrates that density, street network characteristics, and land use mix are mutually interdependent dimensions of the built environment (see Figure 4-2). A more in-depth description of each of the three physical environment characteristics will be provided next.

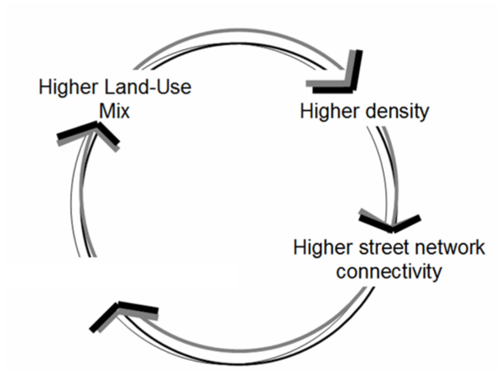


Figure 4-2 Interdependence of residential density, street connectivity, and land use mix

4.3.1. Density

Density describes the concentration of people in cities, neighborhoods, and blocks and refers to the number of people, residential households, or housing units in a given residential area. In the walkability research, the purpose of characterizing the environment in terms of density is useful for understanding how close people are to things, places, and other people around them. As mentioned in the previous section, the literature suggests that more walking occurs in higher density areas.

The term 'high density' usually suggests that people live in close quarters to one another in multifamily housing, apartment buildings, or single family houses on small lots. Low density areas, on the other hand, describe environments consisting of more single-family housing units on larger lots, or with other land uses more readily mixed in. Figure 4-3 shows visual examples of three density levels that can roughly be considered high, medium, and low suburban densities. High density is roughly defined as >6 housing units per acre, low density <3 housing units per acre, and medium density is what falls in-between (Frank et al., 2005a).

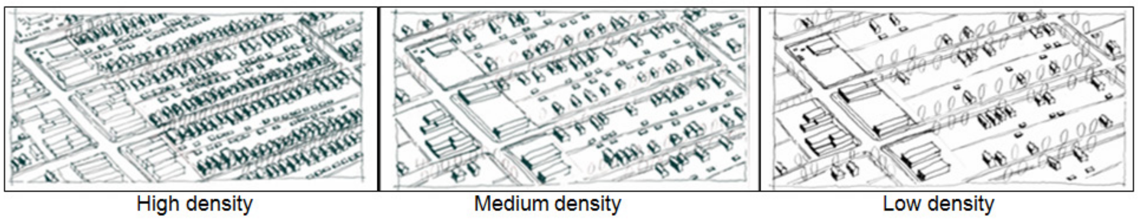


Figure 4-3 Examples of different densities in Detroit neighborhoods that are relevant in this dissertation research: high density, medium density and low density. The literature suggests that more walking occurs in higher density areas.

However, it is difficult to measure or define density appropriate to particular contexts. An insightful article by Arza Churchman (1999) suggests that density is a rather elusive construct because the physical and social contexts of cities differ, and measures of density are indicative of these physical and social characteristics. For example, a high-rise tower in Toronto next to a large park can have the same density as a low-rise suburb of Detroit, but the ways in which everyday life occurs in these settings differ greatly as a result of the disparate distribution of people. Planning practices in different cities apply the construct of density in different ways, and there is no single agreed upon definition of density.

Density can therefore be a rather abstract concept to measure, and a careful consideration of the context is necessary when density is used as a factor in research or design. Another limitation with measures of density is that they do not describe specific design characteristics. For instance, density describes as an aggregated figure how many people live in an area, but it does not describe how people access the [designed] environment. Therefore, other measures such as land use mix and street layout are necessary to supplement measures of density.

One of the widely used measures of residential density is the housing unit density per acre, usually obtained from the US census. This is the measure that will be used in this dissertation to represent density.

4.3.2. Land use mix (diversity)

Land use mix describes the degree of mix of different types of land uses within an area. The proportion of each type of land use compared to other types in the area determines the amount of mix. In their 3Ds article, Cervero and Kockelman (1997) called the degree of mix 'diversity'. This study and others show that areas that are more mix use are associated with higher walking (Cervero & Kockelman, 1997; Frank & Pivo, 1994; Frank et al., 2005a). The notion is that people have more choice of destinations in areas with higher mix, which in turn facilitates more walking. In other words, in areas that are highly mixed and where the opportunities for work, shop, and play are greater, more walking can be expected (Frank & Pivo, 1994; Handy & Clifton, 2001).

In Figure 4-4, three examples of areas with different mixes of land uses are shown. High land use mix (on the left) includes a more equal spread of different kinds of uses (commercial, institutional, educational, recreational, and residential uses). A more moderate amount of mix includes mostly residential uses with a few non-residential uses. Low land use mix areas are dominated by a single land use such as homogenous neighborhoods consisting mainly of residential units. Figure 4-5 shows the land use mix in one of the Detroit neighborhoods.

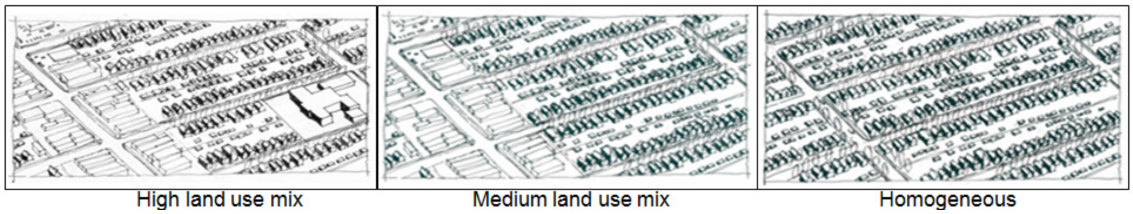


Figure 4-4 Neighborhoods with high, medium and low land use mix. Homogenous land use mix areas consist of mostly residential uses. Previous research shows that higher land use mix (left) attracts higher levels of walking.

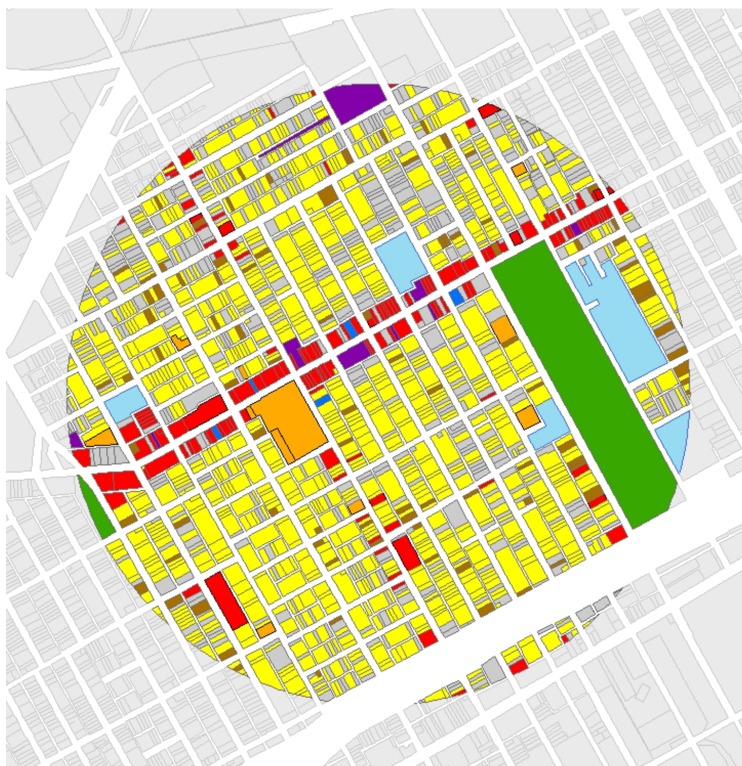


Figure 4-5 The land use composition of an area in Detroit. The proportion that each land use type occupies within a larger area is used to determine the degree of land use mix.

While land uses on a map or a city plan are clearly delineated into parcels, lots, or other designated areas, the way a person on foot experiences the city is less objective, instead depending more on the qualities associated with the mix of uses (residential, commercial, institutional, parks and recreation, etc). Both the type of land use and the combination of land use types create the unique quality of the built environment, which in turn impacts people's experiences. For example, although generalized mix has been shown to be predictive of walking, recent research has begun to show that transportation walking is more impacted by walk-friendly land uses such as shops (Audirac, 1999; Burke & Brown, 2007; Handy, 1996b; Lee & Moudon, 2006a; Lee & Moudon, 2006b, 2008; McCormack et al., 2008; Owen et al., 2007).

Since the quality of physical environments can differ greatly for areas with the same amount of mix, it is hard to describe the environment simply in terms of mix. Land use mix is sometimes more abstract than practically useful in describing the physical environment. To avoid this problem, the type of land uses need to be clearly differentiated, specified, and described before the mix can be determined.

Land use mix is found to have variously a positive, negative or no relationship to physical activity outcomes (Cerin et al., 2007; Giles-Corti et al., 2005; Lee & Moudon, 2006b, 2008). Most studies find that land use mix supports walking, but results from a study in Australia contradict this trend. In this study, Cerin et al. (2007) compared the influence of objective land use categories with that of measures of land use mix. Land use categories were created by matching census collection districts (CCD's) that had similar land use combinations. These land uses include commercial, light industrial, residential, recreational and other uses. No significant association was found between land use mix and weekly minutes of walking, although some land use types were significantly correlated with transport walking. Residents in 'Commercial/Light Industrial' areas reported an average of 39.6 more weekly minutes of transport walking than residents in 'Recreational' CCD's (Cerin et al., 2007). This suggests that land use mix needs to clearly account for contextual variations (Owen et al., 2004; Saelens et al., 2003a).

The measures of mix dominating the literature are land use mix scores and percentages of single land uses by category. Land use mix (as a score) is calculated as the degree of mix after specifying which types of land uses are used in the calculation. Other approaches include the density of single land use categories in terms of the percentage surface area. Examples include uses such as employment (Cervero & Kockelman, 1997; Wells & Yang, 2008) and commercial (Lee & Moudon, 2006b) measured in land area, floor area, or the frequency of occurrence (Frank et al., 2008; Frank et al., 2007; Saelens & Handy, 2008).

The measure of land use mix that will be applied in this dissertation is the entropy score, which has gained recognition in the planning literature since the early 1980's (see Willemain (1980), Frank and Pivo (1994), Cervero and Kockelman (1997), and Leslie et al. (2007)). The entropy score is a normalized value between 0 and 1 of the degree of land use mix: 0 being very little mix and 1 being highly mixed. This score will be described further in chapter 5, RESEARCH METHODOLOGY.

4.3.3. Street connectivity (design)

Attractive land uses in proximity to residents' homes are only accessible if local street patterns (or sidewalks along streets) connect these homes to the sites to be reached by car, bicycle or on foot. The distances between attractive land uses (or destinations) are therefore dependent on the third "D", design. Cervero and Kockelman's description of design emphasizes the street design (rectilinear grid, curvilinear streets, cul-de-sacs, and intersections), site design (proportion of available commercial and service parcels and the design of available parking), and pedestrian and cycling amenities (sidewalks, trees, streetlights; bike lanes, etc.) (1997, p. 206). Of these, street design has emerged in the research as one of the most prominent design characteristics (Frank et al., 2005a; Handy et al., 2003; Krizek, 2003; Lee & Moudon, 2006b; McNally & Ryan, 1993).

One way of understanding the directness of routes to destinations is by looking at the street connectivity. High connectivity suggests a greater continuity of space within an urban layout, making places more connected to each other (Handy & Clifton, 2001). For example, a resident's house could be in close proximity as the crow flies to a neighborhood shopping center, but if the route is interrupted by parcels of overgrown vacant land, industrial sites, or highways, the travel distance may increase exponentially due to the barriers. Consequently, sites may sometimes be inaccessible despite being in close physical proximity.

Proponents of connectivity measures argue that higher street connectivity (smaller blocks or denser street patterns) reduces travel distances and encourages walking and biking. They also point to the detrimental effects of auto-dependence on community social life in disconnected neighborhoods (Duany et al., 2001). However, the evidence from the literature is still ambiguous as to whether connectivity increases walking and biking while decreasing automobile use or whether it promotes increases in all modes of traffic (Handy, 2005). Nonetheless, street connectivity is associated with walking and is therefore relevant to this research. Generally studies associate higher street connectivity with more walking, with design being the second most predictive measure of the three D's (Frank et al., 2008). See Figure 4-6.

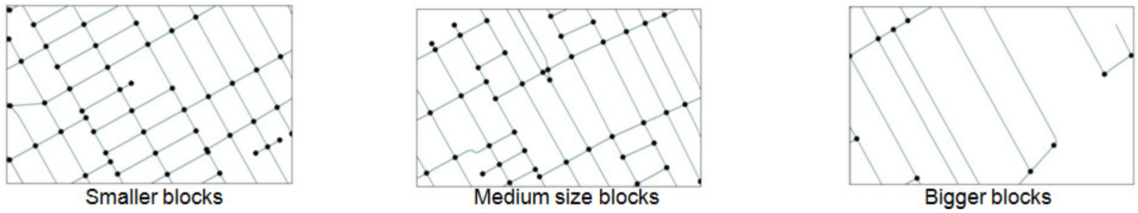


Figure 4-6 **Street connectivity for three areas with smaller blocks, medium size blocks, and bigger blocks. According to previous research, the highest levels of walking occur in areas with smaller blocks.**

Street connectivity also describes how neighborhoods are physically structured, showing that the potential of movement through areas is an important consequence of the physical design of street patterns. In the 1960s, Jane Jacobs discussed the importance of accessibility resulting from the spatial patterns of neighborhoods and cities. She explained how streets that are disconnected from the rest of the city due to large tracks of underutilized land and dead end streets are responsible for making parts of the city inaccessible (1961).

Various approaches have measured connectivity as the percentage of gridded streets in an area (Boarnet & Greenwald, 2000), intersections per square mile (Frank et al., 2005a), average block size (Krizek, 2003), number of entrance and exit links (McNally & Ryan, 1993), and the proportion of the number of streets divided by the number of intersections (Handy et al., 2003).

This last approach is one of the most commonly applied measures of street connectivity in urban planning research and practice and is used in this dissertation research. This measure of the proportion of streets versus intersections considers the spatial characteristics of movement and turns. Described by Susan Handy, the measure accounts for how street spaces are connected by considering both the street intersections and the street spaces (Handy et al., 2003). It has been suggested in a different research context that both [segments of] streets and intersections are important components of how people move through the spatial environment (Peponis et al., 2008; Peponis et al., 2007). This connectivity measure (streets divided by intersections) is perhaps one of the best in common planning practice to describe the design characteristics of street patterns.

A limitation of current measures of street connectivity needs to be mentioned. It is common for measures to be aggregated, and therefore aspects of the designed environment are hard to deduce from the measure. This aggregation limits how much can be understood of the specific street arrangements or layouts of an area with a given street connectivity. This limitation will be addressed later when research questions are proposed to compare street connectivity with other spatial measures.

These three commonly applied environmental factors of density, land use mix (diversity), and street connectivity (design) have been critical in investigating how people can achieve higher levels of physical activity through the types of neighborhoods in which they live. Some researchers, however, have a more skeptical view of what the current literature suggests. They argue that after controlling for neighborhood selection and personal characteristics, urban form (land use, density, and connectivity), only partially accounts for a reduction in vehicular use (Handy & Clifton, 2001) and an increase in overall physical activity (Forsyth et al., 2008b). However, they agree that even modest reductions in vehicular travel, coupled with increases in walking and cycling, may contribute to substantial health benefits. Also, these factors can have the added benefit of making driving or walking once again a matter of choice rather than people having to drive because it is their only option (Handy, 1996c).

Another limitation of the factors of residential density and connectivity is the assumption that a natural equilibrium exists between the density of people and the spatial connectivity, on the one hand, and services available to people on the other. This notion suggests that the higher the density and street connectivity, the higher the amount of available and accessible resources. However, a history of racial/ethnic and economic disparities in the United States across neighborhoods reveals a much more inequitable picture. Population density is not the sole factor determining what is available in the physical environment to different groups (Estabrooks et al., 2003; Moore et al., 2008). A final critique of the 3Ds points out that the interrelatedness of the three factors can be problematic for systematically understanding how the physical environment relates to walking (Handy, 2005; Lee & Moudon, 2006b).

Clearly, despite the strengths of the 3Ds, there are limitations to viewing neighborhoods exclusively through the lenses of density, diversity, and design. Another group of researchers suggests an alternative direction for investigating urban form by focusing on neighborhood access to destinations. As Moudon and Lee suggest, “carefully matching neighborhood services with population habits and needs can strengthen interventions to increase neighborhood walking” (Moudon et al., 2006c, p. 113). This can be done by considering the neighborhood destinations that are part of people’s daily activity patterns.

4.4. Destination and space syntax research as alternatives to the 3Ds

4.4.1. Research on destinations and space syntax

In response to the limitations of the 3Ds: density, land use mix, and street connectivity, two alternative approaches will be investigated in this research. These two approaches both focus on the idea of accessibility of the physical environment, but they characterize the relationship between urban form and physical activity outcomes differently. The first approach is the research in destinations and the second is the research in space syntax.

The literature in support of street connectivity is closely related to the research on destinations. Handy uses the term accessibility to describe how street connectivity and destinations operate as inseparable and mutually reinforcing factors (Handy, 1996c; Handy & Niemeier, 1997). Because accessibility has been used to variously characterize the attractiveness of destinations, the ease of reaching them (Handy, 1992; Handy & Niemeier, 1997), and the possibility for interaction at them (Hansen, 1959), the term accessibility hinges upon both social and physical factors.

This interest in accessibility has enabled the emergence of another line of inquiry that adds to Cervero & Kochelman's 3Ds thesis. To address the potential problems that result from the fairly abstract notions of land use mix and density[10], a few researchers started focusing on destinations and have developed simpler environmental measures as a result. These researchers consider the accessibility of local destinations as an effective predictor of walking. Lee and Moudon (2006b) propose the 3Ds (density, diversity, design) plus R (route distance to destinations). After conducting statistical analyses on models for an exhaustive 932 environmental variables, Lee & Moudon conclude that distance to destinations is an effective indicator of walking. Their research also suggests using simple destination measures in research instead of complicated environmental measures.

10 See Churchman (1999) for his review of the problems with describing the concept of density.

Research conducted by Susan Handy and colleagues similarly applies the concept of accessibility by characterizing the urban form in terms of destinations (Handy, 1996a, 1996b; Handy et al., 2005; Handy et al., 2003; Handy, 1992, 1996c, 2002; Handy et al., 2002; Handy & Clifton, 2001; Handy & Niemeier, 1997). They view the urban environment in terms of the choices it provides, and their studies suggest two broad hypotheses of the relationship between urban environments and activity outcomes (including walking). Their first hypothesis is that accessibility is associated with shorter average travel distances. Their second hypothesis suggests that high levels of accessibility are associated with a greater variety of destinations (Handy, 1996c). Therefore, distance, number of destinations, and the variety of activities available are all important factors to consider.

Measurements of destinations have been applied to understand both how close destinations are to homes (Handy & Clifton, 2001; Lee & Moudon, 2006b, 2008; McCormack et al., 2008; Moudon et al., 2006c), and how much choice is available—the number of destinations (Cerin et al., 2007; Handy & Clifton, 2001; Lee & Moudon, 2008; McCormack et al., 2008; Moudon et al., 2006c). Further measures look at the number of destination groups by categorizing destination bundles as different types—neighborhood clusters, neighborhood units, etc. (Lee & Moudon, 2006b, 2008; Moudon & Hess, 2000). A destination bundle is a group of destinations clustered together in close proximity to one another.

Another alternative approach to the 3Ds is the work conducted in space syntax. Space syntax theory provides a way of characterizing urban form in terms of space and suggests a different framing of accessibility from the research in destinations. This research views the urban environment in terms of the potential for movement that street spaces provide due to their location in larger networks of streets (Hillier, 1996a, 1996b) and suggests that it is the properties of space that facilitate spatial access by means of the greater potential for the copresence of people. Similar to other measures of street connectivity discussed earlier, space syntax theory proposes that streets that are more connected and integrated in the urban pattern are associated with more urban movement[11].

Although syntactical measures are similar to commonly used measures of street connectivity in that they describe characteristics of the built environment by referring to streets and intersections, they have additional benefits. Prior research has limited measures of street connectivity to the description of the *local* environment, whereas space syntax can provide a *local* and a *global* view. Space syntax research has dealt with *global* spatial patterns' prediction of pedestrian movement for quite some time (Hillier, 1996a; Hillier et al., 1993; Penn et al., 1998), but it is not until a recent study by Baran et al. (2008) that the global street network patterns were considered within the walkability and the active living literature. Syntactical measures differ from the approaches of street connectivity in their ability to describe both *local* and *global* patterns and the relationships *between* the two levels.

Space syntax research also contributes to a greater understanding of the design characteristics of streets layouts. As mentioned, the factor that comes closest to describing the layout or the design of streets in urban planning research is street connectivity. However, the aggregation of street connectivity measures limits how findings can be interpreted and applied to design solutions. Space syntax research focuses instead on the spatial properties of streets and the arrangement of street spaces

11 Space syntax theory suggests urban movement irrespective of mode of travel

within a larger area of streets. Space syntax describes the *street network characteristics* (which include *street network integration and street network connectivity)* rather than *street connectivity,* providing more detailed information about design aspects of the environment.

It is useful in design to understand the relationship of street spaces with other street spaces--in other words, the values of individual streets in a network rather than a value aggregated across an area. In addition, because street network characteristics can be described through visual means, they capture more design details of an environment than common measures of street connectivity. To the author's knowledge, no studies in the walkability literature exist that compare *street connectivity* to more advanced measures of *street network connectivity* developed using space syntax techniques. It will later be suggested that measures of street network characteristics may improve the prediction of street layouts on walking and physical activity outcomes. The measures of *street connectivity* will be compared to the space syntax measure of *street network connectivity* to determine the relative predictive strength of each of these measures on pedestrian movement, physical activity, and health outcomes.

4.4.2. Destination and space syntax research capturing place and space

As discussed in Chapter 2, it is suggested that space and place research both refer to similar environmental dimensions, but with varying emphasis. This is also the case with destination research and space syntax research. This point can be explained by referring to the model that presents three dimensions of environmental relationships: the physical environment, people's conceptions of the environment, and the actions that people take within the environment (see Figure 4-7).

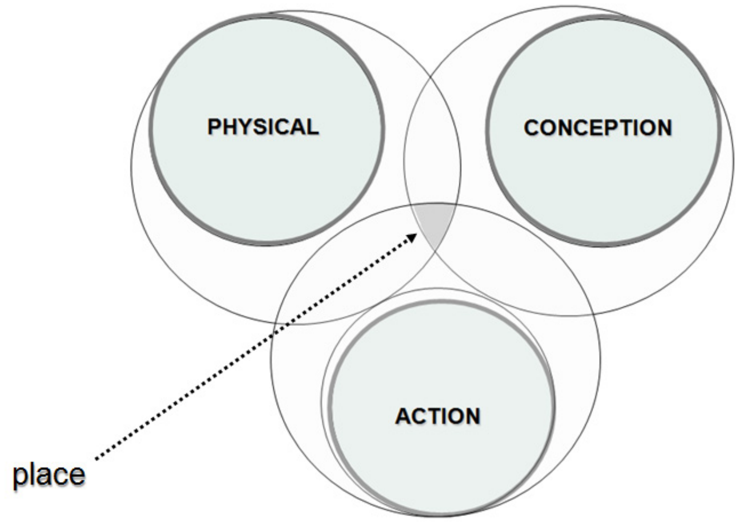


Figure 4-7 Model of environmental relationships adapted from David Canter's model of purposive place.

The overlap of the three dimensions constitute "place," suggesting that the physical environment and people's expectations of the environment are in balance to the extent that people's actions are in line with their conceptions and facilitated by the physical environment (Canter, 1988); when this happens, the urban environment is accessible.

The work of David Canter suggests that the physical dimension of *place* includes both symbolic (meaning) and spatial aspects of the environment. However, his focus in measurement is primarily on people's conceptions of the environment, which take the form of mental patterns. One of the other ways to characterize aspects of place is by looking at destinations. Research in accessibility of destinations, similar to Canter's broader definition of place, examines representations of both meaningful locations and spatial aspects, both of which describe accessibility (Canter, 1986). This is also in line with Susan Handy's definition of accessibility (1996c). Using destinations to characterize *place* is useful in measurement since aspects of space relate to accessibility of street spaces and aspects of place relate to access to meaningful locations. Research in destinations tends to emphasize the relationship between people's conceptions of their environment and their actions such as walking and physical activity.

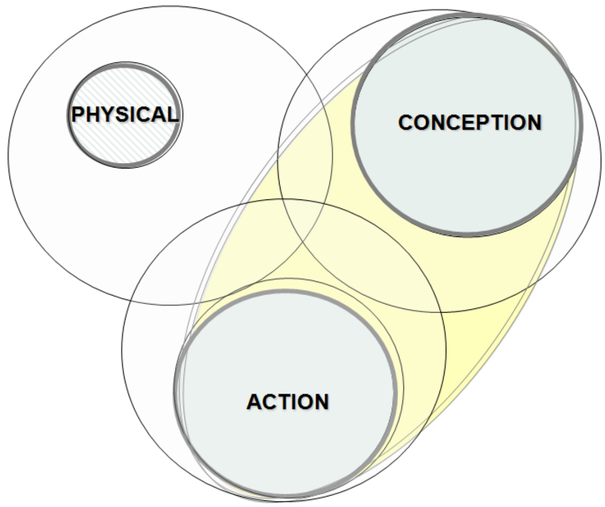


Figure 4-8 Destination research emphasizes the relationship of conceptions and actions

In chapter 2, research in space syntax is described as taking an approach more focused on objectively describing physical characteristics. Space syntax can also be associated with the model of environmental relationships, for the accessibility of space contributes to how people occupy space by making meaningful places. In contrast to Canter's approach to measuring place, the syntactical approach to measurement emphasizes the physical realm in relation to actions (in this case urban movement).

In syntactical measures, the association between the physical and the action realm is emphasized. They rely on the objective measurement of space, while inferring how these spatial descriptions align with people's conceptions of the environment.

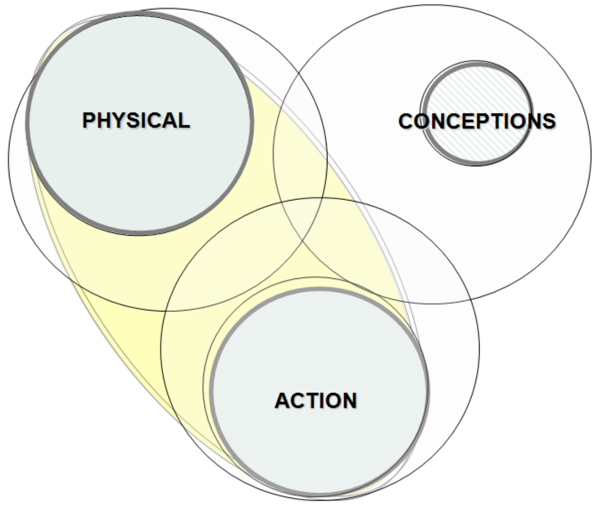


Figure 4-9 Syntactical research emphasizes the physical and action realms

In formulating the following research questions, the intent was to balance aspects of space and place. An attempt is made to represent both sets of characteristics in terms of objective measurement.

Space measures in space syntax already emphasize the objective measurement of the environment. Place measures have also been measured objectively in the past through destination measures (Lee & Moudon, 2006a; Lee & Moudon, 2006b; Moudon et al., 2006c). Additional insights needed to develop appropriate destination measures were drawn from the large body of research on how people conceive their environments in urban cognition. The belief is that developing both spatial and place-related aspects into objective measures presents a more accurate description of the accessibility of environments.

The overarching question guiding this dissertation research is: which neighborhood physical patterns influence neighborhood accessibility? The walkability literature has helped lay the groundwork for the proposed destination measures as they pertain to the physical arrangement of the environment. The research questions developed for this dissertation test the impact of these measures on pedestrian movement and physical activity and also compare their effect against that of traditional urban planning and space syntax measures.

4.5. Destination measures

The destination factors reviewed include (1) *proximity*, (2) *number of*, and (3) *clustering* of neighborhood destinations. The following research question investigates the effects of destinations on selected outcomes:

Research Question 1: *To what extent do destination measures have an association with pedestrian movement and physical activity?*

4.5.1. Proximity

The most widely-used factor in accessibility research is the proximity of destinations to residents' homes. People tend to walk more when they live in proximity to destinations. (Burke & Brown, 2007; Cerin et al., 2007; Handy & Clifton, 2001; King et al., 2003; Lee & Moudon, 2006a; Lee & Moudon, 2006b; McCormack et al., 2008; Miles et al., 2008; Moudon et al., 2006c).

Studies that developed this factor have different definitions of what constitutes a "walkable distance": 90m, ¼ mile, ½ mile, or 1km (Frank et al., 2004; Frank et al., 2005a; Hoehner et al., 2005; Moudon et al., 2006c). Larger buffers (areas within a circle of a specified radius) such as 3km are also associated with certain uses (Lee & Moudon, 2006b). These measures are often examined at both airline and network distances (Frank et al., 2004; Lee & Moudon, 2006b) (Figure 4-10).

Figure 4-10 Distance to the closest destination (example at the airline distance)

Other studies show that the distance people walk to destinations depends on the type of destination, with different distances corresponding to: shops, schools, grocery stores, parks, churches, etcetera (McCormack et al., 2008; Moudon et al., 2006c). Earlier findings by Ittelson (1960), Lee (1970b), Canter & Tagg (1975b), and Nasar et al. (1985) had already demonstrated this idea that heightened desire for destinations makes distances seem nearer. Moudon et al. (2006c) measured people's perceived threshold distances to different types of destinations and found that people consider the physical/psychological cost-benefit ratio and are willing to walk longer distances to more desirable locations. Other studies have found similar results with regards to parks (Giles-Corti et al., 2005), commercial uses (Handy, 1996b; Moudon et al., 2007), schools (Cerin et al., 2007), and offices (Berke et al., 2007; Cerin et al., 2007), all of which corroborate the earlier studies.

However, findings pertaining to a few destination types show different results. Lee et al. studied a sample of urban areas in the Puget Sound, and contrary to most research, found that parks and recreational areas did not show a significant correlation with walking (Lee & Moudon, 2006a). They also found that large housing complexes, office developments, and educational uses discouraged walking and cycling (Lee & Moudon, 2006b, 2008). Similar results were found by Forsyth et al. (2008b), McCormack et al. (2008), and Cerin (2007). Other studies have considered these discrepancies and suggest that factors such as size, quality, and attractiveness of destinations play a role in attracting walkers (Giles-Corti et al., 2005; Moore et al., 2008). Susan Handy uses both quantitative and qualitative evidence from six neighborhoods in Austin, TX to indicate that people will bypass the closest store for a more distant one for its quality, choice, price, or size benefits; the greater distance being one of the main reasons why people decide to drive instead of walk (Handy & Clifton, 2001).

An important aspect to consider when investigating distances to destinations is that people are more likely to walk to transportation destinations such as grocery stores and workplaces. Recreational destinations often require effort above and beyond people's daily schedules (McCormack et al., 2008), and are therefore likely to benefit only the most active sectors of the population (Burke & Brown, 2007; Lee & Moudon, 2008; Moudon et al., 2006c; Sallis et al., 2004).

Earlier in this chapter, the notion of 'place' was described as being dependent upon people's particular needs and preferences which make locations meaningful. Even though previous studies provide some evidence about which destinations are more likely to contribute to meaning within a community, it is also important that the researcher become aware of residents' specific local conceptions of 'place'.

Hypothesis: When destinations are in closer proximity to people's homes, people are more likely to walk to places and therefore be more physically active.

4.5.2. Number of destinations

A few studies have explored the impact of the number of destinations near a resident's home. The number of destinations in a radius area around homes captures the extent to which residents have choices of public resources available to them within their immediate neighborhood (Figure 4-11).

In the Puget Sound study, vigorous physical activity was significantly higher in areas with a higher number of parks or two or more physical activity destinations such as schools or sports facilities (Lee & Moudon, 2008). Using objective pedometer readings and survey questions, King et al. (2003) found a positive relationship between the sum of destinations within walking distance from home and activity levels for older women. In an Australian study, the number of transportation destinations predicted transport walking and the total count of transportation and recreational destinations increased the odds of walking for regular and irregular transport walkers (McCormack et al., 2008). Surprisingly, people often perceive a lower number of destinations than what is objectively available. Moudon et al. (2006c) reported that walkers who reported no grocery stores in their neighborhood actually had an average of 2.46 grocery stores in a 1km radius of their home.

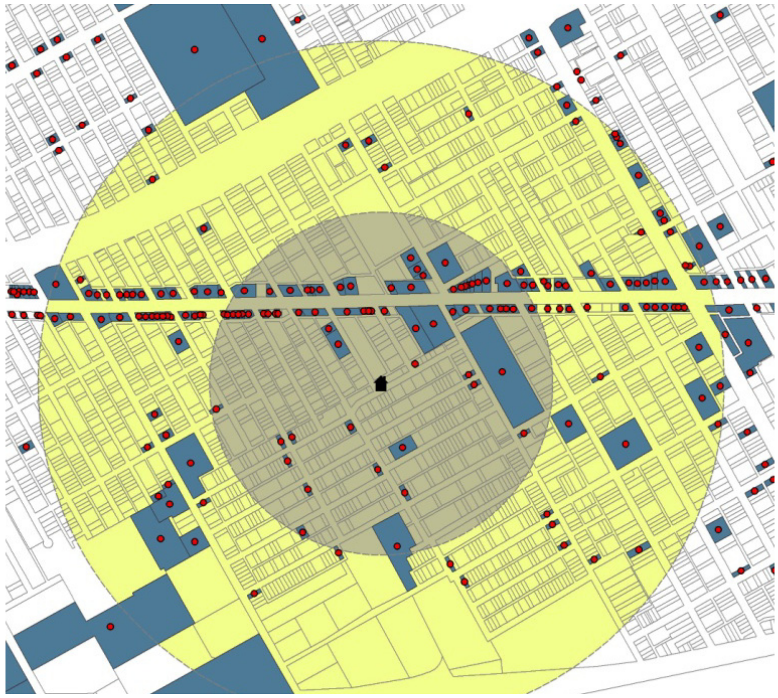


Figure 4-11 Number of destinations located within ½ mile and ¼ mile radius area

Distance also seems to be a factor when considering the number of destinations. As mentioned regarding proximity to destinations, people seem to be less aware of their available destination choices if the destinations are located further away from where they live. Cerin (2007) observed that the perceived number of destinations within a 5-minute walk distance increased participants' overall weekly minutes of walking, but perceived number of destinations between 6-10 minutes away did not.

People are less likely to consider destinations that are not relevant to their needs and tastes. More destinations in close range of people's home turf increases the odds that residents may find destinations close-by that are to their liking. Higher numbers of destinations also increase the chances of these destinations being noticed (Moudon et al., 2006c). The following hypothesis can be formulated:

Hypothesis: Higher number of destinations in an area gives people more choices of places to go, resulting in an increase in walking and physical activity.

4.5.3. Clustering of Destinations

By clustering destinations, residents are more likely to find a sufficient variety of destinations in close proximity, meeting a variety of tastes and interests (Handy & Clifton, 2001; Moudon & Hess, 2000) (Figure 4-12). Canter suggests that 'places' are conceived as units of experience which can take on a variety of scales: from a shop or a public space to a shopping center or even an entire street (1977). Therefore, the proximate arrangement of destinations in an area may have cognitive significance for residents and help create a memorable neighborhood place.

Research in urban cognition suggests that clustering destinations attracts people in a general direction due to the prominent role these places play within an urban setting. A study by Lee et al. (1970b) shows that student participants underestimate the distance to destinations in the direction of downtown and overestimate the distance of journeys outward. He proposes that the underestimation toward downtown is brought about by its desirability. Canter and Tagg (1975b) later suggest that the attraction that Lee attributed to downtowns instead applies to a series of smaller memorable places in the city that are spatially linked. In other words, the clustering of destinations in places such as a downtown is conceived as a coherent mental pattern that exerts an attraction.

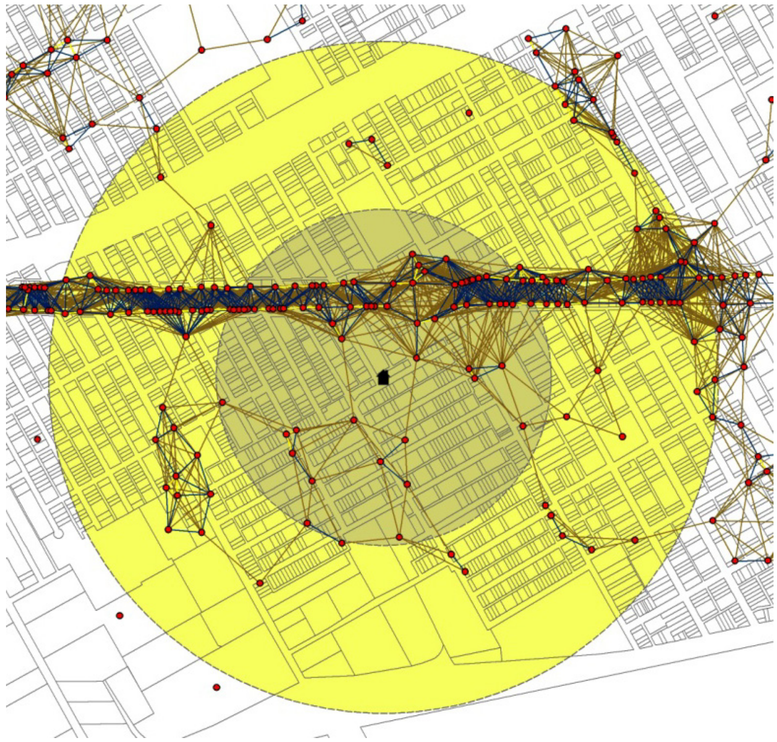


Figure 4-12 Degree of clustering of destinations within ½ mile and ¼ mile radius area

To further explain this attraction of clustering, De Jonge (1962) can provide some insight. He suggests that people have a tendency to economize environmental information by grouping similar environmental aspects together. In human cognition, this simplification occurs for both geometry and distance. For example, spherical street layouts become circles, streets with slight bends and shifts become straight lines, sharp corners are perceived as right angles, and adjacent places are perceived as belonging together (Canter & Tagg, 1975b). Drawing on Gestalt laws, De Jonge (1962) suggests that in people's minds, the relationships that exist between elements are more important than the elements themselves. Multiple destinations located close to each other are economized in that people perceive them as a single coherent place. The phenomena of simplification and distance mis-estimation both show why people [mentally] cluster destinations.

A series of publications in the walking literature also suggest that the clustering of destinations attracts more walking than spatially isolated destinations (Lee & Moudon, 2006b, 2008; Moudon & Hess, 2000). In the Seattle area, neighborhood clusters (NC's) show stronger relationships with walking than do individual destinations. After adjusting for personal characteristics, grocery store + restaurant + retail clusters and school + church clusters both showed a significant positive relationship to walking (Lee & Moudon, 2006b) (Figure 4-13).

Figure 4-13 Number of destination bundles within ½ mile and ¼ mile radius areas

Destination clusters attract people toward a few selected uses of their choice while also exposing them to other unexpected destination opportunities en route, contributing to multi-purpose neighborhood trips. An additional benefit of the clustering of destinations is that it concentrates pedestrian movement in a general direction, minimizing the perceived distance to places while maximizing the opportunities for social interaction.

Another way of considering the impact of destination clustering is to consider the number of destination bundles in an area around people's homes (see Figure 4-13). Bundles are destinations that are grouped together. Instead of looking only at the number of single destinations, the number of bundles can also be considered. An area with a high clustering of destinations can have either all the destinations grouped in one area such as a downtown, or smaller neighborhood bundles arranged throughout an area such as neighborhood shopping area. This idea builds on the distinction that Canter and Tagg made between the attraction to a downtown (from Lee (1970b)) and a series of individual places that in people's minds are linked in a network of places (Canter & Tagg, 1975b).

This review suggests that the clustering of destinations can make a significant positive difference in the amount of walking within neighborhoods. New exploratory measures of the clustering of destinations are used in response to the following hypothesis since no previous attempt has been made to measure clustering in this area of research:

Hypothesis: Destinations clustered together are likely to attract people, resulting in higher levels of physical activity and pedestrian movement.

4.6. Space syntax measures

Spatial factors commonly described in space syntax research will be reviewed in this section. These factors include (4.1) *connectivity*, (4.2) *integration*, and (5) *metric reach*, the first two of which have been widely applied as syntactical measures and the third of which is a more recent syntactical measure. The idea of (6) *destination reach* will also be proposed, measured, and tested during this dissertation. The following research question investigates the effects of spatial characteristics in comparison to the effects of destination characteristics on selected outcomes:

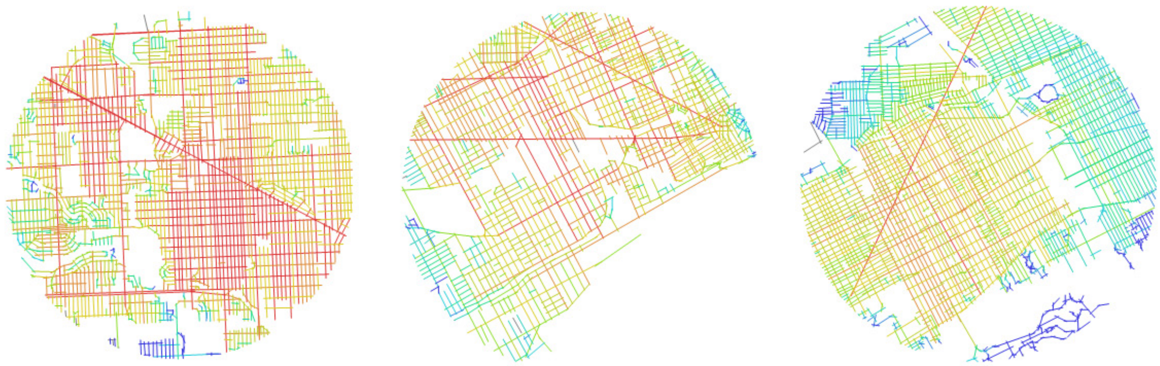
Research Question 2: *What are the relative contributions of destination measures and space syntax measures to pedestrian movement and physical activity?*

4.6.1. Street network characteristics: connectivity and integration

Street network characteristics describe environments in relational terms: any given street is spatially connected to other streets within a given area. A useful graph-based technique to measure the formal properties of street networks is the "axial map", described by Hillier & Hanson in *The Social Logic of Space* (1984). Axial maps describe the built environment by the degree of connectedness and separation that spaces have to one another. To develop a quantitative measurement of space, street layouts are first converted into line diagrams to represent the visual extent of each street space. Lines are extended to the length of the longest sight-line in a street space without having to bend around a corner. The line diagrams can be thought of as extending a visual connection down a street so that two people standing on opposite ends should be able to see each other. A notable contribution by space syntax research is the notion that urban movement is affected by not only the local spatial properties, but also the global spatial properties: how a local space is integrated into a larger system of spaces at the macro-neighborhood, city, or metropolitan scale. The Syntax group has developed measures at both local and global levels.

Two of the most commonly used and predictive measures in the literature are the local measure of *street network connectivity* and the global measure of *street network integration*. Street network connectivity describes how street spaces are locally connected to adjacent street spaces. Street network integration (see Figure 4-14 and

Figure 4-15), on the other hand, is a measure describing how integrated a street is in terms of the global street structure. For a thorough description of these and other space syntax tools please refer to Bafna (2003).



Northwest Detroit | Southwest Detroit | Detroit Eastside

Figure 4-14 Street network integration for three mile radius areas: red indicates the highly integrated streets and blue the least integrated

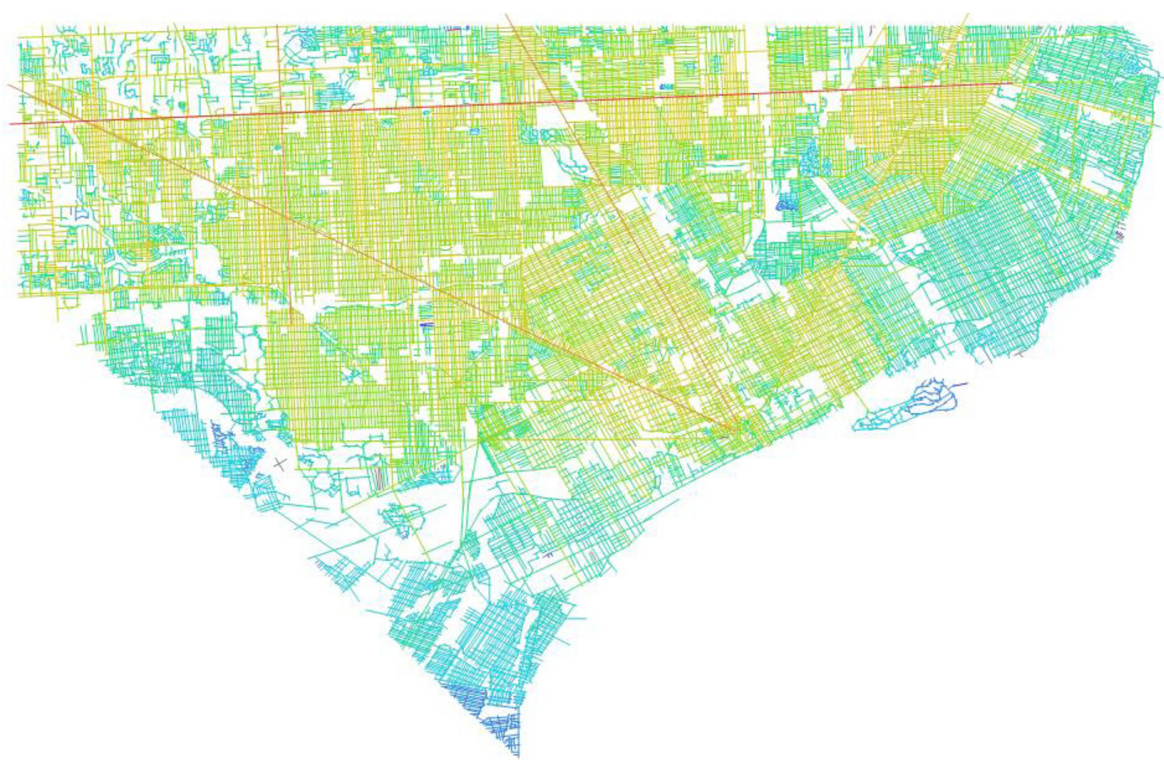


Figure 4-15 Street network integration for the city of Detroit: red shows the most highly integrated streets and blue the least integrated

As mentioned above, *street network connectivity* is a measure of the number of streets (or spaces) that are directly connected to a given street (or space). The main contribution of space syntax techniques, however, is in describing the global properties of space. *Street network integration* describes how integrated a space is relative to all other spaces in a system. In other words, it shows how a pedestrian located on one street (or space) is affected by how his location relates to all other streets in a system of streets (neighborhood, district, or city). Since this measure captures the relational purpose of a street within a large system of streets, it has a large descriptive advantage over other spatial measures.

Most of the space syntax literature exploring the relationship of street network measures and street activity includes both pedestrian and vehicular movement (Hillier, 1996a; Hillier & Hanson, 1984; Hillier et al., 1993; Penn et al., 1998). The studies generally find that high integration is associated with higher movement of both pedestrians and vehicles. This does not imply that people in these areas are necessarily more physically active, but rather that there is more movement in these areas.

Two studies in the United States investigated syntactical spatial properties and pedestrian movement in particular. Baran et al. (2008) used travel diaries of respondents in a conventional suburban community and a New Urbanist community in North Carolina to study the association between three syntactical measures and walking. They found a significant positive relationship between the measure of global integration and transportation and leisure walking, independent of the type of neighborhood that people lived in. Similarly, Peponis et al. found higher pedestrian movement for highly integrated streets in the city of Atlanta, and he also reported a higher range in the distance traveled by pedestrians on integrated streets.

Recently, researchers in space syntax have made advances in the description of environments more typical of American cities. Characteristics such as lower-density suburban environments and the uneven distribution of land uses and populations more characteristic of US cities have been addressed (Peponis et al., 2008; Peponis et al., 2007; Peponis et al., 2006; Stahle et al., 2006). This dissertation proposes that the use of space syntax measures may uncover more detailed information about the street design of the Detroit neighborhoods (locally and globally) and how they [spatially] fit into the larger context of the city.

Hypothesis: Pedestrian movement and physical activity are higher for streets that are locally well connected to each other.

Hypothesis: Pedestrian movement and physical activity increase for streets that are more integrated into the street network of the rest of the city.

4.6.2. Metric reach

Recent syntactical measures of local street connectivity developed by Peponis et al. (2008; 2007; 2006) help to explicate the interplay between the metric (distance-related) and the topological (relational) properties of street networks. Peponis et al. proposed two measures called *metric reach* and *directional distance*, but only *metric reach* is utilized in this dissertation. *Metric reach* measures how much street distance can be covered when walking a specific distance from a single location in all possible directions (Figure 4-16). The greater the distance, the greater the chances of reaching new places along the way (Peponis et al., 2006).

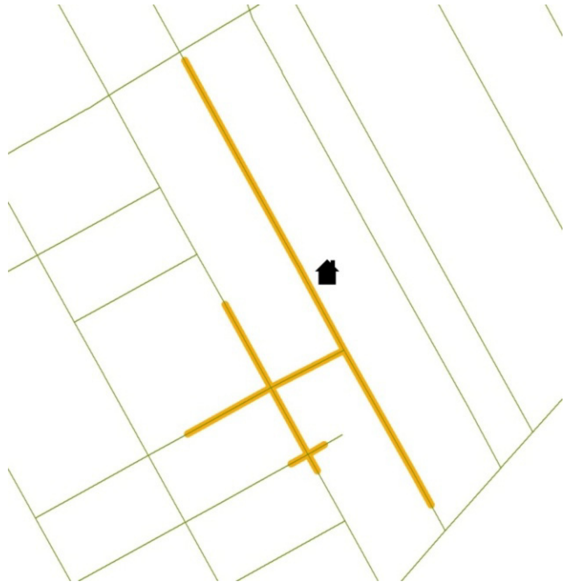


Figure 4-16 ***Metric reach*** **from the center point of a street**

An advantage of reach measures over street network connectivity is that they include information about metric distance. They can also distinguish between specific locations on the same street because they are based on maximum travel distance from a specific origin, whereas the standard street network connectivity measure considers the entire street to have the same connectivity value. Preliminary results using field observations show that these spatial reach measures show slightly better prediction to movement than standard space syntax measures of connectivity (Peponis et al., 2008).

Hypothesis: A higher footprint of local street space contributes to higher pedestrian movement and physical activity.

4.6.3. Destination reach

Destination reach is a measure developed for this dissertation that attempts to combine the configurational characteristics of street spaces with the distance to destinations. Peponis et al. (2007) suggest that different cities may have different profiles in how the interaction between street network density and other density factors play out. Developing a measure that also accounts for the destinations within a spatial framework is one way of addressing the fact that within low-density cities, a tight network of streets may not necessarily correlate with the concentration of land uses. In these cases, it is expected that a higher concentration of street networks and destinations will significantly contribute to urban movement.

Peponis et al. (2008) reviewed literature in urban cognition and cognitive neuroscience dealing with the role of directional turns on navigational effort. They cite how turns: increase the amount of time necessary to complete a total path length (Crowe et al., 2000), increase the estimation of path length (Sadalla & Staplin, 1980), and add configurational complexity which hinders wayfinding (Moeser, 1988; O'Neill, 1991). These studies show evidence that suggests that there is a concentration of cognitive information at street intersections because they provide more directional choices and reveal more urban information in multiple directions. Other studies such as Canter & Tagg (1975b) indicate that other prominent features in the urban environment such as rivers, rails, and general topographic and geographic features also add to the cognitive load on memory and can result in distance being overestimated. One can assume that a significant destination on a path provokes information loading similar to a significant environmental feature.

The destination reach measure combines characteristics of the space syntax metric reach measure while also including information about the destination environment. The distance from a single location on a grid up to a threshold distance is calculated in all directions unless a destination en route is reached first, in which case the distance in this direction terminates (Figure 4-17).

Figure 4-17 Destination reach

Hypothesis: A tight network of streets and closely located destinations in all directions around a home contribute to higher pedestrian movement and physical activity.

4.7. Urban planning measures

The previous two sections reviewed destination factors and spatial factors. These factors were reviewed as alternative—and potentially more useful—concepts for considering the links between the built environment and walking and/or physical activity. The following research question refers back to the common factors in urban planning research discussed earlier in Section 4.3 as the 3Ds: density, land use mix, and street connectivity. This research question seeks to compare these measures with the environmental measures applied in the alternative approaches. The intent of this research question is not to downplay the urban planning measures of density, land use mix (diversity), and street connectivity (design) but rather to supplement them with more nuanced descriptions of the environment.

Research Question 3: *Are destination measures and space syntax measures more predictive of pedestrian movement and physical activity than commonly used urban planning built environment measures?*

Three hypotheses emerged from the literature discussed earlier in section 4.3.

Density hypothesis: Higher density facilitates more walking and as a result, higher levels of physical activity.

Land use mix hypothesis: Higher land use mix is associated with more walking and physical activity.

Street connectivity hypothesis: More connected streets encourage more walking and physical activity.

4.8. Neighborhood perceptions of the physical and psychosocial environments

Figure 4-1 presented in the beginning of this chapter shows that psychosocial factors are also a major factor in influencing neighborhood physical activity such as walking. The following research question tests the mediating role of one psychosocial factor, that of neighborhood perceptions:

Research Question 4: *Do perceptions of the psychosocial environment mediate the associations between the built environment and physical activity?*

As described earlier, Anne Buttimer pointed out as early as 1972 that the sociological dimension is often missing from environment and activity research (see Chapter 2 and Chapter 3). Almost forty years later, there is once again mounting criticism that research in built environment and physical activity neglects critical social dimensions that affect neighborhood behavior. McDonald suggests that this may be because transportation researchers view the environment mostly as a physical entity (McDonald, 2007, p. 54). In addition, time and financial constraints often put pressure on the planning and design processes; the resources are rarely available to fully assess issues that impact people's lives or to fully involve the appropriate community stakeholders. Yet, an ongoing commitment to the understanding of how environmental characteristics facilitate or hinder neighborhood social processes seems crucial.

A reassuring trend in the research on spatial behavior is that researchers do at times return to social issues in order to understand the links between people and their environments. A few recent studies have included social factors in their analyses of the built environment, mostly from an Australian contingent of researchers. Prominent social dimensions thought to have associations with physical activity are safety (Carver et al., 2005; Carver et al., 2008; Cervero & Duncan, 2003; Timperio et al., 2004), socializing (Handy et al., 2005), trust, and sense of cohesion (Carver et al., 2008).

The psychosocial dimension in environmental research most often focuses on perceptions of the physical environment itself. These perceptions have been the main focus in walkability research and include people's attitudes toward the aesthetics, accessibility, and convenience associated with environmental features. Because this dimension is so integral to how people relate to the environment, it helps to explain why people respond to settings in certain ways. Research in this area often suggests that perceptions of the physical environment mediate the relationship between the built environment and physical activity (Booth et al., 2000; Brown et al., 2007; Ewing et al., 2006; Humpel et al., 2004; Humpel et al., 2004a).

Another important direction was investigated by Kim and Kaplan (2004). In a comparative study of a New Urbanist and a traditional suburban community, they conducted a structured survey, asking people to rate important physical features of their neighborhoods in terms of four domains of 'sense of community'—their feelings of attachment, their decision to walk, interaction with other residents, and the distinctive character or identity of the communities. One of the contributions of their study is a proposed framework of four dimensions of sense of community: pedestrianism, community attachment, community identity, and social interaction. They suggest that two of the components of sense of community refer to the dimension of the physical environment: pedestrianism and community identity, whereas the other two components refer to dimensions of the psychosocial environment: community attachment[12] refers to individual meanings and social interactions[13] refer to community activities.

Findings from Kim and Kaplan's (2004) study show that respondents in both the New Urbanist neighborhood and the traditional suburban community rate the psychosocial dimensions of sense of community (community attachment and social interaction) as important. The two components of sense of community that relate to the physical

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12 Community attachment includes the dimensions of (a) community satisfaction, (b) sense of connectedness, (c) sense of ownership, and (d) long-term integration.
13 Social interaction includes the dimensions of (a) neighboring, (b) casual social encounters, (c) community participation, and (d) social support. For a complete review of the literature, see Kim and Kaplan (2004).

environment (pedestrianism and community identity), on the other hand, received the highest rating in the New Urbanist community only after accounting for people “selecting” themselves into the neighborhood. Kim and Kaplan suggest that people may choose to live in a neighborhood where they anticipate having a strong sense of community (eg. the New Urbanist neighborhood), but a rich physical setting and plenty of pedestrian amenities are also necessary for this high sense of community to occur. Therefore, they suggest that the built environment contributes to sense of community.

Thirty years ago, Ahlbrandt and Cunningham (1979) suggested that *sense of community* was integral to people’s sense of satisfaction with their neighborhoods and its social relations. *‘Sense of community‘* and other psychosocial constructs were then developed into measures by people like McMillan and Chavis (1986). Some recent studies in the walkability literature have begun to include neighborhood psychosocial perceptions such as social support and trust in neighbors as mediating variables and independent variables (Addy et al., 2004; Giles-Corti & Donovan, 2003).

Much current research examining psychosocial perceptions as independent measures has focused on perceptions of safety in the neighborhood and physical activity outcomes for adolescents and/or children (Carver et al., 2005; Gómez et al., 2004; Molnar et al., 2004; Timperio et al., 2004). The following two studies are exceptions in that they focus on the physical activity outcomes of adults. Cervero and Duncan (2003) used the percentage low income as a proxy for neighborhood quality and safety in San Francisco; they found no relationship between safety and walking. Another study in Austin and Northern California included both measures of safety (“quiet neighborhood”, “low crime rate”, etc.) and socializing (“lots of interaction among neighbors”). The researchers found that neighborhoods that were perceived to be safer with more socializing have more strolling trips by residents (Handy et al., 2005).

As explained above, some previous research has focused on whether perceptions of the *physical* environment mediate the relationship between the built environment and physical activity (Booth et al., 2000; Brown et al., 2007; Ewing et al., 2006; Humpel et al., 2004; Humpel et al., 2004a). Other realms of research focus on *psychosocial* perceptions of the environment as independent measures (see Cervero and Duncan ((2003) and Handy et al., (2005)). However, with the exception of the study by Addy et al. (2004), limited research has been done in the fields of walkability and the built environment on whether perceptions of the *psychosocial* environment (such as sense of community, sense of safety, neighborhood satisfaction, etc.) play a mediating role between the built environment and physical activity. This fourth research question aims to contribute to the knowledge base in this area.

Hypothesis: Neighborhood psychosocial perceptions mediate the relationships between the built environment and physical activity.

4.9. Pedestrian movement and physical activity measures

The last section in this chapter reviews how the outcomes of this research—neighborhood pedestrian movement, physical activity, and waist circumference— are conceptualized and measured.

4.9.1. Difference between pedestrian movement and physical activity

In recent years, a body of evidence has associated specific factors of the built environment with people's activities such as walking or cycling (Frank et al., 2004; Frank et al., 2005a; Giles-Corti & Donovan, 2003; Lee & Moudon, 2006a). These specific forms of physical activity have received a great deal of attention due to the role that they may play in increasing overall physical activity in neighborhoods. In addition, researchers successfully isolated discrete environmental measures such as residential density, land use, or street connectivity as main predictors of walking (Frank et al., 2008).

These studies often assume that walking is the main form of physical activity. This notion is supported by respondent reports that suggest that walking is the most common type of physical activity (Ball et al., 2001; Booth et al., 2000; Giles-Corti & Donovan, 2003; Troped et al., 2001). The common assumption, widely embraced by proponents of New Urbanism, is that environmental characteristics that support more walking also support higher levels of physical activity. Other studies show that most walking occurs in neighborhood streets close to residents' homes (Brownson et al., 2001) and 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). Most of the literature, therefore, uses walking or pedestrian movement as the outcome measure.

However, complex relationships exist between the built environment and resident physical activity, especially for population subgroups. Frank et al.'s (2008) study of 13,065 participants in Metropolitan Atlanta found consistently higher associations with walking for all population groups living in more walkable neighborhoods, but did not find a relationship between the built environment and rates of obesity or being overweight. Different subgroups also seem to have different relationships to their neighborhood environments with regard to physical activity outcomes. In men, highly walkable neighborhoods were associated with lower self-reported body mass indexes, but in women and non-whites, walkability was associated with higher self-reported body mass indexes. Frank et al. suggest that these findings may be due to crime and other social factors in some of the neighborhoods in Atlanta.

Improvement in measurement and advances in the understanding of the relationships between physical environments and forms of physical activity have started to reveal a picture that is more complex than originally assumed. For example, Forsyth et al. (2008b) propose that increases in self-reported walking for certain purposes do not imply increases in *overall* physical activity for 715 participants in the Twin Cities in Minnesota. A closer reading of the sources mentioned above suggests that Forsyth et al.'s critique needs serious consideration. For example, even though Giles-Corti et al. (2003) suggest that walking is a popular form of physical activity (72.1% of respondents had walked for transport, and 68.5% for leisure), only 17.2% of their sample met the recommended levels of walking (180 minutes or more per week). In Troped et al. (2001), 86.1% of respondents reported walking as the most important physical activity. Although 62% of respondents reported doing recreational physical activity, they engaged in these activities for less than 45 minutes per week on average (p. 195).

These findings and others may be disconcerting for advocates in the field of public health, epidemiology, and urban planning. Some are starting to question whether identifying the pathways in which the built environment affects *overall physical activity* can be more helpful in public health outcomes, or whether the recommended levels of physical activity are even attainable through the design of neighborhoods. The research supports these recent concerns that the impact of the physical environment on overall physical activity outcomes may have been overestimated (Diez Roux, 2004; Forsyth et al., 2008a; Oakes, 2004).

Results from studies that investigate overall physical activity seem equivocal about the link between the physical environment and overall physical activity. Rodriguez et al. (2006) compared residents from a conventional suburb and a New Urbanist development and found no significant difference in reported levels of physical activity, despite the fact that residents in the New Urbanist development were more likely to engage in transport walking. Rutt and Coleman (2005) found no association between the built environment and physical activity (as measured by self-reported body mass index) in a sample of Hispanic respondents, with the exception of their most vigorous physical activity category, which was related to the built environment. Two articles by Forsyth et al. used self-reported measures of overall walking and physical activity and found that walking for specific purposes (transportation and recreational) is associated with environmental characteristics as previous studies suggest. However, both articles report that there is no or very weak evidence that environmental measures affect *overall physical activity* for a sample of 715 residents in the Twin Cities Minnesota area (Forsyth et al., 2008a; Forsyth et al., 2007).

A recent direction in the research that attempts to bridge the gap between the concepts of walking and physical activity suggests that the use of objective measures, rather than self-reported measures, may better reflect the extent to which the environment contributes to both outcomes (Forsyth et al., 2008a; Frank et al., 2005a; Rundle et al., 2007). Even though studies increasingly rely on such objectively measured data, they often still use walking, cycling, and physical activity somewhat interchangeably, making the distinction between physical activity and pedestrian movement (or other specific forms of physical activity) fuzzy at best.

A few of the most prominent studies that objectively measure the built environment includes Hoehner et al. (2005), Lee and Moudon (2006a), McGinn et al. (2007a) and Frank et al (2008; 2007; 2005a). After surveying 1,068 respondents in St. Louis, MO and Savannah, GA, Hoehner et al. (2005) found an association between objective built environment characteristics and self-reported transportation and recreational walking. However, they did not report on overall physical activity. Similarly, Lee and Moudon (2006a) show several objective Geographic Information System (GIS) environmental measures (residential density, destinations, sidewalks) to be associated with either transportation walking, recreation walking, or both, but overall physical activity was not measured. McGinn et al. (2007a) use both objective and perceived measures of the environment and found independent associations with "physical activity", measured as recreational and transportation walking.

A few studies have included objective measurements of physical activity. King et al. (2003) found that the perceived environment had strong associations with pedometer readings of older women. Forsyth et al. (2008b), however, point out that the results in a second study by King et al. (2005) were significantly more modest than those originally presented in King et al. (2003). According to a GIS-based walkability index, Frank et al. demonstrate that people living in the most highly walkable environment are 2.4 times more likely to meet the recommended >30 minutes of moderate physical activity per day than people living in the lowest walkability quartile. These physical activity measures were obtained using 2-day accelerometer readings (Frank et al., 2005a). The findings from these above studies using objective measures of physical activity have found some associations between physical activity and the built environment.

It is becoming more apparent that increases in walking facilitated by pedestrian-friendly environments do not necessarily translate into higher levels of *overall* physical activity. The literature in public health, epidemiology, and urban planning is now revisiting some of the assumptions previously made in the literature about the direct links between the built environment and physical activity outcomes.

4.9.2. Waist circumference as a measure of physical activity

A study by Li et al. (2009) targeted more specific pathways that may affect objectively measured physical activity and weight gain. This study used a 1-year follow-up survey of 1,145 adults between the ages of 50 and 75 in Portland, Oregon and found that residents living near a high concentration of fast-food outlets experienced weight gain and greater waist circumferences. Another finding indicated that residents in neighborhoods with high walkability had a decrease in weight and waist circumferences. This study suggests that access to certain types of destinations, such as fast-food restaurants, may in fact counteract weight loss associated with physical activity.

Li et al.'s (2009) study helps to set a precedent for using objectively measured waist circumference as an indicator of physical activity. Earlier studies by Rutt and Coleman (2005) and Frank et al. (2004) used self-reported body mass index as a physical activity outcome. Both of these measures are generally considered health outcomes, but they are also related to physical activity. Along with other factors such as dietary intake and genetics, physical activity is an important contributing factor to waist circumference. One can therefore say that waist circumference is one outcome measure that fits within the broadly-defined category of physical activity. Similar to Li et al., this dissertation research utilizes waist circumference in this way, looking at both overall physical activity and waist circumference as two physical activity outcome measures.

4.9.3. Observed pedestrian movement capturing community-level physical activity

One main limitation of previous research is that physical activity is conceptualized in different ways, causing findings related to physical activity to appear inconsistent and contradictory. It has been proposed that physical activity related outcomes are affected by individual, interpersonal, and community level domains (Baker et al., 2000). In order to capture the best picture of physical activity, a range of strategies is needed.

Baker et al. (2000) suggest that a great deal is known about the individual characteristics (attitudes, knowledge, skills, and behaviors) and individual health behaviors that affect physical activity outcomes. Research focusing on the health outcomes of individuals has applied a variety of measurement strategies. Some studies have asked respondents to give self-reports on their walking, biking, and other physical activity behaviors (Booth et al., 2000; Cerin et al., 2007; Forsyth et al., 2008b; Giles-Corti et al., 2006; Lee & Moudon, 2006a; Moudon et al., 2006c; Owen et al., 2007; Voorhees & Rohm Young, 2003), or to report their perceptions about individual, social, and physical barriers to physical activity (Addy et al., 2004; Boslaugh et al., 2006; Hoehner et al., 2005; Humpel et al., 2004a; Librett et al., 2007; McGinn et al., 2007a; Miles et al., 2008; Nasar, 2008; Sallis et al., 1997). Other researchers have investigated individual-level physical activity through objective measures of accelerometer readings (Frank et al., 2005a), body mass index (Rundle et al., 2007), and waist circumference (Li et al., 2009). Research in this individual domain links physical activity outcomes to specific respondents, allowing variations in outcomes to be associated with specific individual-level variations in health behaviors, attitudes, and/or environmental conditions (Baker et al., 2000).

However, Baker et al. (2000) suggest that less is known about the contributors to physical activity at the other levels of their proposed ecological framework: the interpersonal and community domains. Approaches in these areas have been primarily environmental and sociopolitical strategies attempting to enhance community-level health outcomes. At the interpersonal and community-levels, the focus is on benefiting all people exposed to the environment rather than changing the behavior of one person at a time (Brownson et al., 2001; King et al., 1995; Sallis et al., 1998). Baker et al. (2000) suggest that research investigating programs and environmental interventions that can promote the heath of large numbers of people holds great potential and can compliment individual strategies that focus on behaviors and lifestyles.

One of the most notable approaches in research focusing on community-level physical activity outcomes is the use of unobtrusive observations. Significant contributions applying this method have been made in health research (Cheadle et al., 1991, 1993; Cheadle et al., 1995; Cheadle et al., 1992). Using this strategy, data is collected without the community or individuals knowing that observations are being conducted. The benefit of this approach is that it provides valid and reliable accounts of people's behaviors in environments because people do not modify their behaviors knowing that they are being observed (Webb et al., 1966; Zeisel, 1984). Observations of pedestrians give an objective account of collective behaviors in neighborhoods and can reflect residents' shared attitudes that are translated into behaviors (Baker et al., 2000). As discussed earlier, pedestrian movement is only one form of physical activity, but much of the research in this area considers pedestrian movement to be an important outcome related to physical activity.

Objective observations have been conducted in environment behavior, architecture, urban planning, and landscape architecture research to assess activities in urban settings (Appleyard, 1981; Cooper Marcus & Francis, 1998; Moore, 1991; Sommer, 1969; Whyte, 1980). Observations of people’s physical activity behaviors have been applied to parks (Floyd et al., 2008), greenways (Lusk, 2002), sidewalks and streets (Suminski et al., 2006). The literature in space syntax often reports using systematic unobtrusive observations to measure the frequency of pedestrian use in neighborhoods and cities. The observations in the space syntax studies provide an effective method for assessing the overall pedestrian movement in an area by avoiding any misrepresentation of pedestrian movement that may result from self-reports. Observed movement provides the most accurate account of pedestrian behaviors across various interest groups that use the neighborhood or city (Desyllas & Duxbury, 2001; Hillier, 1996a; Hillier, 1999; Hillier et al., 1993; Peponis et al., 2007; Read, 1999).

The importance of community-level unobtrusive observations for understanding how neighborhood physical activity is connected to the built environment needs emphasis. Observations measure physical activity behaviors as they take place in the built environment in a specific place and time. Because the exact geographic location can be pinpointed and the environmental characteristics can be readily recorded, observed behavior can be more easily associated with the physical characteristics of the environment than individual-level self-reports. Another benefit that cannot be captured with other measurement strategies is that observational methods demonstrate the potential for physical activity afforded by the environment regardless of whether it is residents or visitors who are participating in the urban environment. This is especially important for urban designers and planners because they focus on the environment as a whole and its effect on all people.

The main limitation of observations of pedestrian behavior is that the observed physical activity cannot be linked directly to physical activity outcomes of individuals living within the area. Because the focus of this method is on the overall community, individual-level outcomes are not explicated. Some researchers have suggested that the benefits of pedestrian observations outweigh the limitations. For example, Suminski et al. (2006) show that observed behaviors in an area often match the characteristics of the population that resides in the blocks where observations were taken. Fewer runners were observed in census blocks that had a higher percentage of people in the labor force, with a higher number of runners observed in areas with a higher percentage of residents working only 14 hours per week or less. Despite this finding, it must be stated that unobtrusive observations of physical activity behaviors cannot reliably be associated with residents living in the area where observations were conducted.

Baker et al. (2000) suggest that observational measures may be an important tool that adds another dimension to individual-level measures in community based health promotions and interventions. Because physical characteristics of the environment are likely to affect not only residents, but anyone using the area, research demonstrating specific ways in which the environment is associated with physical activity outcomes can benefit everyone. Individual-level approaches are important as well and should be used if the focus is on identifying residents' perceived barriers to physical activity and improving their physical activity outcomes in particular. To capture both dimensions, this dissertation research will apply observations of pedestrian movement (community-level outcome), self-reported overall physical activity, and objectively-measured waist circumference (individual-level outcomes).

4.10. Conclusion

This chapter started off by discussing factors of the built environment that have become associated with higher levels of physical activity and walking in the literature. Most of the developments in the empirical description of environmental factors have occurred within the field of urban planning. For the past 13 years, a large focus has been on Cervero and Kockelman's (1997) 3Ds thesis. Studies have shown that a higher *density*, greater diversity of *land use mix*, and higher *street connectivity* are all associated with higher amounts of neighborhood walking. Due to the limitations of these measures, however, two other broad categories of built environment factors were also explored. Research question 3 of this dissertation focuses on a comparison of the effects of these urban planning measures on pedestrian movement and physical activity outcomes with the effects of destination and space syntax measures.

Research on place accessibility posits an alternative way of discussing and measuring environmental effects by focusing on issues of the accessibility of the destination environment. Three destination measures discussed in this chapter are *proximity of destinations*, *number of destinations*, and *clustering of destinations* (including *destination bundles*). The associations of these factors with pedestrian movement and physical activity are explored in research question 1, with the hypotheses being that closer proximity to, higher number of, and more clustering of destinations leads to higher levels of pedestrian movement and physical activity. Destination research holds promise for participatory research and community development projects, since issues of destination environments are often a central concern in communities and people find these issues intuitive to discuss.

A final category of built environment factors included in this dissertation is space syntax measures. The variables discussed include three commonly-applied space syntax measures: *street network connectivity*, *street network integration*, *metric reach*, and a measure called *destination reach* that was developed specifically for this dissertation. The hypotheses related to these measures state that higher levels of connectivity and integration and less reach are associated with higher levels of pedestrian movement and physical activity. These hypotheses are explored in research question 2, which compares the relative strength of the associations between space syntax and destination measures on the one hand with pedestrian movement and physical activity outcomes on the other.

Neighborhood perceptions, which are examined in research question 4, were also discussed. Some previous research has investigated the mediating effects of peoples' perceptions of the physical environment on the relationship between the built environment and physical activity. Other studies have focused on neighborhood perceptions as independent variables. Research question 4 of this dissertation focuses on the possible mediating effects of perceptions of the psychosocial environment on physical activity outcomes.

A final discussion included in this chapter focuses on the two categories of outcome variables included in this dissertation: pedestrian movement and physical activity. Although many researchers use the two terms interchangeably, it is important to make a conceptual distinction. Reviewing the literature, it becomes clear that the majority of the research on the built environment has focused on pedestrian movement or walking outcomes rather than overall physical activity, even if these studies label the walking outcomes as “physical activity.” The rest of this dissertation discusses these two outcomes in separate sections.

Chapter 5
RESEARCH METHODOLOGY

5.1. Chapter overview

This chapter reintroduces the main research questions, presents the study background and data sources, outlines the variables in detail, and gives an overview of the statistical analyses performed. The independent variables are discussed first because they are the focus of the investigation. This is followed by discussions of the mediating variables, outcome variables, and covariates. Within the discussion of the variables is the explanation of how the measures were developed.

The section on statistical analysis describes two separate analyses: first the analysis of the pedestrian movement outcomes and second the overall physical activity and waist circumference outcomes. The main outcome variables are analyzed separately due to their conceptual differences. Each of the analytical sections is structured by the research questions.

5.1.1. Objectives and research questions

The research questions in this study aim to find empirical evidence of how accessibility of the spatial and destination environment contributes to local pedestrian movement and physical activity. The intent is not to ignore the qualitative aspects of experiencing place, but to quantitatively measure and express the locational and spatial characteristics that people use to organize and find meaning in their environment (also see the discussion in

Chapter 3). These patterns can be readily observed by looking at how characteristics of the physical environment relate to people's perceptions and actions.

Research questions were formulated to investigate whether characteristics of the physical environment are associated with health outcomes such as physical activity and walking. Quantitative measures were constructed and tested in statistical models to capture sociophysical aspects of the environment. A range of objective environment measures previously used in research was applied, and new measures were created.

The following research questions will guide the investigation:

Research Question 1: *To what extent do destination measures have an association with pedestrian movement and physical activity?*

Research Question 2: *What are the relative contributions of destination measures and space syntax measures to pedestrian movement and physical activity?*

Research Question 3: *Are destination measures and space syntax measures more predictive of pedestrian movement and physical activity than commonly used urban planning built environment measures?*

Research Question 4: *Do perceptions of the psychosocial environment mediate the associations between the built environment and physical activity?*

5.2. Background

5.2.1. The Healthy Environment Partnership

This dissertation research draws upon data from the Lean Green in Motown (LGM) project, a study conducted by a community-based participatory research initiative called the Healthy Environments Partnership (HEP). HEP is affiliated with the Detroit Community-Academic Research Center and is funded by the Health Disparities Initiative of the National Institute of Environmental Health Sciences (NIEHS). The HEP research team draws from a wide spectrum of organizations, departments, and institutions including Brightmoor Community Center, the Detroit Department of Community Health and Wellness Promotion, Friends of Parkside, Detroit Hispanic Development Corporation, the Warren/Conner Development Coalition, and the University of Michigan's School of Public Health and College of Architecture and Urban Planning. The partnership is dedicated to investigating the contributions of the social and physical environments to variations in cardiovascular disease risk in non-Hispanic Black, non-Hispanic White, and Hispanic populations in three areas of Detroit, Michigan (Schulz et al., 2005b).

One of the aims outlined in the HEP conceptual model is to investigate the contribution of the built environment to cardiovascular health and risk factors (Schulz et al., 2005b). The specific focus of the LGM project is to examine the predictive significance of the built environment on health outcomes in the three study areas. This dissertation adds to the LGM project's broader aims by exploring the significant contributions of destination and space syntax measures. Participation in the LGM group enabled access to the 2002 HEP survey datasets and ensured feedback on progress from the rest of the LGM research team as well as the HEP Steering Committee on two occasions (the Steering

Committee is a group containing representatives from all of HEP's partner organizations) (Schulz et al., 2005b).

5.2.2. Setting and Context

At the outset, it seems ironic to study walkability issues in Detroit, home to the 'Big Three' automobile companies: Ford, Chrysler, and General Motors. Although the 'Motor City' was a thriving industrial metropolis for the first half of the 20th century, the city has experienced population decline, worsening economic conditions, and a range of socio-economic problems since the 1950's. The Detroit of today has a high poverty rate and a lower population than in the mid-20th century (Schulz et al., 2005b).

One area of concern is the citywide health problems. The city of Detroit[14] has higher mortality rates than the state[15] and national[16] averages due to cardiovascular disease for both African American and white residents (Schulz et al., 2005b). Other health-related issues associated with the built environment in Detroit neighborhoods have also been proposed (Israel et al., 2006; Parker et al., 2001; Schulz et al., 2005b; Zenk et al., 2005). The HEP initiative explores the links between the city's physical and social environments and variations in health outcomes. The study focuses on three sectors of the city with varied socioeconomic and racial/ethnic compositions (Israel et al., 2006). These study areas include [1] Northwest (3x3 miles), [2] Southwest (2x3 miles) and [3] Eastside (2.5x2.5 miles) Detroit (See Figure 5-1).

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14 MDCH (Michigan Department of Community Health). 2004. Natality, Mortality, and Other Vital Statistics. Available: http://www.michigan.gov/mdch [accessed 01 July 2010].

15 MDCH (Michigan Department of Community Health). 2003. Mortality Statistics. Available: http://www.mdch.state.mi.us/pha/osr/chi/Deaths/frame.html [accessed 01 July 2010].

16 U.S. Department of Health and Human Services, 2001. Health, United States, 2001. PHs 01-1232. Washington, DC: U.S. Department of Health and Human Services.

Figure 5-1 The city of Detroit and the HEP study areas: [1] Northwest, [2] Southwest, [3] Eastside

Several recent studies have found that people in economically disinvested communities are more likely to walk for transportation rather than recreational purposes (Giles-Corti et al., 2008; Ross, 2000; Ross & Mirowsky, 2001; Weinstein & Schimek, 2005, 2007; Yen & Kaplan, 1998). These groups are less likely to own cars and therefore rely on walking and public transportation for their everyday movement (Giuliano & Narayan, 2003; Lee, 2004a; Pucher, 2003). In the 2002 HEP sample, only 65% of the 919 adults owned a car or had access to a car through a friend or acquaintance.

Another factor at play in Detroit is the relatively low population density: the average density for a ¼ mile radius around respondents' homes is 5.09 housing units per acre, with a standard deviation of 1.5. This low population density is accompanied by a lower density of destinations, which means that fewer destinations are likely to be near people's homes than if the density of the destination environment were higher. This is further explained by Cervero and Kockelman's (1997) discussion of the multicolinearity of measures of density, land use mix, and street connectivity. The combination of: lack of access to cars, low residential and destination densities, and further distance to destinations means that many residents in the study areas may have to walk long distances for transport purposes.

It is not surprising that the presence of the automobile industry has left its imprint on the city. The car companies, with their strong economic foothold in the city, favored the single family car-dependent suburban model, rendering other forms of mass-transit a less viable option (Farley et al., 2000; Mallach et al., 2008). Because of these distinctive characteristics, the city of Detroit is a unique place to investigate pedestrian movement and neighborhood physical activity.

The evolution of the city plan over approximately 100 years shows how the movement of the car became inscribed in the city form (see Figure 5-2). A recent article analyzing the street system of Detroit over the last century showed the 1807 ‘Woodward Plan’ with a fine-grain urban block structure and radial avenues cutting through the city blocks at diagonals. In the original plan (shown on the left), main avenues were the most efficient way of moving through the city, but the tightly woven urban fabric also allowed for cross movement in all directions. A century of deterioration of the urban fabric through the consolidation of blocks into mega-blocks and the loss of blocks due to highway construction concentrated much of the traffic on a few main thoroughfares (Ryan, 2008).

Figure 5-2 Detroit downtown street plan in 1897 (left) and 2002 (right) from Ryan (2008)

Street widening projects on the main avenues and east-west connecters such as Mack Avenue were intended to stimulate through-traffic from the surrounding suburbs and turned large parts of the city into environments friendlier for cars than for pedestrians (Ryan, 2008). These avenues occur as outliers in the spatial integration data. The citywide street network integration map illustrates the historical processes that shaped the city form to accommodate vehicular efficiency: the through-movement of automobile traffic. Highly integrated avenues dominate the city structure and extend from downtown outward for several miles (also refer back to Figure 4-15 on page 83). This observation of the Detroit city streets led to the development of two additional spatial measures that test how the main avenues impact the outcomes of respondents living in close proximity: distance to “main streets” and distance to “place chains”. These measures will be discussed in more detail in section 5.3.2.a.

5.2.3. Overview of data sources

The main data sources used in the statistical analysis in this dissertation include the [1] 2002 Healthy Environment Partnership survey, [2] 2006 systematic neighborhood observations [3] Geographic Information Systems (GIS) data (parcel land uses, roads data), [4] space syntax axial line data, and [5] US census data.

The objective environmental variables were developed from a few data sources. Measures were developed in GIS using parcel level land use, road, and US census housing unit density data. 2002/2003 parcel level assessor's data was obtained from the Detroit Planning and Development Department[17]. Land use designations were re-coded into the appropriate categories for the study. The data showing locations of food stores was supplemented with more accurate data collected by Zenk, a HEP team member researching the spatial accessibility of supermarkets in Detroit. Her work using this data is published in Zenk et al. (2005). Space syntax base-maps were drawn in Autocad 2007 using United States Geological Survey (USGS) aerial orthophotographs.

Since cross-sectional analysis was performed using 2002 land use data for the independent variables and 2006 systematic neighborhood observations of the three studies areas for one of the outcome variables, any possible changes in the land use needed to be ruled out. The percentage change between 2002 and 2006 in square foot parcel area was calculated in GIS; it averaged around 2% - 3% and only a few cases exceeded 5%. Furthermore, the large scale school closings during 2007/2008 that otherwise would have raised concerns about data reliability occurred after the 2006 neighborhood observation data was collected. Because of the aggregated level at which measures were constructed, it was concluded that none of the unit areas had significant land use changes that would affect the environmental measures.

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[17] http://www.detroitmi.gov/DepartmentsandAgencies/PlanningDevelopmentDepartment.aspx

Another dataset used in the analysis is the 2002 Healthy Environment Partnership survey, conducted from March 2002 – March 2003. A stratified two-stage equal probability sample was employed for occupied households located within three areas of Detroit: Northwest, Southwest, and Eastside. The survey was designed to interview 1000 respondents over the age of 25 from different households. The selection of households was intended to result in a representative sample of socioeconomic status, race, and ethnicity, allowing comparisons by both race and class. In the end, face-to-face interviews were performed with 922 respondents, with a final sample *n*=919. To account for the overrepresentation of certain racial/ethnic groups due to the population distribution in Detroit and to better estimate population effects, a weighting strategy was employed to adjust the sample (Schulz et al., 2005b).

Utilizing data from the 2000 census, the HEP team also developed variables of the percentage African American, percentage poverty, and mean length of residency that are included in this dissertation. The discussion of findings (Chapter 8) is accompanied by photographic documentation from the three areas in Detroit intended to support the empirical findings. Verbal permission of human subjects was obtained on-site prior to taking the photographs, and faces have been masked to ensure anonymity.

5.2.4. Summary of variables

Sections 5.3 to 5.6 of this chapter are organized around the variables: independent, mediating, outcome, and covariates. Figure 5-3 provides a summary table.

Independent variables	Mediating variables	Outcome variables	Covariates
<u>Destination measures</u>			**<u>Individual level</u>**
Proximity to destinations	Sense of community	Pedestrian movement	Age
Number of destinations	Neighborhood satisfaction	(+ sedentary behavior)	Gender
Clustering	Safety stress	Physical activity	Race/ethnicity
Number of bundles		Waist circumference	Annual household income
			Employment status
<u>Space syntax measures</u>			Length of residency
Street network connectivity			
Street network integration			**<u>Neighborhood-level</u>**
Distance to “main streets”			**<u>context</u>**
Distance to “place chains”			Percentage African American
Reach			Percentage poverty
Destination reach			Residential stability
<u>Planning measures</u>			
Density			
Land use mix (diversity)			
Street connectivity (design)			

Figure 5-3 The independent, mediating, and outcome variables and the individual-level and neighborhood-level context covariates used in the analysis

5.2.5. Criteria for the independent measures

5.2.5.a. Type of destination

The walkability literature provides some evidence for which types of destinations are expected to contribute to walking and other physical activity outcomes. As discussed earlier, a range of qualitative factors play a role in whether the destination type actually fulfills its intended role within a community. To avoid assumptions about the effectiveness of destinations in the Detroit neighborhoods, several destination-type models were constructed and tested for each destination factor. Walk-enhancing uses examined in the Detroit areas were *commercial* (retail, fast food outlets, restaurants, banks, gas stations with food, car repair shops, and barber shops), *institutional* (libraries, churches, museums, daycare facilities, community centers, and offices), *educational* (elementary, middle, high schools, colleges and/or universities), and *parks* (including recreational open spaces).

Separate models were also calculated for *all destinations* (including all destination types mentioned above), *all destinations without parks* (*all destinations* except for parks and open spaces), and *food destinations* (focusing specifically on the food destinations within the commercial use category). This last model was included in response to prior research showing that parks may not contribute to more walking (Moudon et al., 2006c). *Institutional destinations* were not analyzed independently, only as part of the *all destinations* category. Light industrial uses were excluded from all the destination measures.

Models were constructed by combining the destinations in the following ways:

- *All destinations*: commercial, institutional, educational, and parks
- *All destinations without parks*: commercial, institutional, and educational
- *Commercial destinations*: retail and food-related uses
- *Educational destinations:* elementary, middle, high schools, colleges and/or universities
- *Food destinations:* grocery stores, convenience stores, supermarkets, drug stores, gas stations with food, restaurants (fast-food; sit-down; coffee shops), and liquor stores (often carrying food-related products)

5.2.5.b. Neighborhood size

Defining neighborhood size when researching human-environment relationships has been an issue of great disagreement. More recently, even the definition of ‘neighborhood’ is hotly debated in the health literature (Diez Roux, 2004; Furstenberg, 1997; Gephart, 1997; Tienda, 1991). It was proposed in chapter 3 that people hold multiple definitions of the term and define their neighborhoods by referring to a range of sociophysical characteristics. Neighborhood size has been linked with the location of neighborhood destinations (Lee, 1976; Lee T., 1970a). Other researchers have shown that threshold distances are associated with the proximity and the type of destinations, which in turn may influence people’s conceptions of their neighborhood (Lee T., 1970a; McCormack et al., 2008; Moudon et al., 2006c).

For this dissertation, most measures were developed at the ¼ mile and ½ mile radius because an average walkable distance is generally considered to fall somewhere between these ranges (Moudon et al., 2006c). A few measures were calculated at scales that are specific to the type of measure: proximity was calculated to the closest destination, reach and destination reach up to a maximum of 1 mile distance, and an additional density measure at the block level. The outcome measures of *pedestrian movement* were calculated at the block and rook level; the use of these levels resulted from practical considerations of collecting pedestrian data along neighborhood streets. The rook is defined as the block faces of the respondent block and additional block faces of all the blocks surrounding the respondent block. It is the unit at which all environmental data was collected by the HEP study and it provides a characterization of a micro-neighborhood environment within immediate proximity of a resident’s home. Due to the large block sizes in the Detroit neighborhoods, the rook level is similar to the ¼ mile radius level and these two levels will therefore be associated with each other in some of the analysis.

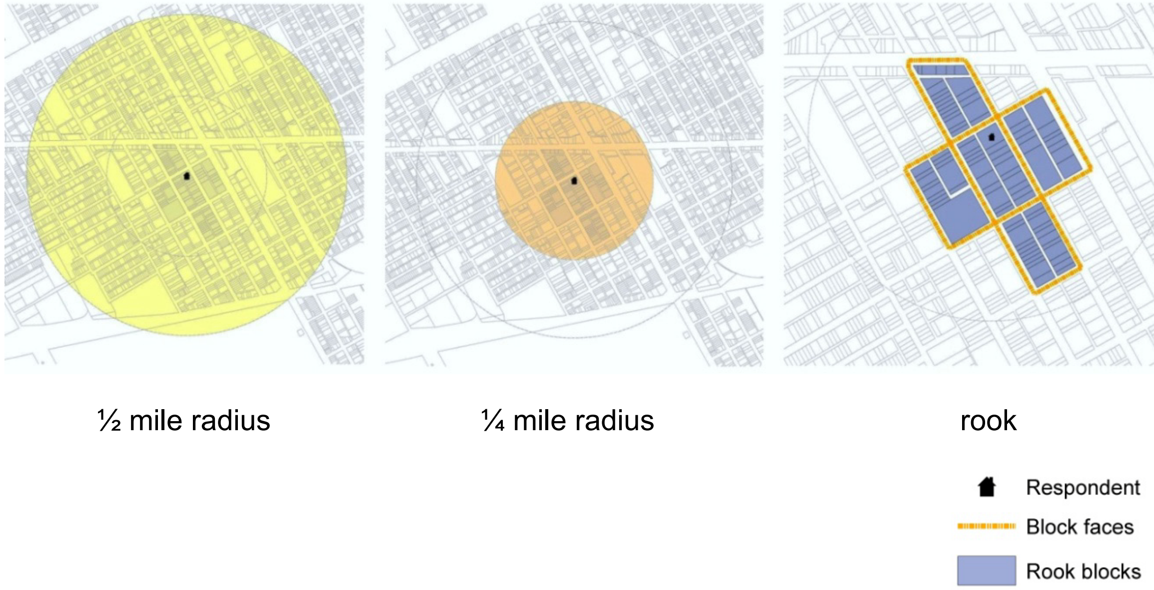

Figure 5-4 Diagrams of the units of measurement: ½ mile, ¼ mile, and rook level

5.2.5.c. Airline and network distance

Proximity measures to specific destinations were developed at both the airline distance (as the crow flies) and the network distance (along street networks). Moudon et al. (2006c) suggest that both airline and network distance are useful for interpreting how people perceive neighborhood access, and both measurement strategies are commonly used in the walkability research. The distinction poses an important question about how people conceive of their neighborhoods: whether people estimate the distance to destinations in a general direction or whether they consider the actual traversable street distance when they think about how far they walk to places.

5.3. Independent variables: objective environmental measures

5.3.1. Destination measures

Some researchers have suggested that destinations add an important layer to the accessibility of neighborhoods (Handy & Clifton, 2001; Handy & Niemeier, 1997; Lee &

Moudon, 2006a; Lee & Moudon, 2006b; Moudon et al., 2006c; Stahle et al., 2006). The following destination measures were developed to test the hypotheses that were formulated from the research questions: *proximity to destinations*, *number of destinations*, and *clustering of destinations*. They were created using the 2002/2003 parcel level land use data. Line data of the street networks of Detroit was added to the land use data to calculate the proximity to destination measures at the network distance.

5.3.1.a. Proximity to destinations

Proximity to destinations measures were calculated from a respondent's home to the closest destination of a specified type. Measures were calculated at both the airline (as the crow flies) and the street network (along the streets) distances. Different types of destination groups were also distinguished. *Proximity measures to destinations* were calculated for *all destinations* (commercial including food, institutional, educational, and parks); *all destinations without parks*; *commercial destinations*; *educational destinations*; and *food destinations* (see Table 5-1). All proximity measures used parcel land use data and were calculated in ArcGIS 9.3 software from the geocoded location of respondents' homes to the closest destination. Network distances were calculated using the TIGER (2000 Topologically Integrated Geographically Reference-file) street file of the city of Detroit in the ArcGIS extension, Network Analyst.

For the analysis of the *pedestrian movement* outcomes, the outcome measures were calculated for the block and the rook levels. The variables in the analyses, therefore, occur at two different levels; proximity measures taken from a single respondent's home are at the individual-level and outcomes of observed street behavior are at the block or the rook levels. To conceptually link the individual-level proximity measure and the block and rook level pedestrian movement outcomes, the mean proximity value of all the respondents residing in a single block was calculated to create a block-level proximity measure.

Proximity to destinations	Airline distance	Network distance	Number of variables
All destinations	X	X	2
All without parks	X	X	2
Commercial	X	X	2
Educational	X	X	2
Food	X	X	2
Total:	5	5	10

Table 5-1 Variables developed of the proximity to destinations, total number: 10

5.3.1.b. Number of destinations

This measure captures the number of destinations within a ¼ mile and ½ mile radius from the centroid (midpoint) of the blocks in which respondents reside (see Table 5-2). Destinations that fell within the radius buffer were captured in ArcGIS software; the buffer refers to the area within a circle of a specified radius. To relate the measure to respondents located in sample blocks, it was calculated from the center of the block. The *number of destinations* measures were calculated for *all destinations*; *all destinations without parks*; *commercial destinations*; and *food destinations.*

Number of destinations	¼ mile radius	½ mile radius	Number of variables
All destinations	X	X	2
All without parks	X	X	2
Commercial	X	X	2
Food	X	X	2
Total:	4	4	8

Table 5-2 Variables developed of the number of destinations, total number: 8

5.3.1.c. Clustering

Clustering represents the extent to which destinations are clustered in an area near a respondent's home. A widely used measure in network theory called the clustering coefficient was used to calculate destination clustering. The *clustering coefficient* enables the measurement of what network theorists call the 'small-world phenomena' by quantifying the degree to which proximate destinations combine to form, in this application, neighborhood places. Introduced by Michael Batty (2003), the idea of 'small-worlds' is that an effective network system needs numerous local connections but only a small number of interconnections to other systems. Small, dense clusters with a small number of links between the clusters enable a great reduction in path lengths between all nodes[18]. In terms of pedestrian movement, this leads to a great reduction in walking distance through trip chaining and multi-purpose trips. The cluster tolerance is the maximum distance between proximate neighbors for a link to become realized. Once the tolerance is determined, the *clustering coefficient (C)* is calculated as the ratio of links in the cluster divided by the total number of links, providing a value of the cluster strength (Albert & Barabasi, 2002; Watts, 1999).

$$C = \frac{number\ of\ realized\ links\ between\ destinations}{number\ of\ all\ possible\ links\ between\ destinations}$$

The threshold at which clustering occurs (eg. 1/8th, 1/16th, 1/32nd of a mile) also needs to be specified. For instance, two or more destinations participate in forming a bundle if they are within the specified distance from each other. Each grouping of destinations was calculated three times at three different destination bundle sizes (1/32nd, 1/16th, 1/8th of a mile). Destination *clustering coefficients* were calculated for destinations located within a ¼ mile and ½ mile radius area of the midpoints of blocks where respondents live. ArcGIS and Hawth's extensions provided the capability to calculate the

18 In network theory, links are often called "nodes"

coefficients using a land use parcel point file. The clustering coefficients were calculated for *all destinations*; *all destinations without parks*; *commercial destinations*; and *food destinations* (see Table 5-3).

Another measure of clustering developed for this dissertation is called the *number of destination bundles.* This measure is similar to *number of destinations* discussed in section 5.3.1.b, but instead of counting the number of individual destinations, the number of *destination bundles* (clusters) is counted. Destinations form a bundle if they are within a specified distance of one another; in the case of this dissertation, the specified distances are 1/32th and 1/16th of a mile. The bundles were identified and summed in Arcmap GIS software at the ½ mile and ¼ mile radius around sample blocks. Variables were developed for the following categories: *all destinations, all destinations without parks,* and *commercial destinations.* See Table 5-3 for an outline of the *clustering* and *number of destination bundles* variables.

Clustering	**¼ mile radius**	**½ mile radius**	**Number variables**
All destinations (1/8th, 1/16th, 1/32nd of a mile)	X	X	6
All without parks (1/8th , 1/16th, 1/32nd of a mile)	X	X	6
Commercial (1/8^{th,} 1/16th, 1/32nd of a mile)	X	X	6
Food (1/8^{th,} 1/16th, 1/32nd of a mile)	X	X	6
Total:	12	12	24
Number of destination bundles		**½ mile radius**	**Number variables**
All destinations (1/16th, 1/32nd of a mile)		X	2
All without parks (1/16th, 1/32nd of a mile)		X	2
Commercial (1/16th, 1/32nd of a mile)		X	2
Total:		6	6

Table 5-3 Variables developed of the clustering of destinations, calculated at 3 different bundles sizes (1/32nd, 1/16th, and 1/8th of a mile), total number: 24 and the number of destination bundles, calculated at 2 different bundle sizes (1/32nd and 1/16th of a mile), total number: 6.

5.3.2. Space syntax measures

5.3.2.a. Street network integration and street network connectivity

Space syntax axial maps were drawn in Autocad 2007 based on aerial orthophotographs obtained from the United States Geological Survey (USGS). Measures of both street network integration and street network connectivity were computed using the Syntax2D software, which was developed at the University of Michigan's A. Alfred Taubman College of Architecture and Urban Planning. Street network integration (HH[19]) and street network connectivity (Hillier & Hanson, 1984) were both calculated at the street level on a city-level and a neighborhood-level basis. Vehicular highways were excluded from the street map. To address outliers in the distribution, the mean of the syntactical values for both a ¼ mile and ½ mile radius was calculated from the midpoint of the respondent blocks. Both measures relate to a center block where respondents live, and each individual in the same block is associated with the same average values at the ¼ mile radius and ½ mile radius (see Table 5-4).

One limitation of the line diagrams used in space syntax graphs relates to the length of lines that represent streets. In space syntax axial graphs, a value (integration or connectivity) is assigned along the entire street irrespective of the length the street. The longer the line (street), the more integrated a street is determined to be in the urban system. This assumption overestimates the importance of some streets in the larger system of streets; as a result, these streets become outliers relative to other streets. In this dissertation, the length factor was addressed by also calculating the overall integration values for the three neighborhood subsections. Each neighborhood is defined as a circular area of approximately 3 miles in diameter.

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19 HH stands for the original integration measure developed by Hillier and Hanson

Two additional measures were applied to account for the high integration values of the main avenues through the city and were calculated as follows. First, the most integrated avenues in each neighborhood were identified. Next, a measure called *distance to "main streets"* was calculated from the center of sample blocks to the closest main avenue and a measure called *distance to "place chains"* [20] was calculated of the distance from the center of the block to the closest destinations on the main avenues (see Figure 5-5). These two measures examine whether the spatial dominance of the avenues alone is associated with *pedestrian movement* and *physical activity*, or whether the destinations located on these avenues enhance the relationships. This argument is in line with Hillier's proposal that through the evolution of cities, highly integrated streets tend to attract land uses that depend on the high through-movement of people (Hillier et al., 1993). See Table 5-4 for the table showing the connectivity, integration, and distance to "main streets" and "place chains" variables.

Figure 5-5 Main avenues and *place chains:* destinations located within 330 feet (1/16th mile) of the street centerline

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20 Destinations within 330 feet from the centerline of the main avenue were included

Space syntax variables	¼ mile radius	½ mile radius	Number variables
Mean city level integration (HH)	X	X	2
Mean neighborhood level integration (HH)	X	X	2
Mean city level connectivity	X	X	2
Mean neighborhood level connectivity	X	X	2
Distance to “main streets”	N/A	N/A	1
Distance to “place chains”	N/A	N/A	1
Total:	4	4	10

Table 5-4 Variables developed of integration, connectivity, distance to “main streets” and distance to “place chains”; total number: 10

5.3.2.b. Reach

After a training session with Martin Scoppa, a colleague of John Peponis, the *metric reach* was calculated for the streets in the Detroit sample using their Reach software (see Table 5-5). The threshold distance was set at 1 mile for this analysis, while reach values were averaged at the ½ mile and ¼ radius areas. This measure, developed in 2006 at the morphology lab at Georgia Institute of Technology, is currently being tested in cities all across the United States. Reach measures combine the benefits of the relational properties of space (*through*-movement) and localized distance factors (*to*-movement) (Peponis et al., 2008; Peponis et al., 2007; Peponis et al., 2006). *Metric reach* measures the distance covered by following streets in all directions up to a fixed “threshold” distance from the origin point: the center point of each street segment between two intersections (see Figure 5-6). The street spaces that can be reached when walking in all possible directions increase as the density of streets increases. In other words, the *metric reach* is a way of describing the urban potential at a localized level.

Lower reach means that more streets are available in the immediate surroundings, allowing a greater integration of private and public spaces.

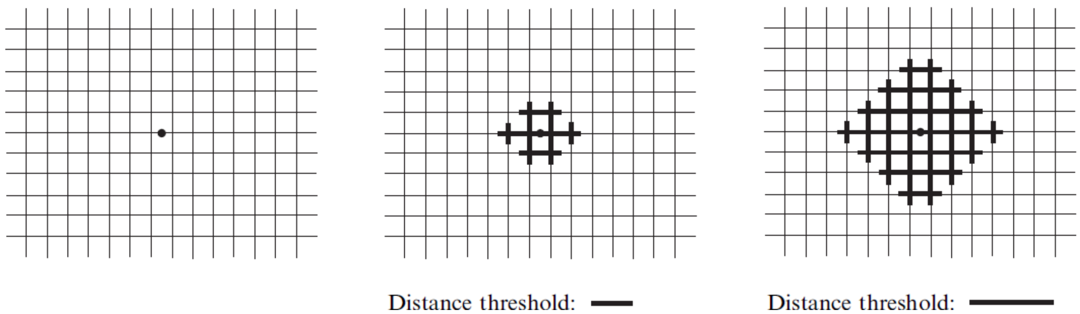

Figure 5-6 Diagram of metric reach in Peponis et al. (2008, p. 883)

Reach	¼ mile radius	½ mile radius	Number variables
Mean reach: 1 mile away	X	X	2
Total:	1	1	2

Table 5-5 Variables developed of metric reach; total number: 2

5.3.2.c. Destination reach

The destination reach measure was calculated using the 2002/2003 parcel level land use data and the roads data from the 2000 US census TIGER-file of Detroit. The network analyst function was used in Archmap 9.2 to calculate the total distance to all destinations along the streets from a respondent's home. The distances along streets were reached with either the first destination along each of the paths or when the specified maximum distance of either ½ mile or 1 mile was reached without having passed a destination. The average of the total reach distances surrounding the sample respondents in the same block provided a block level measure. Destination reach was calculated for *all destinations*, *all destinations without parks*, and *commercial destinations* (see Table 5-6).

Destination reach	1 mile maximum distance	½ mile maximum distance	Number variables
All destinations	X	X	2
All without parks	X	X	2
Commercial	X	X	2
Total:	3	3	6

Table 5-6 Variables developed of destination reach; total number: 6

5.3.3. Planning measures

5.3.3.a. Density

US census 2000 data provided block-by-block housing unit density for all three sample areas. Visual observation of the block level residential unit density in ArchGIS 9.2 indicated large variation in density for adjacent blocks. See the map (Figure 5-7) produced in Archmap, Geographic Information Systems, of density at the block level and ¼ mile radius areas.

Figure 5-7 Section of Detroit illustrating the sharp differences in block density of adjacent blocks in the city; the circles on the diagram represent ¼ mile radius areas

Initially, housing unit density at only the ¼ mile and ½ mile radius areas was going to be calculated. However, the variation of density within the ½ mile or even ¼ mile areas is often greater than the variation between sampled areas. For example, the mean densities of the areas included in the survey sample are: 4.9 (std 1.3) housing units per acre (HUD) at the ½ mile, 5.1 (std 1.5) HUD at the ¼ mile, and 5.4 HUD (std 3.3) at the block level. The densities at the three levels are fairly similar, but the standard deviations are quite different. Figure 5-8 shows a graph of the variation in density between the respondent blocks at the three levels. (In this study, the middle block is always the block where the respondents reside). Because of the high variation of density in the other levels, residential unit density was calculated at the block level in addition to the ¼ mile level and the ½ mile level. Table 5-7 in section 5.3.3.c shows all the planning variables included in the analysis.

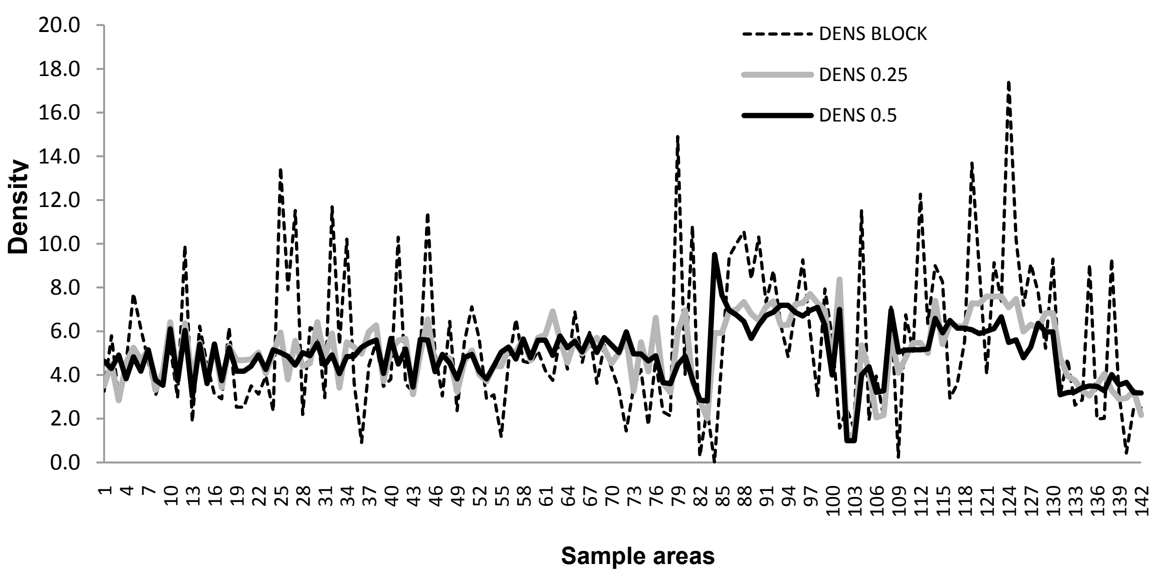

Figure 5-8 **Variation in housing unit density by block, ¼ mile, and ½ mile as measured from the central blocks where respondents live**

5.3.3.b. Land use mix (Diversity)

Land use mix was calculated using the 2002/2003 land use parcel data. The land uses were recoded and entered into the entropy formula, providing a normalized score of degree of mix (Frank & Pivo, 1994; Frank et al., 2004; Frank et al., 2007; Frank et al., 2005a; Leslie et al., 2007). The following formula was used to calculate the entropy score at the rook, ¼ mile, and ½ mile levels from the centroid of respondent blocks:

$$\text{Land use mix} = -\sum_{i=1}^{n} (p * \log p) / \log n$$

where $\boldsymbol{p}$ is the percentage of a single land use in the specified area $\boldsymbol{i}$, and $\boldsymbol{n}$ is the number of land uses in the equation. This measure provides a normalized score of land use mix between 0 and 1, with 0=no mix and 1=high mix (minimum score obtained at the rook level was 0.13; and the maximum was 0.93). One limitation of this measure is its inability to discern between different uses after the score is calculated. Therefore, land use categories needed to be specified beforehand based on their contribution to walking as discussed in the literature review. These land use categories include: *commercial* (retail and food); *educational*; and *parks* and recreation. Land use mix was analyzed at both the ¼ mile and the ½ mile radius areas.

5.3.3.c. Street connectivity (design)

The road file of Detroit from the 2000 US census (2000 TIGER file) was used to calculate the connectivity index, an easily computable measure of street connectivity described by Susan Handy and widely applied in cities all across the United States (Handy, 2005). See Figure 5-9 for a diagram of this measure.

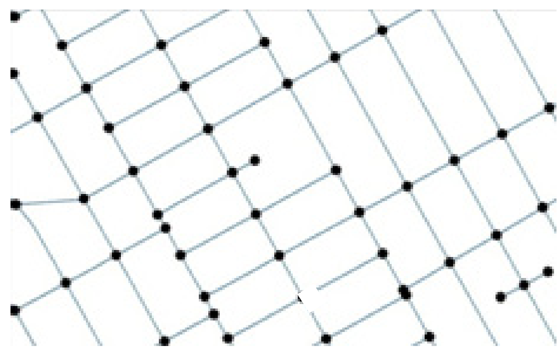

Figure 5-9 Susan Handy's street connectivity index

The index is calculated by $\frac{(links)}{(nodes)}$ that fall within a radius area around the midpoint of respondent blocks (calculated at the ¼ mile and ½ mile). The nodes extending one step beyond the buffer were also counted.

Planning measures	Block level	¼ mile radius	½ mile radius	Number variables
Residential unit density	X	X	X	3
Land use mix (diversity)	N/A	X	X	2
Street connectivity (design)	N/A	X	X	2
Total:	1	3	3	7

Table 5-7 Variables developed of the common planning variables; total number: 7

5.4. Mediating variables: neighborhood perceptions

5.4.1. Sense of community

The measure of *sense of community* (Cronbach's alpha, 0.80) was constructed from six questions in the 2002 HEP survey that each had five-point Likert scale response categories of: (1) "Strongly agree"; (2) "Somewhat agree"; (3) "Neither agree nor disagree"; (4) "Somewhat disagree"; (5) "Strongly disagree." The individual items asked the extent to which respondents agreed or disagreed with the following statements:

- "this neighborhood is a good place to live";
- "people in this neighborhood share the same values";
- " [they] feel at home in this neighborhood";
- "it is important to [them] to live in this particular neighborhood";
- " [they] expect to live in this neighborhood for a long time"; and
- "people in this neighborhood generally know each other."

All the response categories were reverse coded, meaning a higher number indicates a higher sense of community. The source of the six questions in this scale is Wandersman et al. as adapted by Parker et al. (2001). The measure is the mean of the responses to the six questions and follows the 75% rule, meaning that at least five of the questions had to be answered for the respondent to be included in the analysis.

5.4.2. Neighborhood satisfaction

The measure of *neighborhood satisfaction* (Cronbach's alpha, 0.82), with the same Likert scale response categories as above, was constructed from five questions from the 2002 HEP survey:

- “this neighborhood is a good place to live”;
- “I feel at home in this neighborhood”;
- “it is important to me to live in this particular neighborhood”;
- “I expect to live in this neighborhood for a long time”; and
- “I would move out of this neighborhood if I could.”

This scale was not reverse coded: the lower the number, the higher the neighborhood satisfaction. The first four questions used in this scale were also used in the *sense of community* measure described above and come from Wandersman et al. as adapted by Parker et al. (2001). The final question was developed by the HEP team specifically for this survey. Similar to *sense of community*, the measure is the mean of the responses to the five questions, and following the 75% rule, at least four of the questions have to have been answered.

5.4.3. Safety stress

The measure of *safety stress* (Cronbach’s alpha, 0.82) combines responses from the following three questions in the 2002 HEP survey:

- “how often did you worry about your safety in your home?”;
- “how often did you worry about being robbed or having your home broken into?”;
- “how often did you worry about your safety in your neighborhood?”

Response categories on these items include (1) “Never”; (2) “Hardly ever”; (3) “Sometimes”; (4) “Often”; (5) “Always”. Again, the measure is the mean of the responses to the three questions, and at least two of the questions have to have been answered.

5.5. Outcome variables: pedestrian movement and physical activity measures

Two pedestrian movement outcome measures and two physical activity outcome measures were identified in this research to test the effects of the built environment on: observed *pedestrian movement* (and *pedestrian movement* + *sedentary behavior*), self-reported overall *physical activity*, and objectively measured *waist circumference*.

5.5.1. Pedestrian movement

The pedestrian movement outcomes are ecological measures of neighborhood use that count people on the streets; no distinction is made between residents and visitors. The measures provide a comprehensive snapshot of general pedestrian movement that speaks to the potential of urban locations to attract people. Since people can be attracted from anywhere, it is expected that the measures rely on the physical accessibility associated with the physical characteristics of the environment.

One limitation of these measures is that the pedestrian counts cannot be connected to the physical activity outcomes of the respondents living in the sampled areas since the observed pedestrians do not necessarily live locally. However, the notion of localization was offered in chapter 3 to theoretically position people's tendencies to focus their daily lives locally. In either case, whether the measures of pedestrian movement counted locals or outsiders, the potential for pedestrian use remains an important dimension of residents' physical activity.

Future research can disentangle the local/outsiders problem by comparing objective pedestrian counts with residents' reports about their walking behavior within their neighborhoods. (Questions about walking behavior for transportation, recreational, work-related purposes were included in the 2008 Healthy Environment Partnership survey). If for some reason locals are found to not use their neighborhood environments to the extent that outsiders do, this issue can be investigated further; strategies to retrofit places to make them more accessible to the local population may need to be considered. What remains in either case is that highly used public places have the potential for attracting people.

The systematic neighborhood observations conducted in 2006 by the author provided the data on pedestrian movement and street use (see Figure 5-10). Arrangements were made with the LGM research team and the HEP Steering Committee, and the police were alerted that data would be collected within their precincts. This enabled the author to collect systematic neighborhood observational data of pedestrian movement and sedentary behaviors during the fall of 2006. Three measurement days were taken for each of the three neighborhoods—two weekdays and one weekend day per area. Each day consisted of 3 time segments (9:00-12:00; 12:30-3:30; 4:00-7:00). This yielded a wide representation of neighborhood life. The same 50 miles of each neighborhood's street space was observed during each time segment; overall, a total of 1,350 miles of street space was covered across the areas.

Figure 5-10 **People counts in all three Detroit areas: Northwest (top left), Eastside (top right), and Southwest (above) obtained during 2006 systematic neighborhood observations**

Counts of people along the neighborhood streets were used to calculate measures of pedestrian movement and sedentary behavior. The average number of people per acre was calculated for blocks and rooks by dividing the number of people counted by the square acreage of the block/rook. The measures consist of the pedestrian movement counts per block and rook, and the pedestrian movement + sedentary behavior counts per block and rook.

All the block faces within each rook were observed. Community residents from the neighborhoods were recruited, trained, and compensated to drive the vehicle while the researcher recorded observation counts of people on a personal computer tablet containing Geographic Positioning System/Geographic Information System (GPS/GIS) software. The average speed of the vehicle was maintained around 20 to 30 miles an hour in order to allow all the designated street spaces to be covered within the allotted time of three hours per segment. Data entry took place in real time, allowing for the recording of both moving and sedentary behaviors. Activities taking place in the streets, sidewalks, contiguous yards, and visible public areas were recorded.

The collected observational data maintained strict geographic correspondence with the locations of sampled residential households in the 2002 HEP survey. These systematic neighborhood observations therefore provide a rich dataset of ecological neighborhood data on how people—both locals and visitors—are moving around the neighborhoods where survey respondents live.

5.5.2. Physical activity

The second type of outcome measure included in this research is physical activity as reported by the 2002 HEP survey respondents. This outcome measure allows for the examination of the link between the built environment and *overall physical activity*. As discussed in section 4.9.1, the literature suggests that physical activity from walking appears to be relatively low on average. This suggests that links between the physical environment and *overall physical activity* are potentially weak.

The physical activity measure used in the analysis was constructed by the HEP group from respondents' self-reported answers to six general physical activity questions. These questions were taken from The Behavioral Risk Factor Surveillance System (BRFSS), a telephone health survey system that is part of the National Center for Chronic Disease Prevention and Health Promotion[21]. The scale is a composite measure of minutes of moderate and vigorous physical activity per week and is used as a continuous variable in the analysis. To construct the scale, the answers to the four questions below were combined to create a total number of minutes of physical activity per week that the respondents engage in. The interviewer asked first whether the subjects engage in moderate or vigorous physical activity for at least 10 minutes at a time doing things such as walking, vacuuming, gardening, or anything that causes small increases in breathing or heart rate. The respondents that answered "yes" to one or both of the moderate or vigorous physical activity questions were asked pertinent follow-up questions:

- "*how many days per week do you do these moderate activities for at least 10 minutes at a time*?" (in days per week);

[21] Refer to the BRFSS website for more information: http://www.cdc.gov/brfss/

- "*On days when you do moderate activities for at least 10 minutes at a time, how much total time per day do you spend doing these activities?*" (in hours and minutes per day);
- "*how many days per week do you do these vigorous activities for at least 10 minutes at a time?*" (in days per week); and
- "*On days when you do vigorous activities for at least 10 minutes at a time, how much total time per day do you spend doing these activities?"* (in hours and minutes per day).

5.5.3. Waist circumference

The third outcome measure is waist circumference, used as an objective measure of physical activity. This measure can provide additional evidence as to whether higher physical activity associated with pedestrian-friendly environments contributes to better physical health in terms of reduction in waist size. Other studies have used waist circumference in a similar manner. These studies used waist circumference as a physical activity outcome and looked at its relationships with neighborhood of residence (Ellaway et al., 1997) and fast-food restaurant density (Li et al., 2009). Waist circumference for each respondent was taken at the time of the 2002 HEP survey interview and used as a continuous variable in the analysis.

5.6. Covariates

5.6.1. Individual-level covariates

Included in the statistical models were individual socio-demographic variables obtained from the HEP community survey: age in years; gender (0=male; 1=female); self-reported race/ethnicity (African American; white; Latino; and other); total household annual income (<$4,499; $4,500 – $7,499; $7,500 — $16,199; >$16,200); employment status (0=not currently working; 1=currently working); and length of residency in years. All categorical variables were included as dummy variables in the regression models. African-American was used as the referent racial group in the models and the highest income category was used as the referent income group.

5.6.2. Neighborhood-level context covariates

Three additional neighborhood-level context variables at the block group level based on the 2000 US census were obtained from HEP and included in the regression models analyzing the *physical activity* outcomes. Previous research in the Detroit neighborhoods showed the relevance of these covariates (Coombe, 2007; Schulz et al., 2005b; Zenk et al., 2005). These variables were *percentage African American*, *percentage poverty*, and *residential stability*. All of these measures were included as continuous variables. The neighborhood-level context variables were included in the regression analyses at Level-3 by nesting respondents in 64 census block groups. The analyses on *pedestrian movement* and *pedestrian movement* + *sedentary behavior* included the covariate of mean block-level age taken from the 2000 US census.

5.7. Statistical analysis of pedestrian movement outcomes

The first section of the analysis investigates the link between the built environment and pedestrian movement employing pedestrian movement data from the 2006 neighborhood observations. Ordinary least squares regressions were performed for the continuous outcome measures of pedestrian movement and pedestrian movement + sedentary behavior along neighborhood streets. The outcome measures consisted of aggregated people counts per square acre at both the block-level and the rook-level. The environmental measures were entered consecutively into the regression models.

Because of the large concentration of older adults residing in parts of the Detroit neighborhoods, mean age by block was taken from 2000 US census data and also included in the analysis as a covariate (see section 5.6.1). Figure 5-11 diagrams the analysis used to test the relationships between the built environment factors and the pedestrian movement outcomes.

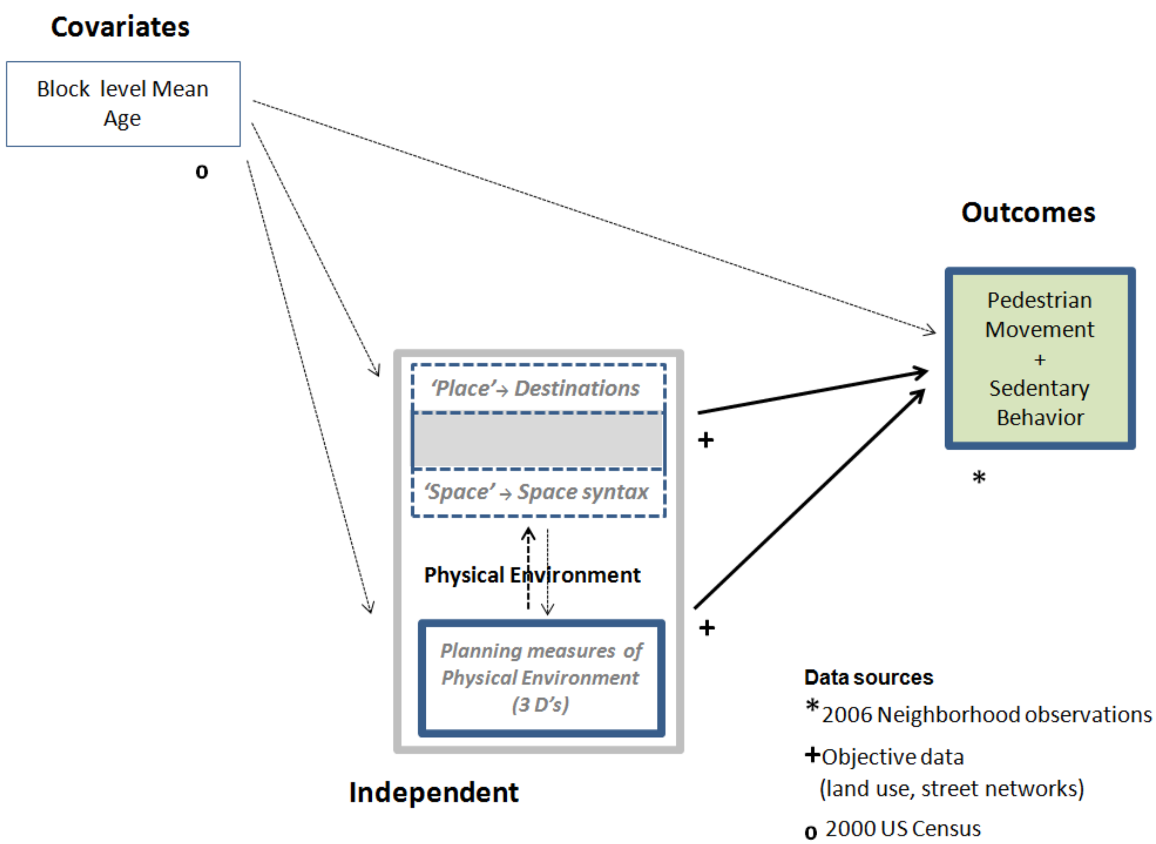

Figure 5-11 Analytical diagram showing the hypothesized relationships of built environment factors with pedestrian movement

The main hypothesis states that physical environment characteristics are positively associated with pedestrian movement. However, sedentary behavior (people resting, watching other people, or interacting with others) also occurs alongside pedestrian movement. Therefore, the associations between the built environment measures and sedentary behaviors along streets are also analyzed as a secondary relationship (refer to Figure 5-12). Regression analyses tested the associations between the physical environmental indicators and the outcomes of pedestrian movement and pedestrian movement + sedentary behavior. The analyses described in the following section are shown in Figure 5-12 and are adjusted for block-level mean age as shown in Figure 5-11.

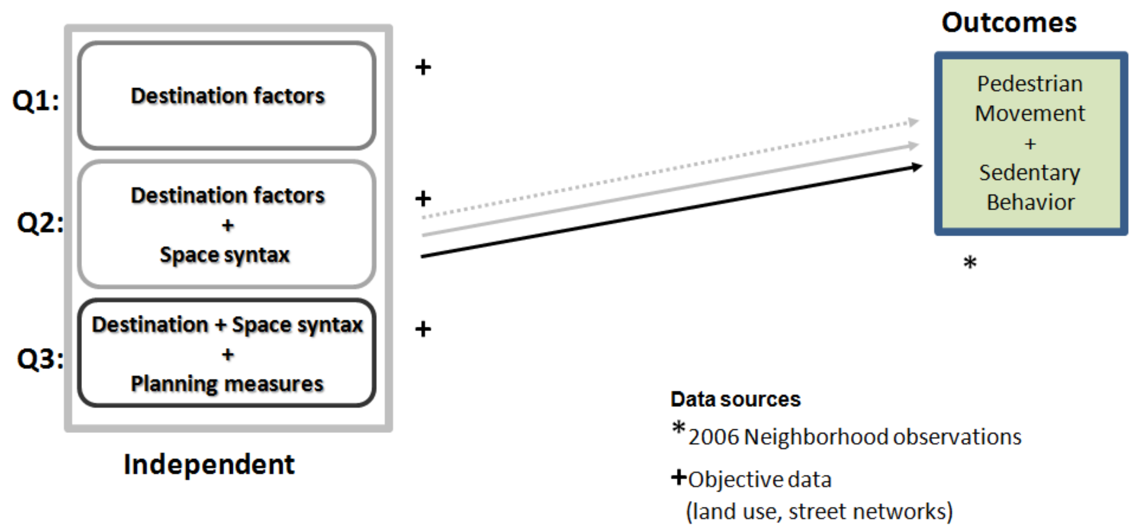

Figure 5-12 Analysis model of the hypothesized main effects of the built environment measures (Q1, Q2, Q3) on pedestrian movement

The first part of research question 1 (Q1 in Figure 5-12) asks: ***to what extent do destination measures have an association with pedestrian movement?*** The hypothesis suggests that there is a positive relationship between the three destinations measures (closer proximity, higher number of, and more clustering of destinations) and higher pedestrian movement. The selected measures were analyzed in separate regression models. The relationships were tested while adjusting for block and rook level mean age.

The first part of research question 2 (Q2 in Figure 5-12) is: ***what are the relative contributions of destination measures and space syntax measures to pedestrian movement?*** These models first tested the hypothesized positive association between both higher street network integration and higher street connectivity and higher pedestrian movement. They then analyzed the hypothesized negative association between pedestrian movement and both reach and destination reach, adjusted for block and rook level mean age.

The first part of research question 3 (Q3 in Figure 5-12) tests the relationships between the destination measures, space syntax measures, common planning measures, and pedestrian movement: ***are destination measures and space syntax measures more predictive of pedestrian movement than commonly used urban planning built environment measures?*** The hypotheses state that higher density, higher land use mix, and higher street connectivity are all associated with higher pedestrian movement. Density, land use mix, and street connectivity were entered individually into separate regression models, while another model tested the additive impact of the three measures. Density, street network connectivity, and land use mix were entered consecutively in order of their hypothesized predictive power according to the work of Frank et al. (2008; 2005a).

Models were also tested to investigate the additive association of destination factors and syntactic measures in research questions 2 and 3. Variables were included one after another into the models. The variance inflation factor (VIF), which estimates the degree to which variables are correlated, eliminated variables with a VIF>5 from inclusion into the multifactor regression models. In this study, VIF values <5 were accepted. Only indicators with lower correlations were entered into the same regression model and no more than three environmental variables were included at one time. This same process was also used in the analysis of physical activity outcomes (discussed next).

5.8. Statistical analysis of physical activity outcomes

Three-level weighted hierarchical generalized regression models were estimated for two continuous outcome variables: physical activity and waist circumference. (The data sources are indicated with symbols in Figure 5-13). The analysis was performed using HLM 6.02 (Scientific Software International, Lincolnwood IL, 2005). The physical environment measures at the neighborhood level (Level 2, *n*=146) were tested in HLM for their associations with the outcomes of individual-level overall physical activity and individual-level waist circumference (Level 1) (main effect). The analyses adjusted for individual-level socio-demographic variables including length of residency and employment status (Level 1, *n*=919) and neighborhood-level social context variables of percentage poverty, percentage African American, and residential stability (Level 3, *n*=64). The individual-level psychosocial perceptions of sense of community, neighborhood satisfaction, and safety stress (Level 1) are hypothesized to mediate the main effects.

In the above analyses, continuous variables were entered as grand mean centered variables into the models. By applying grand mean centering to the continuous independent variables, multicolinearity among components is reduced (Aiken & West, 1991; Bickel, 2007; Raudenbush & Bryk, 2002). The remaining socio-demographic variables were included as dummy variables (employment status, income, and race/ethnicity). All the analyses were adjusted for sample weights to ensure unequal probabilities of selection and to match the sample to the 2000 US census for the sampled areas. Figure 5-13 diagrams the analysis used to test the relationships between the built environment factors and the physical activity outcomes. Step-wise models were performed by including the physical environment measures one-by-one at Level-2. In some cases, two or three environmental variables were then included simultaneously in the models.

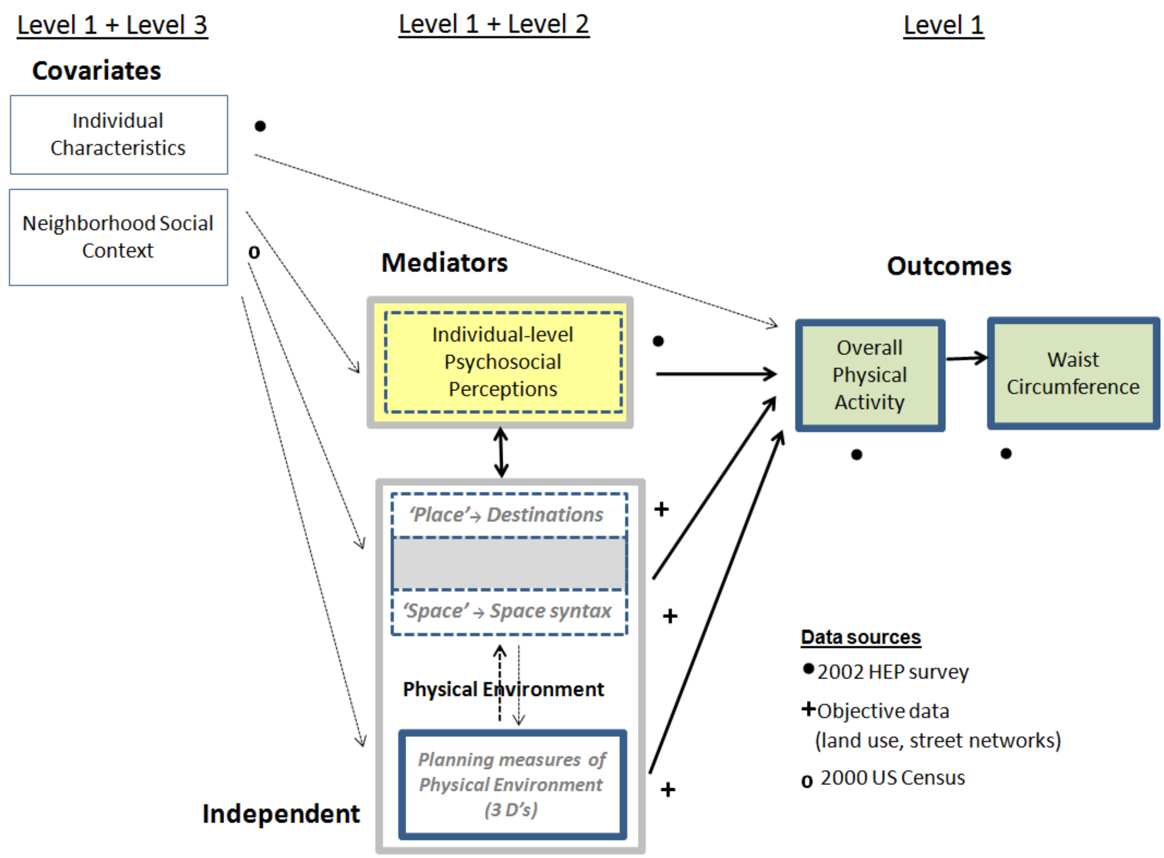

Figure 5-13 Analytical diagram showing the hypothesized relationships of built environment factors with physical activity.

The main interest in conducting this analysis was to look at the relationships between the built environment measures and overall physical activity and waist circumference. A secondary part of the analysis looked at the mediating role of psychosocial perceptions on the main effects (see Figure 5-14). The analyses described in the following section are diagrammed in Figure 5-14 and are adjusted for the individual characteristics and neighborhood social context covariates shown in Figure 5-13.

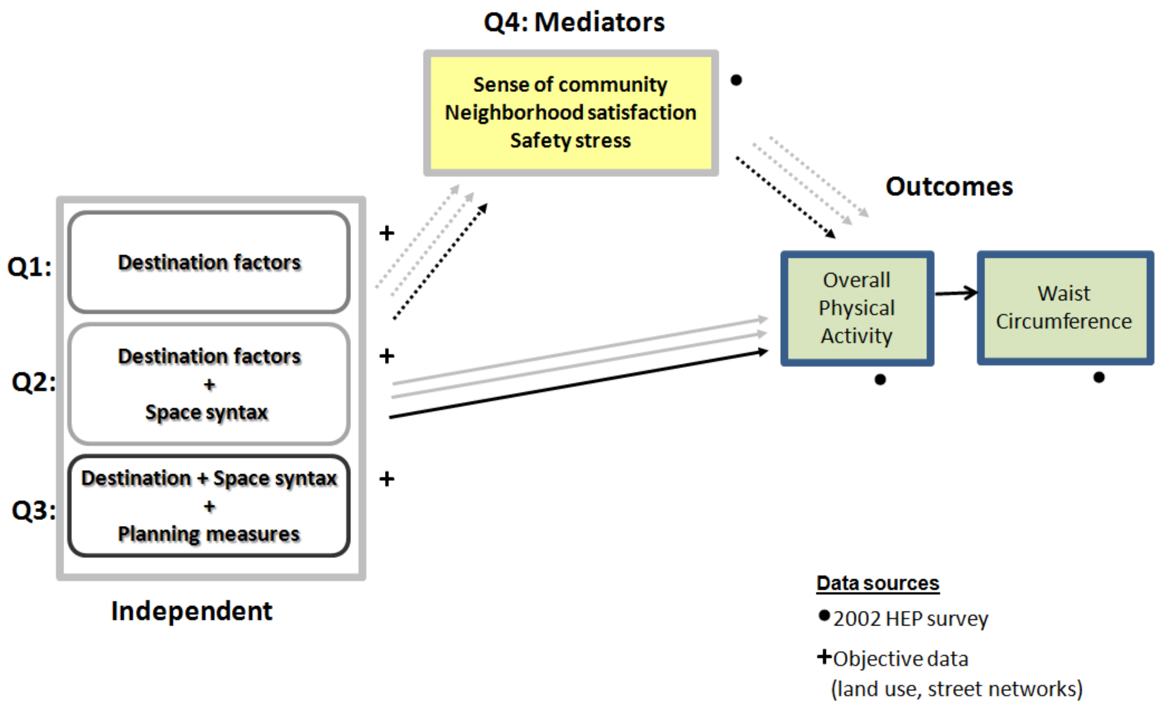

Figure 5-14 Analysis model of the hypothesized main effects of the built environment measures (Q1,Q2,Q3) on overall physical activity and waist circumference, and the hypothesized mediating effects of sense of community, neighborhood satisfaction, and safety stress (Q4)

The second part of research Question 1 (Q1 in Figure 5-14)—***to what extent do destination measures have an association with physical activity?***—is tested as follows. The first set of models tests the hypothesis that there is a positive association between the three destination factors (higher proximity, higher number, higher clustering) and higher overall physical activity. The measures of these three environmental factors were analyzed separately and combined. The same analysis is then repeated for waist circumference as the outcome measure, with the hypothesis predicting the opposite associations.

The second part of research question 2 (Q2 in Figure 5-14)—***what are the relative contributions of destination measures and space syntax measures to physical activity?***—is tested using models that investigate the hypothesized positive associations between both higher street network integration and higher street connectivity and overall physical activity. Further models test the hypothesized negative associations between both metric reach and destination reach with overall physical activity. Again, these two sets of analysis are also repeated for waist circumference as the outcome measure, with the hypotheses predicting the opposite relationships.

The second part of research question 3 (Q3 in Figure 5-14) investigates destination measures, space syntax measures, and common planning measures: ***are destination measures and space syntax measures more predictive of physical activity than commonly used urban planning built environment?*** Analyses were conducted to test the hypothesized positive relationships between higher overall physical activity and the three planning factors of higher density, higher land use mix, and higher street connectivity. The planning measures were entered individually into separate models. Another model tested the additive impact of the three measures. Density was entered first, street connectivity second, and land use mix third in order of their hypothesized predictive power according to the work of Frank et al. (2008; 2005a). These steps were repeated using waist circumference as an outcome measure.

Research question 4 (Q4 in Figure 5-14)***—do perceptions of the psychosocial environment mediate the associations between the built environment and physical activity?***—tested the hypothesis that the psychosocial variables of *sense of community, neighborhood satisfaction,* and *safety stress* mediate the main effects observed between the built environmental factors and the physical activity outcomes. The test for mediation was conducted following the steps proposed by Baron and Kenny (1986), also see Hayes (2009).

Analysis was first conducted to investigate the main effects of each of the destination measures, syntactic measures, and planning measures on the outcomes of overall *physical activity* and *waist circumference* as described in the sections above pertaining to research questions 1-3. Next, analyses were conducted to see whether the independent variables that had a significant relationship with the outcome variables (main effect) also had a significant relationship with the proposed mediating variables (*sense of community, neighborhood satisfaction,* and *safety stress*). Finally, analyses were performed to determine if there were significant relationships between the proposed mediating variables and the outcome variables.

As per Baron and Kenny (1986), the preconditions for mediation are that there are significant relationships between the following sets of variables: independent and outcome (main effect), independent and mediating, and mediating and outcome. If these preconditions are met, mediation occurs when the main effect becomes insignificant after the mediating variable is accounted for. It is predicted that higher *sense of community*, higher *neighborhood satisfaction*, and lower *safety stress* are all associated with higher overall *physical activity* and lower *waist circumference*.

Chapter 6
FINDINGS: BUILT ENVIRONMENT AND PEDESTRIAN MOVEMENT

6.1. Introduction

The findings from this dissertation will be presented in two chapters. Chapter 6 presents the analysis looking at the associations of the built environment and the pedestrian movement outcomes, and Chapter 7 presents the findings pertaining to the relationships between the built environment and the physical activity outcomes. The two main outcomes were separated in analysis due to their different conceptual focus and the different analytical procedures applied. Both chapters follow the sequence of the research questions. Research questions 1-3 are discussed in Chapter 6 and research questions 1-4 are discussed in Chapter 7 (the mediating effects of neighborhood perceptions were not tested for the pedestrian movement outcomes).

The four pedestrian movement outcomes are *pedestrian movement* and *pedestrian movement + sedentary behavior*, each at the block level and the rook level. Correlations were run between the 73 physical environmental measures and each of the four pedestrian movement outcomes. The correlation matrix showing all the results is available in Appendix A on page 275. Table 6-1 provides a summary of the percentage of variables in each group that had significant correlations with the four pedestrian movement outcomes (see page 150). The right column shows those variables with the strongest correlations within in each factor group. Selected variables with significant correlations with the *pedestrian movement* outcomes were then further analyzed using ordinary least squares regression analysis, adjusting for either block level or rook level mean age. Starting with section 6.2, this chapter focuses on the results of the regression analyses that were completed on the environmental variables with the most significant correlations with the pedestrian movement outcomes and the patterns that were identified within each variable group.

Factor groups	Percentage Significant					Strongest correlations with pedestrian movement
	All pedestrian movement outcomes	**Pedestrian movement (block)**	**Ped. Mov. + Sed. Beh. (block)**	**Pedestrian movement (rook)**	**Ped. Mov. + Sed. Beh. (rook)**	
Destination measures						
Proximity to destinations	93% of 40	100%	90%	100%	80%	All destinations without parks Commercial destinations Educational destinations Food destinations
Number of destinations	100% of 32	100%	100%	100%	100%	All destinations without parks Food destinations
Clustering of destinations	47% of 96	50%	46%	42%	50%	All destinations without parks Food destinations
Number of bundles	100% of 24	100%	100%	100%	100%	All destinations without parks bundles
Space syntax measures						
Street network integration	50% of 16	50%	50%	50%	50%	Average city-wide integration at the 1/2 mile radius
Distance to “main streets” and “place chains”	50% of 8	100%	0%	100%	0%	Distance to “place chains”
Street network connectivity	0% of 16	0%	0%	0%	0%	Average city-wide connectivity at the 1/2 mile radius
Reach	0% of 8	0%	0%	0%	0%	Metric reach at ½ mile
Destination Reach	54% of 24	83%	67%	67%	0%	All destinations without parks at 1 mile distance
Urban planning measures						
Density	67% of 12	67%	67%	67%	67%	1/2 mile radius; 1/4 mile radius; block level
Land use mix	13% of 8	50%	0%	0%	0%	1/2 mile radius; 1/4 mile radius
Street connectivity	63% of 8	50%	50%	50%	100%	1/2 mile radius; 1/4 mile radius

Table 6-1 Summary table of the percentage of variables that showed significant correlations with the pedestrian movement and pedestrian movement + sedentary behavior outcomes at the block and rook levels. The number of variables tested in each factor group is outlined in Chapter 5, RESEARCH METHODOLOGY.

6.2. Research question 1: Destination measures and pedestrian movement

Research Question 1: *To what extent do destination measures have an association with pedestrian movement*?

This analysis tests whether proximity to destinations, number of destinations, and clustering of destinations are related to the pedestrian movement outcomes. The hypotheses from the literature are that closer proximity, greater number of, and more clustering of destinations are all related to higher pedestrian movement.

Analyses were run for *pedestrian movement* and *pedestrian movement + sedentary behavior* occurring in the sampled blocks and the sampled rooks. Ordinary least squares regression models were estimated for all the analyses presented in the following section. The analyses are adjusted for age; mean block level age was derived from the 2000 US census and mean rook-level age was calculated for the rook level analyses.

6.2.1. Proximity to destinations

The regression analysis for the proximity to destinations tested the following destination groups: *all destinations, all destinations without parks, commercial, educational*, and *food destinations*. It should be noted that because a negative proximity value means that the destinations are closer, the hypotheses predict a negative association between proximity and *pedestrian movement* outcomes.

A comparison of the regression models of the two proximity measures of *all destinations* and *all destinations without parks* at the airline distance indicates that proximity to *all* *destinations without parks* has a stronger relationship with *pedestrian movement* at the rook and the block levels (see Table 6-2, models 1-2 and 5-6). The variances explained by the proximity to *all destinations* at the airline distance are 3% and 2% (block and rook levels), whereas the variances explained by the proximity to *all destinations without parks* at the airline distance are 8% and 4% (block and rook levels). The results showing proximity to *all destinations* at the network distance (at both the block and rook levels) are exactly the same as the results showing proximity to *all destinations without parks* at the network distance (at the corresponding block and rook levels). Because this finding was quite unexpected, the relevant analyses were each triple-checked to verify the results. The closer *all destinations without parks* are to sample blocks, the higher the observed *pedestrian movement* around the block (β=-0.0019, p=.003; r^2=0.08)[22] and the rook (β=-0.0013, p=.016; r^2=0.04). See Table 6-2, Models 5 and 6.

Although proximity measures to all other destination types show higher prediction to *pedestrian movement* than to *pedestrian movement* + *sedentary behavior*s, proximity to commercial destinations shows a steeper regression slope on *movement* + *sedentary behavior*s than on *pedestrian movement* alone. For example, proximity to commercial destinations at the airline distance and the block level has a steeper regression slope on *pedestrian movement* + *sedentary behavior* (β=-0.0031) than on *pedestrian movement alone* (β=-0.0015)—refer to Table 6-3, models 1A and 1B. A similar pattern is observed at the rook level (Table 6-3, Models 2A and 2B).

22 The first number indicates the estimate, the p-value is two-tailed

Proximity to all destinations (airline and network distances)

	MODEL 1 **Pedestrian movement (block)**			MODEL 2 **Pedestrian movement (rook)**			MODEL 3 **Pedestrian movement (block)**			MODEL 4 **Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.3934	0.7008	<.0001	2.8360	0.7440	0.0002	3.5666	0.7116	<.0001	3.1847	0.7297	<.0001
Age	-0.0338	0.0202	0.098	-0.0197	0.0235	0.405	-0.0364	0.0202	0.075	-0.0262	0.0226	0.248
All destinations (airline)	-0.0016	0.0009	0.065	-0.0014	0.0008	0.080						
All destinations (network)							-0.0015	0.0007	**0.029**	-0.0015	0.0006	**0.011**
Adj R-Square		0.03			0.02			0.05			0.05	

Proximity to all destinations without parks (airline and network distances)

	MODEL 5 **Pedestrian movement (block)**			MODEL 6 **Pedestrian movement (rook)**			MODEL 7 **Pedestrian movement (block)**			MODEL 8 **Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.6830	0.6797	<.0001	3.0335	0.7434	<.0001	3.5666	0.7116	<.0001	3.1847	0.7297	<.0001
Age	-0.0385	0.0198	0.054	-0.0244	0.0233	0.296	-0.0364	0.0202	0.075	-0.0262	0.0226	0.248
All destinations without parks (airline)	-0.0019	0.0006	**0.003**	-0.0013	0.0005	**0.016**						
All destinations without parks (network)							-0.0015	0.0007	**0.029**	-0.0015	0.0006	**0.011**
Adj R-Square		0.08			0.04			0.05			0.05	

Table 6-2 **Regression models of *pedestrian movement* and proximity to all destinations and all destinations without parks, adjusted for block and rook level age**

The proximity measures to commercial destinations indicate associations with *pedestrian movement* and *pedestrian movement* + *sedentary behavior* at both the airline and network distances—see Table 6-3. However, *pedestrian movement* and *pedestrian movement* + *sedentary behavior* have a higher explained variance at the block level than at the rook level. For example, proximity to commercial destinations at the airline distance is more highly negatively associated with *pedestrian movement* at the block level (β=-0.0015, p=.0004; r^2=0.011) than at the rook level (β=-0.0009, p=.023; r^2=0.04), and the same holds true for *pedestrian movement* + *sedentary behavior*: (β=-0.0031, p=.0008; r^2=0.11) at the block level compared to (β=-0.0018, p=.019; r^2=0.04) at the rook level (see Table 6-3, models 1A, 1B, 2A, and 2B).

Proximity to commercial destinations at the block level explains 11% of the total variance on *pedestrian movement* at both the airline and network distances, and it explains 11% (airline distance) and 9% (network distance) of the variance on *pedestrian movement* + *sedentary behavior*. The closeness of these figures suggests that regardless of airline distance or network distance, the closer the distance to commercial destinations, the higher the *pedestrian movement* and *pedestrian movement* + *sedentary behavior*.

Proximity to commercial destinations

Variable	MODEL 1A **Pedestrian movement (block)** Estimate	Std	p-value	MODEL 1B **Ped. mov. + Sed. beh. (block)** Estimate	Std	p-value	MODEL 2A **Pedestrian movement (rook)** Estimate	Std	p-value	MODEL 2B **Ped. mov + Sed. beh.. (rook)** Estimate	Std	p-value
Intercept	3.5585	0.6437	<.0001	8.6051	1.3746	<.0001	3.0576	0.7510	<.0001	6.1915	1.4566	<.0001
Age	-0.0308	0.0192	0.113	-0.0741	0.0411	0.074	-0.0252	0.0233	0.283	-0.0301	0.0453	0.508
Commercial destinations (airline)	-0.0015	0.0004	**0.0004**	-0.0031	0.0009	**0.001**	-0.0009	0.00039	**0.022**	-0.0018	0.0008	**0.019**
Adj R-Square	0.11			0.11			0.04			0.04		

Variable	MODEL 3A **Pedestrian movement (block)** Estimate	Std	p-value	MODEL 3B **Ped. mov. + Sed. beh. (block)** Estimate	Std	p-value	MODEL 4A **Pedestrian movement (rook)** Estimate	Std	p-value	MODEL 4B **Ped. mov + Sed. beh.. (rook)** Estimate	Std	p-value
Intercept	3.6372	0.6526	<.0001	8.6448	1.4050	<.0001	3.2598	0.7370	<.0001	6.4881	1.4341	<.0001
Age	-0.0338	0.0193	0.083	-0.0795	0.0415	0.058	-0.0309	0.0227	0.176	-0.0395	0.0441	0.372
Commercial destinations (network)	-0.0012	0.0003	**0.001**	-0.0022	0.0007	**0.003**	-0.0008	0.0003	0.011	-0.0015	0.0006	**0.014**
	0.11			0.09			0.05			0.04		

Table 6-3 Regression models of *pedestrian movement* and *pedestrian movement + sedentary behavior* and the proximity[23] to commercial destinations, adjusted by block and rook level age

23 All proximity measures were calculated in linear feet. Negative values (-) indicates that destinations are closer

Proximity to food destinations at both the airline and network distances showed a significant negative relationship with *pedestrian movement* at both the block and rook levels (Table 6-4, Model 1-4). This means that the closer the food destinations, the higher the *pedestrian movement* at both the airline distance (block level: β=-0.0005, p=.003; r^2=0.08) and the network distance (block level: β=-0.0004, p=<.0001; r^2=0.08)—see Table 6-4, Models 1 and 2. These measures of food destinations show similar associations with *pedestrian movement* at the airline and network distances. However, more variance in *pedestrian movement* is explained by the proximity to food destinations at the rook level (10%) than at the block level (8%).

Proximity to food destinations

	MODEL 1 **Pedestrian movement (block)**			MODEL 2 **Pedestrian movement (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.0062	0.6275	<.0001	3.0232	0.6283	<.0001
Age	-0.0147	0.0201	0.466	-0.0145	0.0202	0.474
Food destinations (airline)	-0.0005	0.0002	**0.003**			
Food destinations (network)				-0.0004	0.0001	**0.003**
Adj R-Square	0.08			0.08		

	MODEL 3 **Pedestrian movement (rook)**			MODEL 4 **Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	2.4435	0.6679	0.0004	2.5251	0.6668	0.0003
Age	0.0056	0.0226	0.804	0.0038	0.0225	0.865
Food destinations (airline)	-0.0006	0.0001	**<.0001**			
Food destinations (network)				-0.0005	0.0001	**<.0001**
Adj R-Square	0.10			0.10		

Table 6-4 Regression models of *pedestrian movement* and the proximity to food destinations, adjusted for block and rook level age

Similar to the other destination types discussed above, closer proximity to educational uses was related to higher *pedestrian movement*. These associations were stronger at the rook level than the block level at both airline and network distances—in Table 6-5, compare Models 1 and 3 to Models 2 and 4. An example at the airline distance demonstrates that proximity to educational destinations at the rook level (β=-0.0007, p=.0002; r^2=0.12) is more strongly associated with *pedestrian movement* than it is at the block level (β=-0.0004, p=.040; r^2=0.04).

Proximity to educational destinations

	MODEL 1 **Pedestrian movement (block)**			MODEL 2 **Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.1986	0.6594	<.0001	3.2297	0.6928	<.0001
Age	-0.0245	0.0202	0.227	-0.0193	0.0218	0.380
Educational destinations (airline)	-0.0004	0.0002	**0.040**	-0.0007	0.0002	**0.0002**
Adj R-Square	0.04			0.12		

	MODEL 3 **Pedestrian movement (block)**			MODEL 4 **Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.1011	0.6470	<.0001	3.0113	0.6751	<.0001
Age	-0.0202	0.0204	0.323	-0.0102	0.0219	0.640
Educational destinations (network)	-0.0003	0.0002	**0.028**	-0.0005	0.0001	**<.0001**
Adj R-Square	0.05			0.14		

Table 6-5 Regression models of *pedestrian movement* and the proximity to educational destinations, adjusted for block and rook level age

6.2.2. Number of destinations

All the *number of destinations* measures were significantly correlated with *pedestrian movement* (block and rook level) and *pedestrian movement* + *sedentary behavior* (block and rook level). The analyses showed that the measures had stronger correlations with *pedestrian movement* than with *pedestrian movement* + *sedentary behavior* at both levels—see the correlation table in Appendix A on page 275. Regression analyses of the environmental variables demonstrated that the *number of all destinations without parks* at the ¼ mile is most related to *pedestrian movement*; the results show a strong positive association at the block level (β=0.057, p<.0001; r^2=0.27), and the rook level (β=0.054, p<.0001; r^2=0.30). Table 6-6 shows the difference between the ¼ mile and ½ mile levels for the *number of all destinations without parks*. Even though all the analyses show p<.0001, the ¼ mile values show steeper regression slopes and higher explained variance—compare Models 1 and 2 (1/4 mile radius) with Models 3 and 4 (1/2 mile radius).

The rest of the *number of destinations* measures also showed better relationships at the ¼ mile level. Results from the associations of the other *number of destinations* measures (tables not shown) with *pedestrian movement* are:

[1] *All destination*s at the ¼ mile: block level (β=0.056, p<.0001; r^2=0.25) and rook level (β=0.054, p<.0001; r^2=0.28),

[2] *commercial destinations* at the ¼ mile: block level (β=0.062, p<.0001; r^2=0.26) and rook level (β=0.058, p<.0001; r^2=0.28),

[3] *food destinations* at the ¼ mile: block level (β=0.032, p<.0001; r^2=0.18) and rook level (β=0.030, p<.0001; r^2=0.17).

Number of destinations

	MODEL 1 Pedestrian movement (block)			MODEL 2 Pedestrian movement (rook)		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	1.0744	0.6290	0.091	0.7593	0.6648	0.256
Age	-0.0143	0.0176	0.418	-0.0036	0.0197	0.856
All destinations without parks (1/4 mile radius)	0.0566	0.0091	**<.0001**	0.0535	0.0079	**<.0001**
Adj R-Square	0.27			0.30		
	MODEL 3 Pedestrian movement (block)			MODEL 4 Pedestrian movement (rook)		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	-0.0670	0.7801	0.932	-0.4351	0.8313	0.602
Age	-0.0134	0.0181	0.460	0.0031	0.0209	0.884
All destinations without parks (1/2 mile radius)	0.0274	0.0049	**<.0001**	0.0252	0.0044	**<.0001**
Adj R-Square	0.23			0.23		

Table 6-6 Regression models of *pedestrian movement* and the number of all destinations without parks at the ¼ mile and ½ mile radius, adjusted for block and rook level age

6.2.3. Clustering of destinations

24 *clustering of destinations* variables were analyzed for correlation with the *pedestrian movement* outcomes. The measures distinguished between the type of destination group (*all, all without parks, commercial, food*), the neighborhood size (¼ mile, ½ mile), and the size of the destinations bundles (1/32nd, 1/16th, and 1/8th of a mile). The *clustering of destinations* measures at the ¼ mile could be ruled out early on for three of the destination groups; none of the clustering measures at the ¼ mile showed significant correlations with any of the pedestrian movement outcomes except for the *clustering of food destinations*, which were associated with the *pedestrian movement* outcomes almost exclusively at the ¼ mile level—see correlation table in Appendix A on page 275.

The correlations between the *clustering of destinations* measures and the *pedestrian movement* outcomes at the block level are slightly stronger than the correlations at the rook levels. Therefore, results from the block level analyses will be presented.

Significant results from the regression analyses indicate that the clustering of destinations is better associated with *pedestrian movement* + *sedentary behavior* than with *pedestrian movement* alone. See Table 6-7 and Table 6-8 below and Table B-1 and Table B-2 in Appendix B (page 282). For example, the variance of *pedestrian movement* + *sedentary behavior* explained by the clustering of *all destinations without parks* with $1/32^{nd}$, $1/16^{th}$, and $1/8^{th}$of a mile bundles are 10% each, whereas the variance of *pedestrian movement* explained by the clustering of *all destinations without parks* is 6% with $1/32^{nd}$ and $1/8^{th}$ mile bundles and 7% with $1/16^{th}$ mile bundles (see Table 6-7).

A comparison of the explained variances of clustering of *all destinations*, *all destinations without parks*, *commercial*, and *food destinations* on *pedestrian movement* and *pedestrian movement* + *sedentary behavior* is presented in the following tables. Clustering of *all destinations without parks* (see Table 6-7) shows a significant negative association and clustering of *food destinations* (see Table 6-8) shows a significant positive association with *pedestrian movement* and *pedestrian movement* + *sedentary behavior.* Similar tables with the results for *clustering of all destinations* (Table B-1) and *clustering of commercial destinations* (Table B-2) can be found in Appendix B (page 282). An unexpected finding shows that *pedestrian movement* and *pedestrian movement* + *sedentary behavior* decrease as some types of destinations become more clustered. See, for example, the negative coefficients in Table 6-7 on the clustering of *all destinations without parks*.

The size of the destination bundles also plays a role in how the clustering measures relate to the *pedestrian movement* outcomes. The results show that the smallest destination bundles (1/32nd of a mile), show the strongest associations with *pedestrian movement* and *pedestrian movement + sedentary behavior*. For example, clustering of *all destinations without parks* is more strongly associated with less *pedestrian movement + sedentary behavior* at the 1/32nd of a mile bundle (β= -58.94, p=.0001; r^2=0.10) than at the 1/8th of a mile bundle (β= -5.65, p=0.001; r^2=0.10)—see Table 6-7, Models 2 and 6.

Clustering of all destination without parks at the ½ mile radius

	MODEL 1 **Pedestrian movement (block)**			MODEL 2 **Ped. mov. + sed. beh. (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.7709	0.7206	<.0001	9.6016	1.5010	<.0001
Age	-0.0314	0.0198	0.115	-0.0767	0.0412	0.066
All destinations without parks (1/32th mile bundle)	-22.1970	8.5157	**0.011**	-58.9423	17.7373	**0.001**
Adj R-Square	0.06			0.10		

	MODEL 3 **Pedestrian movement (block)**			MODEL 4 **Ped. mov. + sed. beh. (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.6801	0.7016	<.0001	9.4366	1.4543	<.0001
Age	-0.0318	0.0198	0.111	-0.0779	0.0410	0.060
All destinations without parks (1/16th mile bundle)	-5.2902	1.9918	**0.009**	-14.5486	4.1287	**0.001**
Adj R-Square	0.07			0.10		

	MODEL 5 **Pedestrian movement (block)**			MODEL 6 **Ped. mov. + sed. beh. (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.6040	0.6919	<.0001	9.1847	1.4389	<.0001
Age	-0.0302	0.0198	0.130	-0.0734	0.0411	0.077
All destinations without parks (1/8th mile bundle)	-2.1005	0.8030	**0.010**	-5.6536	1.6699	**0.001**
Adj R-Square	0.06			0.10		

Table 6-7 Regression models of *pedestrian movement* and *pedestrian movement + sedentary behavior* and clustering of all destinations without parks consisting of 1/32nd, 1/16th, and 1/8th of a mile destination bundles, adjusted for block or rook level age

Clustering of all destinations and *clustering of commercial destinations* follow the same trend—see Table B-1 and Table B-2 in Appendix B (page 282). Clustering of food destinations also follow a similar pattern, with higher positive associations with *pedestrian movement* outcomes for the smaller destination bundle sizes. *Clustering of food destinations* at the 1/16th mile bundle (β= 2.159, p=0.004; r^2=0.08) has a steeper regression slope on *pedestrian movement* + *sedentary behavior* than at the 1/8th mile bundle (β= 1.153, p=0.001; r^2=0.10)—see Table 6-8, Models 2 and 4.

Clustering of food destination at the ¼ mile radius

	MODEL 1 **Pedestrian movement (block)**			MODEL 2 **Ped. mov. + sed. beh. (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	2.1200	0.6745	0.002	5.6671	1.4354	0.000
Age	-0.0141	0.0202	0.487	-0.0398	0.0430	0.357
Food destinations (1/16th mile bundle)	1.0476	0.3447	**0.003**	2.1596	0.7335	**0.004**
Adj R-Square		0.08			0.08	

	MODEL 3 **Pedestrian movement (block)**			MODEL 4 **Ped. mov. + sed. beh. (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	2.4799	0.6564	0.000	6.0557	1.3552	<.0001
Age	-0.0266	0.0199	0.184	-0.0630	0.0411	0.128
Food destinations (1/8th mile bundle)	0.3905	0.1596	**0.016**	1.1528	0.3294	**0.001**
Adj R-Square		0.06			0.10	

Table 6-8 Regression models of *pedestrian movement* and *pedestrian movement* + *sedentary behavior* and clustering of food destinations consisting of 1/16th and 1/8th of a mile destination bundles, adjusted for block or rook level age

There was concern during the analysis with the *clustering of food destinations* at the ¼ mile that 1/32nd of a mile bundle is too small and the land use is too specific for reliable analysis. The occurrence of food destinations at the ¼ mile for 1/32nd of a mile destination bundles is so infrequent that the analysis is unable to show reliable results; the mean number of food destinations in a ¼ mile radius area is 2.5 with a standard deviation of 2.1. At least two destinations are needed for one cluster to form, leaving a ¼ mile area with only one food cluster. For this reason, the 1/32nd of a mile bundle size was excluded from analysis of the *clustering of food destinations* at the ¼ mile. In addition, measures of the *clustering of food destinations* at the 1/32nd of a mile bundle were not correlated with the *pedestrian movement* outcomes. Therefore, no further analyses were conducted at the 1/32nd mile bundle size.

6.2.3.a. Number of destinations and clustering

The significance of the *clustering of destination* measures at the ½ mile radius was presented in the preceding pages. One concern with the measure of clustering is that the *number of destinations* may confound the "effects" of clustering. Regression models were run to test for the possible confounding effect of the *number of destinations* on the results of the *clustering of destinations*. As already discussed, the *number of all destinations without parks* at the ½ mile and the *clustering of all destinations* without parks at the ½ mile were both shown to be important measures in their factor groups, and these measures were identified for further analysis.

Findings from the analysis show that the *number of all destinations without parks* located within a ½ mile radius from sample blocks is positively associated with *pedestrian movement* at the block level (β=0.027, $p<.0001$; r^2=0.23) when run in its own regression model. The *clustering of all destinations without parks* is also significantly associated with *pedestrian movement* at the block level when analyzed independently (β=-22.197, p=0.011; r^2=0.06). See Table 6-9, Models 1 and 2.

However, the *clustering of all destinations without parks* becomes insignificant after including the *number of destinations* variable in the model (p=0.186). This combined regression model explains almost a quarter of the variance ($r^2=0.24$) on *pedestrian movement* (Table 6-9, Model 3), with the *number of destinations without parks* remaining as the significant variable. The variance inflation factor is 2, an acceptable value indicating low multicolinearity. Regression analyses combining the *clustering of all destinations* and *clustering of commercial destinations* with the corresponding *number of destinations* variables reveal a similar pattern.

	Number of destinations			**Clustering**			**Number of destinations + clustering**		
	MODEL 1			MODEL 2			MODEL 3		
	Pedestrian movement (block)			**Pedestrian movement (block)**			**Pedestrian movement (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	-0.06696	0.78013	0.9318	3.77092	0.72064	<.0001	-1.30333	1.21115	0.2844
Age	-0.01344	0.01814	0.4603	-0.03144	0.01979	0.1153	-0.00858	0.01843	0.6427
Number of all destinations without parks (1/2 mile radius)	0.02744	0.00493	**<.0001**				0.03367	0.00678	**<.0001**
Clustering of all destinations without parks (1/2 mile radius; 1/32nd mile bundle)				-22.197	8.51568	**0.0105**	14.11601	10.6051	0.1861
Adj R-Square	0.23			0.06			0.24		

Table 6-9 Regression models of *pedestrian movement* and number of all destinations without parks and clustering of all destinations with parks, adjusted for block level age

An investigation of the scatter plots of the *number of destinations* and *clustering of destinations* shows an exponential decline in *clustering* as the *number of destinations* increases for *all destinations* (-0.418, p<.001), *all destinations without parks* (-0.667, p<.001), *and commercial destinations* (-0.4806, p<.001)—complete results not shown. Since these three *number of destinations* measures remain highly significant after including the *clustering of destinations* measures in combined regression analyses and the three *clustering of destinations* measures become insignificant, it is likely that the *number of destinations* is the dominant factor affecting pedestrian movement for *all destinations, all destinations without parks, and commercial destinations*.

This is not the case, however, with *food destinations.* Because *food destinations* at the ¼ mile were not analyzed at the 1/32 bundle size, the *clustering of food destinations* at the ¼ mile and 1/16th bundle size is reported in Table 6-10. The correlational scatter plot comparing the *number of food destinations* and *clustering of food destination* did not turn out significant, unlike the other three types of destination measures discussed above. Also unlike the other destination types, *clustering of food destinations* remains significantly associated with *pedestrian movement* even when the *number of food destinations* was included in the analysis (β=0.722, p=.031; r^2=.14)—see Table 6-10, Model 3. The VIF for *number of food destinations* and *clustering of food destinations* is 1.1. These findings indicate that the *number of food destinations* does not confound the effects of *clustering of food destinations* on *pedestrian movement*; neither factor is clearly dominant as with the other three types of destination groups.

	Number of destinations			**Clustering**			**Number of destinations + clustering**		
	MODEL 1			MODEL 2			MODEL 3		
	Pedestrian movement (block)			**Pedestrian movement (block)**			**Pedestrian movement (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	1.04250	0.6678	0.035	2.1200	0.6745	0.002	1.0652	0.6761	0.118
Age	-0.0117	0.0189	0.536	-0.0141	0.0202	0.487	-0.0031	0.0190	0.871
Number of food destinations (1/4 mile radius)	0.3238	0.0685	**<.0001**				0.2878	0.0692	**<.0001**
Clustering of food destinations (1/4 mile radius; 1/16nd mile bundle)				1.0476	0.3447	**0.003**	0.7215	0.3297	**0.031**
Adj R-Square	0.20			0.08			0.14		

Table 6-10 Regression models of *pedestrian movement*, number of food destinations, and clustering of food destinations, adjusted for block level age

6.2.3.b. Number of bundles

The number of destination bundles is the factor group found to have the strongest positive associations with the *pedestrian movement* outcomes as compared to all other destination measures in this study—see summary Table 6-21 on page 179 at the end of this chapter. All of the correlations of the *number of destination bundles* and the *pedestrian movement outcomes* show significant positive relationships. See Table 6-11 for the results of the regression analyses showing the relationships between *pedestrian movement* and *number of destination bundles* for *all destinations, all destinations without parks,* and *commercial destinations*.

Number of destination bundles at the ½ mile radius

	MODEL 1 **Pedestrian movement (block)**			MODEL 2 **Pedestrian movement (block)**			MODEL 3 **Pedestrian movement (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	1.3027	0.6030	0.0331	1.2482	0.5902	0.0369	1.3902	0.5982	0.0221
Age	-0.0219	0.0173	0.2070	-0.0184	0.0170	0.2819	-0.0184	0.0173	0.2896
All destinations bundles (1/16th mile bundle)	0.0523	0.0081	**<.0001**						
All destinations without parks bundles (1/16th mile bundle)				0.0529	0.0077	**<.0001**			
Commercial destination bundles (1/16th mile bundle)							0.0577	0.0089	**<.0001**
Adj R-Square	0.29			0.32			0.29		

Table 6-11 Regression models of *pedestrian movement* and number of destination bundles for all destinations, all destinations without parks, and commercial destinations, adjusted for block level age

A general pattern emerged showing that the associations are stronger with *pedestrian movement* than with *pedestrian movement + sedentary behavior* and stronger at the block level than at the rook level (see correlation table in Appendix A on page 275 for all results). The *number of bundles* for the destination types *all destinations, all destinations without parks, and commercial destinations* showed a stronger relationship with *pedestrian movement* than with *pedestrian movement + sedentary behavior* (see Table

B-3 in Appendix B, page 282). Therefore, this discussion focuses on the outcome of *pedestrian movement.* At the ½ mile radius, the *number of all destinations without parks bundles* (1/16th of a mile clusters) is more strongly related to *pedestrian movement* at the block level (β=0.053, p<.0001; r^2=0.32) than at the rook level (β=0.044, p<.0001; r^2=0.27)—see Table 6-12, Models 1 and 2.

Similar to the discussion in section 6.2.3.a on *number of destinations* and *clustering,* there is a concern that the *number of destinations* may have a confounding effect on the relationship between the *number of bundles* and the *pedestrian movement* outcomes since the more destinations there are, the greater the chances of there also being a higher *number of bundles.* The regression models testing whether *number of destinations* confounds the relationship between *number of bundles* and the outcome of *pedestrian movement* + *sedentary behavior* are shown in Table B-4 in Appendix B (page 282). The results are not shown here because the two independent measures combined in the regression analysis explained less of the variance on *pedestrian movement* + *sedentary behavior* than they explained on *pedestrian movement* alone.

In Table 6-12, Models 3 and 4, the *number of bundles* was adjusted for the *number of all destinations without parks* to test for any confounding effects on the *pedestrian movement* outcomes. The results show that the *number of all destinations without parks bundles* remained significantly associated with *pedestrian movement* at the block level (β=0.040, p<.0001; r^2=0.34) and the rook level (β=0.031, p<.0001; r^2=0.31). This demonstrates that the *number of destinations* does not confound the effects of the *number of bundles* for this destination type*.* The variance inflation factor was estimated at 1.57, well in the acceptable range for minimal multicolinearity.

	Number of destination bundles						Number of destination bundles + Number of all destinations					
	MODEL 1 **Pedestrian movement (block)**			MODEL 2 **Pedestrian movement (rook)**			MODEL 3 **Pedestrian movement (block)**			MODEL 4 **Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	1.2482	0.5902	0.037	1.1297	0.6597	0.090	0.2566	0.7253	0.724	-0.1166	0.7909	0.883
Age	-0.0184	0.0170	0.282	-0.0099	0.0199	0.622	-0.0135	0.01677	0.424	0.0011	0.0198	0.958
All destinations without parks bundles (1/2 mile radius; 1/16th mile bundle)	0.0529	0.0077	**<.0001**	0.0444	0.0070	**<.0001**	0.0403	0.00937	**<.0001**	0.0309	0.0085	**0.000**
Number of all destinations without parks (1/2 mile radius)							0.0129	0.00568	**0.025**	0.01340	0.0052	**0.008**
Adj R-Square	0.32			0.27			0.34			0.31		

Table 6-12 Regression models of *pedestrian movement* and number of destination bundles, adjusted for the number of all destinations without parks and block and rook level age

6.3. Research question 2: Destination and space syntax measures and pedestrian movement

Research Question 2: *What are the relative contributions of destination measures and space syntax measures to pedestrian movement?*

Syntactical approaches of space suggest that higher *pedestrian movement* occurs along streets that are highly connected locally and highly integrated into the city. The following section presents results from the space syntax measures. The comparison between the destination measures and the space syntax measures in terms of the relative strength of their associations with *pedestrian movement* is discussed in section 6.4.2 on page 180. Similar ordinary least squared regression analyses were run to test the relationships between the space syntax measures and the *pedestrian movement* outcomes as were run for the destination measures. The analyses were adjusted for block and rook level mean age.

6.3.1. Street network integration and street network connectivity

Correlations of all the space syntax variables with the *pedestrian movement* (block and rook level) and *pedestrian movement* + *sedentary behavior* (block and rook level) outcomes indicate two general patterns:

> [1] the city-wide syntax measures show better correlations than the neighborhood-wide measures (± 3 miles in diameter),
>
> [2] the mean connectivity and integration values at the ½ mile level show stronger correlations than the mean values at the ¼ mile level.

The average city-wide integration at the ½ mile radius based on the spatial layout of Detroit showed a significant negative relationship with *pedestrian movement* at both the block (β=-2.71, p=0.000; $r^2$0.13) and rook (β=-2.72, p<.0001; r^2=0.16) levels—see Table 6-13, Models 1 and 2. The relationships between *street network connectivity* and *pedestrian movement* were weaker than the explained variance of the measure of *street network integration*. Average city-wide *street network connectivity* showed a significant negative relationship with *pedestrian movement* at the block level (β=-0.088, p=0.027; r^2=0.05) and a non-significant relationship at the rook level (β=-0.062, p=0.084; r^2=0.02)—see Table 6-13, Models 3 and 4. It should be noted that street network connectivity did not show significant associations in the correlational analysis (see Appendix A, page 275) before adjusting for block level age in the regression analysis.

Street network integration and street network connectivity at the ½ mile radius												
	MODEL1 **Pedestrian movement (block)**			MODEL2 **Pedestrian movement (rook)**			MODEL3 **Pedestrian movement (block)**			MODEL4 **Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	7.2299	1.2799	<.0001	7.0097	1.1664	<.0001	3.5199	0.7006	<.0001	3.0905	0.7537	<.0001
Age	-0.0116	0.0196	0.556	-0.0059	0.0217	0.787	-0.0246	0.0201	0.223	-0.0208	0.0231	0.370
Average city-wide integration	-2.7125	0.7006	**<.0001**	-2.7206	0.6015	**<.0001**						
Average city-wide connectivity							-0.0884	0.0395	**0.027**	-0.0616	0.0354	0.084
Adj R-Square	0.13			0.16			0.05			0.02		

Table 6-13 Regression models of *pedestrian movement* and street network integration and street network connectivity, adjusted for block and rook level age

The measures of integration and connectivity are typically used in conjunction to explain higher levels of urban movement. For this reason, both measures were included in a regression model to test their relative associations with *pedestrian movement* and *pedestrian movement + sedentary behavior*s. The variance inflation factor was calculated at 2.4. Individually, both measures explained a greater percentage of *pedestrian movement* alone than when *sedentary behavior*s were added to the outcome measure (results not shown).

After including both street network integration (global measure) and street network connectivity (local measure) in the model, however, the paired street network characteristics indicated a stronger relationship with the combined outcome measure of *pedestrian movement + sedentary behavior*s. 15% of the variance of *pedestrian movement + sedentary behavior*s was explained at the block level and 25% at the rook level as compared to the percent variance explained for *pedestrian movement* alone: 13% and 20%, respectively (see Table 6-14). After adjusting for street network integration, connectivity showed a positive relationship with *pedestrian movement* and *pedestrian movement + sedentary behavior*s (the relationship had been negative when the measure was analyzed independently). This indicates that higher pedestrian activity occurs in locally connected areas that are less integrated into the larger city street system.

Street network integration + connectivity at the ½ mile radius

	MODEL5 **Pedestrian movement (block)**			MODEL6 **Pedestrian movement (rook)**			MODEL7 **Ped. mov. + Sed. beh. (block)**			MODEL8 **Ped. mov. + Sed. beh. (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	8.1178	1.5719	<.0001	8.9023	1.3700	<.0001	19.9063	3.2985	<.0001	19.1670	2.5686	<.0001
Age	-0.0094	0.0198	0.634	-0.0022	0.0212	0.919	-0.0250	0.0415	0.549	0.0188	0.0398	0.637
Average city-wide integration	-3.5251	1.0900	**0.002**	-4.4384	0.9073	**<.0001**	-8.8783	2.2873	**0.000**	-10.1736	1.7011	**<.0001**
Average city-wide connectivity	0.0572	0.0588	0.333	0.1228	0.0495	**0.015**	0.2157	0.1233	0.083	0.3544	0.0927	**0.000**
Adj R-Square	0.13			0.20			0.15			0.25		

Table 6-14 Regression models of *pedestrian movement* and the combination of street network integration and street network connectivity, adjusted for block and rook level age

6.3.1.a. Main streets and place chains

In section 5.2.2, issues regarding the urban form of the city of Detroit and its impact on urban movement were discussed. An initial screening of the spatial variables in the study areas indicated that Detroit's urban pattern consists of a hierarchy of street spaces. To account for the fact that some of the prominent street spaces appear as statistical outliers in the data, it was decided to create new measures. Measures of distance to main avenues (*"main streets")* and distance to destinations on those main avenues (*"place chains"*) were developed and included in the analysis. After analyzing both measures, distance to *"place chains"* was selected since it was slightly more significant and predictive than distance to *"main streets."* The regression models show a negative relationship between *pedestrian movement* at the block level and both distance to *"main streets"* (β=-0.0005, p=.001; r^2=0.07)—results not shown—and distance to *"place chains"* (β = -0.0006, p=.0001; r^2=0.10)–see Table 6-15, Model 1. A negative relationship between these two measures and *pedestrian movement* confirms the hypotheses: that shorter distance to "main streets" and "place chains" is associated with more *pedestrian movement.* Blocks that are closer to destinations located on the main avenues (*distance to "place chains)* show higher *pedestrian movement*.

This finding that closer *distance to "place chains"* is related to more *pedestrian movement* remains significant even after accounting for the *street network integration* (β=-0.0006, p=0,0004, overall r^2=0.22)—see Table 6-15, Model 2. An in-depth exploration of this finding is beyond the scope of this dissertation, but briefly, the blocks that are closer to the main avenues (or in this case destinations on the main avenues) are associated with higher observed *pedestrian movement*.

	"Place chains"			**"Place chains" + Integration**			**"Place chains" + Number of all destinations without parks**		
	MODEL 1 **Pedestrian movement (block)**			MODEL 2 **Pedestrian movement (block)**			MODEL 3 **Pedestrian movement (block)**		
Variable	**Estimate**	**Std**	p-value	**Estimate**	**Std**	p-value	**Estimate**	**Std**	**p-value**
Intercept	3.2616	0.6308	<.0001	7.6603	1.2134	<.0001	0.4805	0.8450	0.571
Age	-0.0211	0.0195	0.282	-0.0029	0.0187	0.876	-0.0114	0.0180	0.528
Distance to "place chains"	-0.0006	0.0002	**0.001**	-0.0006	0.0002	**0.0004**	-0.0003	0.0002	0.109
Average city-wide integration (1/2 mile radius)				-2.7380	0.6612	**<.0001**			
Number of all destinations without parks (1/2 mile radius)							0.0240	0.0053	**<.0001**
Adj R-Square	0.10			0.22			0.24		

Table 6-15 Regression model of *pedestrian movement* and distance to "place chains", street network integration, and number of "no parks" destinations, adjusted for block level age

There seems to be an apparent contradiction within these results, for the main avenues were initially identified due to their high *street network integration* values, and higher integration values are generally associated with lower *pedestrian movement* in this analysis. In the combined regression model, *street network integration* remained significant (β=-2.738, $p<.0001$, overall r^2=0.22)—see Table 6-15, Model 2; the negative relationship means that less integration is associated with higher *pedestrian movement*. These findings seem to suggest that main streets fulfill a different purpose from other highly integrated street spaces, perhaps due to the high number of destinations located on them.

To do preliminary testing of this idea, *distance to "place chains"* and the *number of all destinations without parks* were both included in Model 3. *Distance to "place chains"* turned out insignificant, whereas number of destinations was positively related to movement (β=0.024, $p<.0001$, overall r^2=0.24). This analysis provides some support for the idea that pedestrians are attracted to the destinations located on these highly integrated main streets.

6.3.2. Reach and destination reach

Analyses were conducted to compare two local measures of spatial reach: *metric reach* and *destination reach*. *Metric reach* is a measure developed by Peponis et al. (2008), and *destination reach* is a measure developed for this dissertation. No associations were found between the *metric reach* variables and the *pedestrian movement* outcomes after a regression analysis was run—results not shown.

Destination reach at the ½ mile network distance

	MODEL 1			MODEL 2			MODEL 3		
	Pedestrian movement (block)			**Pedestrian movement (block)**			**Pedestrian movement (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.2699	0.6839	<.0001	3.4746	0.6840	<.0001	3.4639	0.6578	<.0001
Age	-0.0348	0.0204	0.091	-0.0380	0.0202	0.063	-0.0304	0.0196	0.124
All destinations	-0.00003	0.00002	0.087						
All destinations without parks				-0.00003	0.00001	**0.018**			
Commercial destinations							-0.00003	0.00001	**0.004**
Adj R-Square	.03			.05			.08		

Destination reach at the 1 mile network distance

	MODEL 4			MODEL 5			MODEL 6		
	Pedestrian movement (block)			**Pedestrian movement (block)**			**Pedestrian movement (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.2731	0.6566	<.0001	3.3810	0.6555	<.0001	3.2663	0.6304	<.0001
Age	-0.0344	0.0200	0.088	-0.0357	0.0198	0.074	-0.0259	0.0194	0.185
All destinations	-0.00001	0.00001	**0.016**						
All destination without parks				-0.00001	0.000005	**0.006**			
Commercial destinations							-0.00001	0.000003	**0.001**
Adj R-Square	.06			.07			0.10		

Table 6-16 Regression models of *pedestrian movement* and destination reach, adjusted for rook level age

The correlation table shows that the strongest correlations of *destination reach* measures and *pedestrian movement* are at the block level—see correlation table in Appendix A (page 275). *Destination reach* for *commercial destinations* was significant at both the ½ mile radius (β= -0.00003, p=0.004; r^2=0.08) and the 1 mile radius

(β= -0.00001, p=0.001; r^2=0.10) network distances and had the highest variance explained of the three types of destination groupings included in Table 6-16 (See Models 3 and 6). The regression models shown in Table 6-16 also show evidence that *destination reach* measures at the1 mile distance away from the sample blocks show better associations with *pedestrian movement* at the block level than at the ½ mile distance from the sample blocks—compare results from Models 4-6 with Models 1-3.

6.4. Research question 3: Destination, space syntax, and urban planning measures and pedestrian movement

Research Question 3: *Are destination measures and space syntax measures more predictive of pedestrian movement than commonly used urban planning built environment measures?*

Testing of the relationships of the urban planning measures with *pedestrian movement* outcomes adds the final piece necessary for the comparison between destination, space syntax, and urban planning measures. From the literature, hypotheses were formulated that suggest that higher density, higher street network connectivity, and higher land use mix are related to higher *pedestrian movement*. These relationships were tested using ordinary least squares regression modeling, adjusting for block and rook level age.

6.4.1. Density, land use mix, street connectivity

Planning measures of *density, land use mix*, and *street connectivity* were entered into in regression analyses with the *pedestrian movement* outcomes. In every analysis, *density* was the measure most highly related to *pedestrian movement.*

At the block level, *density* shows a stronger positive association with *pedestrian movement* at the ¼ mile radius (β=0.477, p=<.0001; r²=0.17) than at the ½ mile radius (β=0.414, p=0.002; r²=0.09), although it is significant at both levels (see Table 6-18, Models 1 and 3). Higher *density* at the ¼ mile radius is associated with higher *pedestrian movement*, explaining 23% of the total variance of *pedestrian movement* occurring in the rook (see Table 6-17, Model 4). *Street connectivity* at the ¼ mile radius also shows better associations with rook level *pedestrian movement* (β=1.938, p=0.007; r²=0.06)—see Table 6-17, Model 5—than at the ½ mile level (results not shown). The relationship is in the expected direction, with *street connectivity* showing a positive relationship with *pedestrian movement*, explaining 6% of the variance.

Density, street connectivity, land use mix, and pedestrian movement

	MODEL 1 ***Pedestrian movement*** **(block)**			MODEL 2 ***Pedestrian movement*** **(block)**			MODEL 3 ***Pedestrian movement*** **(block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	-0.4377	0.9461	0.645	0.7979	1.4595	0.586	0.6672	1.0135	0.512
Age	-0.0050	0.0194	0.796	-0.0274	0.0201	0.176	-0.0284	0.0197	0.153
Density (1/4 mile)	0.4770	0.1055	**<.0001**						
Street connectivity (1/4 mile)				1.2573	0.7921	0.116			
Land use mix (1/2 mile)							3.1148	1.1180	**0.006**
Adj R-Square	0.17			0.02			0.07		

	MODEL 4 ***Pedestrian movement*** **(rook)**			MODEL 5 ***Pedestrian movement*** **(rook)**			MODEL 6 ***Pedestrian movement*** **(rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	-1.1795	0.9197	0.203	-0.2040	1.2458	0.870	1.0776	1.0358	0.301
Age	0.0129	0.0213	0.547	-0.0329	0.0226	0.150	-0.0215	0.0229	0.349
Density (1/4 mile)	0.5052	0.0881	**<.0001**						
Street connectivity (1/4 mile)				1.9381	0.6978	**0.007**			
Land use mix (1/2 mile)							2.1186	1.0102	**0.038**
Adj R-Square	0.23			0.06			0.03		

Table 6-17 Regression models of *pedestrian movement* and density (1/4 mile radius), street connectivity (1/4 mile radius), and land use mix (1/2 mile radius), adjusted for block and rook level age

Unlike the other two planning measures but similar to the space syntax measures, *land use mix* is more predictive of *pedestrian movement* at the ½ mile radius than the ¼ mile radius. For example, *land use mix* is more predictive of block level *pedestrian movement* at the ½ mile radius (β=3.115, p=0.006; r^2=0.07)—see Table 6-17, Model 3—than at the ¼ mile (insignificant results not shown). This suggests that higher land use mix for a ½ mile radius area is positively related to *pedestrian movement*.

Density and pedestrian movement

	MODEL 1 Pedestrian movement (block)			**MODEL 2 Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	0.0750	1.0809	0.945	-1.1525	1.0328	0.267
Age	-0.0083	0.0206	0.688	0.0121	0.0225	0.591
Density (1/2 mile radius)	0.4138	0.1303	**0.002**	0.5209	0.1091	**<.0001**
Adj R-Square		0.09			0.17	

	MODEL 3 Pedestrian movement (block)			**MODEL 4 Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	-0.4377	0.9461	0.645	-1.1795	0.9197	0.203
Age	-0.0050	0.0194	0.796	0.0129	0.0213	0.547
Density (1/4 mile radius)	0.4770	0.1055	**<.0001**	0.5052	0.0881	**<.0001**
Adj R-Square		0.17			0.23	

	MODEL 5 **Pedestrian movement (block)**			MODEL 6 **Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	2.0324	0.7109	0.005	1.5907	0.7690	0.041
Age	-0.0239	0.0198	0.231	-0.0125	0.0229	0.587
Density (block level)	0.1185	0.0460	**0.011**	0.1244	0.0405	**0.003**
Adj R-Square		0.06			0.07	

Table 6-18 Regression models of *pedestrian movement* and density, adjusted for block and rook level age

The analyses also show that the planning measures are more associated with *pedestrian movement* at the aggregated rook level than at the block level—see Table 6-18 and Table 6-20. For example, housing unit density for a ½ mile radius explains 17% of the variance in *pedestrian movement* at the rook level (β=0.52, p<.0001; r^2=0.17), but only 9% of the variance in *pedestrian movement* at the block level (β=0.414, p=.002; r^2=0.09)—see Table 6-18, Models 1 and 2.

Another finding suggests that block-level density is more strongly associated with *pedestrian movement* + *sedentary behavior* at both the block (β=0.333, p=0.0007; r^2=0.11) and the rook levels (β=0.256, p=0.002; r^2=0.08) than with *pedestrian movement* alone at the block (β=0.119, p=0.011; r^2=0.06) and the rook levels (β=0.124, p=0.003; r^2=0.07)—see Table 6-19, Models 1 and 2 and Table 6-18, Models 5 and 6.

Density and pedestrian movement + sedentary behavior

	MODEL 1 **Ped. mov. + Sed. beh. (block)**			MODEL 2 **Ped. mov. + Sed. beh. (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	4.8735	1.4731	0.001	3.2625	1.4877	0.031
Age	-0.0561	0.0411	0.175	-0.0057	0.0443	0.897
Density (block level)	0.3327	0.0954	**0.0007**	0.2564	0.0784	**0.002**
Adj R-Square	0.11			0.08		

Table 6-19 Regression models of *pedestrian movement* + *sedentary behavior* and density, adjusted for block and rook level age

As suggested earlier, the combined impact of all three urban planning measures is believed to yield the best relationships with *physical activity* outcomes. Therefore, after analyzing the three planning measures individually, they were included in step-wise and additive regression models. The variance inflation factors range from 1.16 to 2.44, depending on the order in which the measures were entered into the regression model; this range is well <5, avoiding concerns about multicolinearity.

When the three measures were combined into a single regression model, significant results were observed for all three urban planning measures at the ½ mile radius as well as the ¼ mile radius (see Table 6-20). The association of the three measures is strongest at the ¼ mile radius, explaining 24% of the variance on *pedestrian movement* in the sample block and 33% of the variance on *pedestrian movement* in the rook. At the ½ mile radius, the corresponding results for variance on *pedestrian movement* are 17% (block level) and 32% (rook level)—see Table 6-20, Models 3-4 and 7-8.

	Density + street connectivity						**Density + street connectivity + land use mix**					
	MODEL 1 **Pedestrian movement (block)**			MODEL 2 **Pedestrian movement (rook)**			MODEL 3 **Pedestrian movement (block)**			MODEL 4 **Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	1.213	1.860	0.516	-2.311	1.643	0.162	-8.156	3.359	0.017	-13.742	2.813	<.0001
Age	-0.008	0.020	0.674	0.010	0.022	0.625	-0.007	0.019	0.643	0.022	0.020	0.284
Density (1/2 mile radius)	0.406	0.129	**0.002**	0.517	0.108	**<.0001**	0.373	0.125	**0.004**	0.503	0.099	**<.0001**
Street connectivity (1/2 mile radius)	-0.702	0.972	0.472	0.791	0.818	0.336	3.019	1.46	**0.042**	5.149	1.176	**<.0001**
Land use mix (1/2 mile radius)							5.458	1.664	**0.001**	6.347	1.336	**<.0001**
Adj R-Square	0.09			0.17			0.17			0.32		
	MODEL 5 **Pedestrian movement (block)**			MODEL 6 **Pedestrian movement (rook)**			MODEL 7 **Pedestrian movement (block)**			MODEL 8 **Pedestrian movement (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	-1.8363	1.4872	0.220	-2.9112	1.2164	0.019	-4.6365	1.8143	0.012	-5.4763	1.5227	0.0005
Age	-0.0042	0.0194	0.831	0.0050	0.0213	0.817	-0.0083	0.0190	0.663	0.0045	0.0207	0.830
Density (1/4 mile radius)	0.4622	0.1060	**<.0001**	0.4721	0.0880	**<.0001**	0.4425	0.1035	**<.0001**	0.4659	0.0855	**<.0001**
Street connectivity (1/4 mile radius)	0.9047	0.7434	0.226	1.3410	0.6298	**0.036**	2.8871	1.1268	**0.012**	2.4784	0.9278	**0.009**
Land use mix (1/4 mile radius)							1.6157	0.7753	**0.040**	1.9544	0.6535	**0.004**
Adj R-Square	0.19			0.28			0.24			0.33		

Table 6-20 Regression models of *pedestrian movement* and the planning measures: density, street connectivity, land use mix, adjusted for block and rook level age

6.4.2. Comparison of the three types of environmental measures

The get to the heart of research questions 2 and 3, the relative predictive strength of the destination measures, space syntax measures, and urban planning measures on observed *pedestrian movement* is presented in a comparative matrix table (see Table 6-21). Overall, the individual destination measures were the most predictive. The urban planning measure of *density* was also quite predictive, explaining between 17% and 23% of the variance, but the other two planning measures of *land use mix* and *street connectivity* were not predictive individually. The combination of the three planning measures, however, was shown to be quite strong (results not shown in table). With the exception of *street network integration* (16% variance explained), the space syntax measures were not as strong in this study, perhaps because they only account for space aspects, whereas the destination measures account for both space and place aspects. The vast number of different destination measures, compared to the limited number of space syntax measures, may be another reason.

In general, more predictive associations were found with the outcome variable of *pedestrian movement*, except for the independent measure of *proximity to commercial destination*s, which predicted better to *pedestrian movement* + *sedentary behaviors*. The destination measures of *number of destination bundles* (at $1/16^{th}$ of a mile) and *number of destinations* are the two most predictive measures, respectively explaining between 29% - 32% and 28% - 30% of the variance in *pedestrian movement*. The two destination types most often associated with *pedestrian movement* were *all destinations without parks* and *commercial destinations*. *Reach* was the only measure to not explain any variance.

Factor group	Most significant variables	R-square in %
Number of bundles	All destinations without parks (1/16th mile bundles) All destinations (1/16th mile bundles) Commercial destinations (1/16th mile bundles)	32% 29% 29%
Number of destinations	All destinations without parks (1/4 mile radius) All destinations (1/4 mile radius) Commercial destinations (1/4 mile radius)	30% 28% 28%
Density	Density (1/4 mile radius) Density (1/2 mile radius)	23% 17%
Street network integration	Average city-wide integration (1/2 mile radius)	16%
Proximity to destinations	Educational destinations (network distance) Commercial destinations (airline distance) Food destinations (airline and network distances)	14% 11% 10%
Place chains	Distance to "place chains"	10%
Clustering	Food destinations (1/4 mile; 1/16th mile bundles) Commercial destinations (1/2 mile; 1/16th mile bundles) All destinations without parks (1/2 mile; 1/32nd mile bundles)	10% 10% 10%
Destination Reach	Commercial destinations (1 mile network distance) All destinations without parks (1 mile network distance) All destinations (1 mile network distance)	10% 7% 6%
Main streets	Distance to "main streets"	7%
Land use mix	Land use mix (1/2 mile radius)	7%
Street connectivity	Street connectivity (1/4 mile radius)	7%
Street network connectivity	Average city-wide connectivity (1/2 mile radius)	5%
Reach	None	Not significant

Destination measures (dark grey)

Space syntax measures (light grey)

Common urban planning measures (black)

Table 6-21 Summary table of the most predictive environmental measures and the percentage of variance they explain on *pedestrian movement*, presented in decreasing order of r^2

Chapter 7
FINDINGS: BUILT ENVIRONMENT AND PHYSICAL ACTIVITY

7.1. Descriptive results of demographic variables

Respondents in the sample have a mean age of 46 years, and 31% are male, 68% female. The largest racial/ethnic group is African-American: 57%, followed by white: 21%, Hispanic: 20%, and other: 1%. 66% of respondents are in the labor force, and the income distribution is as follows: 26% have a per capita household annual income of <$4,500, 26% between $4,500 and $7,499, 26% between $7,500 and $16,199, and 22% above $16,200. The average length of residency in the neighborhoods is 18 years, and the mean waist circumference measured at the time of the interviews is 97.7 cm (see Table 7-1 for these individual-level socio-demographic variables). At the level of the block group in which respondents reside (Level-3), 68% of residents are African-American and 32% of residents live below the poverty line. 57% of residents in these block groups have lived in the same house for at least 5 years (see Table 7-2).

In this part of the analysis, 3-level weighted hierarchical generalized regression models were estimated in HLM for the 73 physical environmental measures and the 2 outcome variables: *overall physical activity* and *waist circumference.* The environmental variables were included as Level-2 variables, demographic characteristics of the residents in the Detroit neighborhoods were included as Level-1 (individual-level) variables and neighborhood level context variables were included as Level-3 variables. The data was weighted to correspond with the sociodemographic composition of the city of Detroit obtained from the 2000 US census. Built environment measures that showed significant main effects were then tested for mediation (see section 7.5).

Individual-level variables	N[24]	Percent	Mean	Std Dev
Age	903		46.4	15.7
Gender				
Male	284	31.5		
Female	619	68.6		
Race/ethnicity				
Hispanic	180	19.9		
White	194	21.5		
Black	515	57.0		
Other	14	1.6		
Employment status	903		0.7	0.5
Not in labor force	306	33.9		
In labor force	597	66.1		
Income				
<$4,500	235	26.0		
$4500-$7,499	231	25.6		
$7500-$16199	236	26.1		
>$16,200	201	22.3		
Length of residency in neighborhood (years)	903		18.3	15.2
Waist circumference (cm)			97.7	18.3

Table 7-1 Demographic variables (Level-1 in HLM), weighted to match the 2000 US census data for the sample areas

Neighborhood context variables	N	Percent	Mean	Std Dev
% Poverty	66		32.1	7.9
% African American	66		67.9	35.9
% Residential stability	66		56.8	13.7

Table 7-2 Neighborhood social context variables (Level-3 in HLM) for 66 block groups, weighted to match the 2000 US census data for the sample areas

24 16 cases from the original sample (n=919) could not be geocoded correctly and were therefore not included in the analysis.

7.2. Research question 1: Destination measures and physical activity

Research Question 1: *To what extent do destination measures have an association with physical activity*?

The following analysis builds on the hypothesis that closer *proximity to destinations*, greater *number of destinations*, and more *clustering of destinations* all encourage more walking. The focus of the analyses is to test whether the destination measures have the same relationships with *overall physical activity* as for *pedestrian movement* (presented in section 6.2), after adjusting for a range of individual-level socio-demographic and neighborhood social context variables at the block group level.

7.2.1. Proximity to destinations

The 3-level weighted hierarchical generalized regression models were estimated in HLM. The types of destinations included in this analysis were *all destinations, all without parks, commercial, educational,* and *food destinations*. None of the analyses of the *proximity to destinations* measures showed any significant relationships with *overall physical activity* (results not shown).

The same *proximity* measures were analyzed for their effects on objective *waist circumference*. Most of relationships between the *proximity* measures and objective *waist circumference* were also insignificant, with the exception of the *proximity to food destinations*. Results show that closer *proximity to food destinations* is significantly associated with lower *waist circumferences* of respondents at the network distance

(β=0.0014, p=0.043; ICC=0.0005)[25] and marginally significant at the airline distance (β=0.0015, p=0.057; ICC=0.0006) after adjusting for individual-level (level-1) and neighborhood context variables (level-3) at the block group level (see Table 7-3 below).

	Waist circumference					
		MODEL 1			MODEL 2	
	Coef	STD	p-value	Coef	STD	p-value
Level 3						
Intercept	100.43	2.8152	0.000	100.4597	2.7899	0.000
%Poverty	0.0251	0.0616	0.685	0.0241	0.0619	0.698
%African American	0.0086	0.0244	0.724	0.0123	0.0240	0.610
Residential stability	0.1026	0.0684	0.139	0.0988	0.0685	0.154
Level 2						
Proximity to food destinations (network)	0.0014	0.0007	**0.043**			
Proximity to food destinations (airline)				0.0015	0.0008	0.057
Level 1						
Age	0.1598	0.0551	**0.004**	0.1609	0.0544	**0.004**
Gender	-2.1143	1.2463	0.090	-2.1197	1.2379	0.087
Labor force	-0.1126	1.5113	0.941	-0.1355	1.4772	0.927
Length of residency	0.0482	0.0544	0.377	0.0476	0.0535	0.374
Hispanic	-0.0138	2.9648	0.996	0.0088	2.8999	0.998
White	-1.2546	1.6600	0.452	-1.1844	1.6532	0.475
Other	-1.8171	4.2002	0.674	-1.9431	3.8262	0.619
Income						
0 – 45K	3.7012	2.2509	0.100	3.6581	2.2270	0.100
45K – 75K	2.1842	1.9571	0.265	2.1955	1.9496	0.261
75K – 162K (referent)	-1.1266	2.1845	0.606	-1.1602	2.1547	0.590
ICC		0.0004			0.0006	

Table 7-3 Weighted three-Level regression models of *waist circumference* and proximity to food destinations (environmental variable at Level-2), adjusted for socio-demographic (Level-1), and neighborhood context variables (Level-3)

25 The Inter-cluster correlation (ICC) indicates the variance explained by Level-2 variable(s)

7.2.2. Number of destinations

The same destination types were analyzed for *number of destinations* as for *proximity to destinations.* The 10 environmental variables tested in this analysis are described in section 5.3.1.b. Results from the HLM hierarchical regression models show that the relationships between the *number of destinations* and *overall physical activity* and *waist circumference* were all insignificant.

7.2.3. Clustering of destinations

Three-level hierarchical regression models were also estimated for *overall physical activity* and *waist circumference* using the *clustering of destinations* measures as level-2 predictors. The destination types included in this analysis are: *all destinations*, *all destinations without parks*, *commercial*, and *food destinations*. The clustering of food destinations at the ½ mile radius for *destination bundles* that formed at 1/32nd mile apart showed a significant positive relationship with *overall physical activity* (β = 5.9067, p=0.016; ICC=0.09)—see Table 7-4. This suggests that the higher the amount of *clustering*, the higher the *overall physical activity*. None of the other 35 clustering variables showed significant relationships with either *overall physical activity* or *waist circumference* (results not shown).

Physical activity

	MODEL 1		
	Coef	STD	p-value
Level 3			
Intercept	2.0727	0.2880	0.000
%Poverty	-0.0057	0.0057	0.321
%African American	0.0000	0.0023	0.989
Residential stability	0.0048	0.0054	0.378
Level 2			
Clustering of food destinations (½ mile radius; 1/32nd mile bundle)	5.9067	2.4131	**0.016**
Level 1			
Age	-0.0171	0.0054	**0.003**
Gender	-0.0911	0.1463	0.536
Labor force	0.4133	0.1411	**0.004**
Length of residency	0.0079	0.0039	**0.048**
Hispanic	-0.1773	0.2117	0.407
White	-0.0457	0.2200	0.837
Other	0.4115	0.4003	0.308
Income			
0 – 45K	-0.4120	0.2486	0.117
45K – 75K	-0.4745	0.1871	**0.017**
75K – 162K (referent)	-0.2468	0.2184	0.275
ICC		0.090	

Table 7-4 Weighted three-level regression model of ***overall physical activity*** and the clustering of food destinations at 1/32nd mile bundle (environmental variable at Level-2), adjusted for socio-demographic (Level-1), and neighborhood context variables (Level-3)

7.2.3.a. Number of bundles

No significant relationships were found between the *number of destination bundles* and *physical activity* or *waist circumference*.

7.3. Research question 2: Destination and space syntax measures and physical activity

Research Question 2: *What are the relative contributions of destination measures and space syntax measures to physical activity?*

The space syntax measures of *street network integration*, *street network connectivity, reach*, and *destination reach* were tested for their associations with *overall physical activity* and *waist circumference*—see section 5.3.2 in the methods chapter for a description of the variables*.* The hypothesized relationships suggest that higher *integration* and *connectivity* and lower *reach* and *destination reach* are related to higher *physical activity* and lower *waist circumference*.

No significant relationships were found after entering each environmental variable individually into a 3-Level weighted hierarchical linear regression model. However, a marginally significant main effect on *waist circumference* was observed with *street network integration* after entering three syntactical measures: *distance to "main streets"*, *street network connectivity*, and *street network integration* into a single model. The marginal positive relationship between *street network integration* and *waist circumference* suggests that, after adjusting for *street network connectivity* and the *distance to "main streets,"* participants have a higher *waist circumference* in more integrated areas (β = 13.6943, p=.058; ICC=0.004).

A comparison of the destination measures with the space syntax measures indicates that the destination measures are more predictive of *physical activity* and *waist circumference* outcomes than the space syntax measures. The *clustering of food destinations* for ½ mile radius areas (1/32nd mile bundles) is the only measure in these two groups that is associated with *overall physical activity* (9% of the variance explained)*.* Closer *proximity to food destinations* at the network distance shows a significant relationship with lower *waist circumference (*see Table 7-3, Model 1), and this same measure shows a marginally significant relationship with *waist circumference* at the airline distance. The only syntactical measure related to one of the physical activity outcomes is *street network integration,* which shows a marginally positive significant relationship with *waist circumference* after adjusting for *distance to "main streets"* and *street connectivity*—see Table 7-5.

Waist circumference

	MODEL 1		
	Coef	STD	p-value
Level 3			
Intercept	99.7220	2.8678	0.000
%Poverty	0.0086	0.0602	0.887
%African American	0.0032	0.0313	0.920
Residential stability	0.0431	0.0727	0.555
Level 2			
Distance to "main streets"	0.0001	0.0007	0.910
Average city-wide connectivity (1/2 mile radius)	-0.4116	0.2877	0.155
Average city-wide integration (1/2 mile radius)	13.6943	7.1581	**0.058**
Level 1			
Age	0.1670	0.0559	**0.003**
Gender	-1.9532	1.2508	0.119
Labor force	0.1121	1.5546	0.943
Length of residency	0.0380	0.0552	0.491
Hispanic	-0.3886	2.8342	0.892
White	-1.6622	1.6554	0.318
Other	-2.1835	4.2130	0.615
Income			
0 – 45K	4.0550	2.2879	0.076
45K – 75K	2.3491	2.0049	0.242
75K – 162K (referent)	-0.7411	2.1650	0.732
ICC		0.004	

Table 7-5 Weighted three-Level regression model of *waist circumference* and distance to "main streets", street network connectivity, and street network integration (environmental variables at Level-2), adjusted for socio-demographic (Level-1), and neighborhood context variables (Level-3)

7.4. Research question 3: Destination, space syntax, and urban planning measures and physical activity

Research Question 3: *Are destination measures and space syntax measures more predictive of physical activity than commonly used urban planning built environment measures?*

The literature review of the urban planning measures (the 3Ds) suggests that higher residential *density*, higher *street connectivity*, and higher *land use mix* are all associated with higher levels of *physical activity* through walking (section 4.3). To test these hypotheses with the outcomes of *overall physical activity* and *waist circumference*, three-Level HLM analyses were performed with all the planning measures and the two physical activity outcomes.

Results indicate a marginally significant negative relationship between ¼ mile housing unit *density* and reported *overall physical activity* (β=-0.102, p=0.065; ICC=0.05)—see Table 7-6, model 1. This means that higher *density* at the ¼ mile is marginally associated with lower *overall physical activity.* This negative association remains marginally significant even after adjusting for the other two planning measures: *street connectivity* and *land use mix* (β=-0.105, p=0.055; ICC=0.05)—see Table 7-6, Model 2.

	Physical activity					
	MODEL 1			MODEL 2		
	Coef	STD	p-value	Coef	STD	p-value
Level 3						
Intercept	2.0603	0.2870	0.000	2.0606	0.2869	0.000
%Poverty	-0.0067	0.0063	0.289	-0.0069	0.0063	0.281
%African American	-0.0030	0.0024	0.216	-0.0032	0.0029	0.276
Residential stability	0.0079	0.0056	0.162	0.0079	0.0059	0.186
Level 2						
Density (1/4 mile)	-0.1015	0.0546	**0.065**	-0.1050	0.0543	**0.055**
Street connectivity (1/4 mile)				0.0405	0.6950	0.954
Land use mix (1/4 mile)				0.0912	0.3674	0.804
Level 1						
Age	-0.0168	0.0053	**0.003**	-0.0168	0.0053	**0.003**
Gender	-0.1015	0.1477	0.495	-0.1020	0.1480	0.494
Labor force	0.4101	0.1391	**0.004**	0.4089	0.1400	**0.004**
Length of residency	0.0090	0.0039	**0.024**	0.0090	0.0039	**0.024**
Hispanic	-0.1413	0.2189	0.522	-0.1405	0.2209	0.528
White	-0.0532	0.2216	0.812	-0.0517	0.2238	0.819
Other	0.3950	0.4092	0.339	0.3908	0.4054	0.340
Income	-0.4145	0.2467	0.112			
0 – 45K	-0.4892	0.1838	**0.014**	-0.4149	0.2468	0.112
45K – 75K	-0.2410	0.2146	0.278	-0.4909	0.1834	**0.013**
75K – 162K (referent)	-0.4145	0.2467	0.112	-0.2422	0.2135	0.273
ICC		0.05			0.05	

Table 7-6 Weighted three-level regression models of *physical activity* and residential unit density, street connectivity, and land use mix at the ¼ mile (environmental variables at Level-2), adjusted for socio-demographic (Level-1), and neighborhood context variables (Level-3) at the ¼ mile radius

A comparison of all the results from the three groups of built environment measures presented in Table 7-7. This table indicates that *clustering of food destinations* at the ½ mile radius and 1/32nd mile bundle has the strongest association with *overall physical activity, explaining* 9% of the variance. Residential *density* explained 5% of the variance on *physical activity* even though *density* was only marginally significant before and after being adjusted for *street connectivity* and *land use mix*. The average city-wide *street* *network integration* at the ½ mile radius (also only marginally significant) explained 0.04% of the *waist circumference* outcome, and the two *proximity to food destinations* measures (network and airline distances) explain 0.004% of the variance in *waist circumference,* even though the relationship is significant at the network distance and marginally significant at the airline distance.

		Overall physical activity	**Waist circumference**
Factor group	**Variable description**	**ICC (variance explained)**	**ICC (variance explained)**
Clustering	Clustering of food destinations (1/2 mile radius; 1/32nd mile bundles)	**9%**	**Not significant**
Density	Residential density (1/4 mile radius)	**5% (marginal significance)**	**Not significant**
Street network integration	Average city-wide integration (1/2 mile radius), adjusted for connectivity and distance to "main streets"	**Not significant**	**0.04% (marginal significance)**
Proximity to destinations	Food destinations (network)	**Not significant**	**0.004%**
	Food destinations (airline)	**Not significant**	**0.004% (marginal significance)**

Destination measures

Space syntax measures

Common urban planning measures

Table 7-7 Summary of ICC's (inter-cluster correlations) from the weighted hierarchical generalized regression analyses showing the variance of *physical activity* and *waist circumference* explained by the level 2 physical environment indicators

7.5. Research question 4: Built environment, psychosocial perceptions, and physical activity

Research Question 4: *Do perceptions of the psychosocial environment mediate the associations between the built environment and physical activity?*

The hypothesis developed for research question 4 suggests that the individual-level psychosocial perceptions mediate the relationships between characteristics of the physical environment and higher *physical activity*, with higher *sense of community*, higher *neighborhood satisfaction*, and lower *safety stress* hypothesized to be associated with higher *physical activity* and lower *waist circumference*. The physical environmental measures that showed significant main effects in the preceding sections qualified to be tested for such mediating effects. The analyses presented in the remainder of this chapter were estimated with weighted 3-level hierarchical generalized regression models. Level-1 included the socio-demographic covariates and the psychosocial perceptions, Level-2 the physical environment measures, and Level-3 the neighborhood social context variables at the block group level (described in section 7.1).

The steps to test for mediation were as follows. First, significant main effects of the physical environment on the physical activity outcomes were identified. Next, the associations between these physical environment measures and the individual-level psychosocial variables were tested with 3-Level regression models. Then, analyses were conducted to test the relationships between the psychosocial variables and the physical activity outcomes. The test for mediation was only performed if all three analyses described above yielded significant associations. The psychosocial mediators (*sense of community*, *neighborhood satisfaction*, *safety stress*) were included as level-1 variables in the analysis.

7.5.1. Relationships between the independent variables and the proposed mediating variables

Each of the significant or marginally significant main effects are shown in Model 1 in the following tables: Table 7-8 through Table 7-12. The main effects are also listed below:

[1] a significant association between *proximity to food destinations* at the network distance and *waist circumference* (p=0.043)—Table 7-8, Model 1,

[2] a marginally significant relationship between *proximity to food destinations* at the airline distance and *waist circumference* (p=0.057)—Table 7-9, Model 1,

[3] a significant association between *clustering of food destinations* and *physical activity* (p=0.016)—Table 7-10, Model 1,

[4] a marginally significant relationship between average city-wide *street network integration* at the ½ mile radius and *waist circumference*, after adjusting for *distance to "main streets"* and city-wide *street network connectivity* (p=0.058)—Table 7-11, Model 1,

[5] and a marginally significant association between *density* at the ¼ mile and *physical activity*, after adjusting for *street connectivity* and *land use mix* at the ¼ mile (p=0.055)—Table 7-12, Model 1.

After identifying the main effects, the next step was to look for significant relationships between the independent variables and the mediating variables. Models were run to test the relationships between the above physical environment measures and the psychosocial variables of *sense of community*, *neighborhood satisfaction*, and *safety stress*.

Models 2-4 in each of the tables mentioned above (Table 7-8 to Table 7-12) show the results of the analyses testing for associations between the physical environmental variables and the three individual-level psychosocial variables: *sense of community* (Model 2)*, neighborhood satisfaction* (Model 3)*, and safety stress* (Model 4)*.* After adjusting for *street connectivity* and *land use*, *density* at the ¼ mile radius shows a significant positive relationship with *sense of community* (Model 2: β=0.06, p=0.044; ICC=0.04) and *neighborhood satisfaction* (Model 3: β= -0.08, p=0.035; ICC=0.05—reverse coded)—see Table 7-12. However, no further significant associations were found between the physical environmental variables and the proposed mediators. Table 7-11 shows that *street network connectivity* showed significant relationships with all three of the psychosocial variables, but because it did not have a significant main effect on *waist circumference* (p=0.155, see Model 1), the significant associations in Models 2-4 do not hold any meaning in this analysis for mediation. Below is a summary of the results:

[1] *proximity to food destinations* at the network distance not related to *sense of community* (p=0.56), *neighborhood satisfaction* (p=0.47), or *safety stress* (p=0.063)—Table 7-8,

[2] *proximity to food destinations* at the airline distance not related to *sense of community* (p=0.61), *neighborhood satisfaction* (p=0.47), or *safety stress* (p=0.61)—Table 7-9,

[3] *clustering of food destinations* not related to *sense of community* (p=0. 70), *neighborhood satisfaction* (p=0. 35), or *safety stress* (p=0.46)—Table 7-10,

[4] *street network integration* (adjusted for *distance to "main streets"* and *street network connectivity)* not related to *sense of community* (p=0.90), *neighborhood satisfaction* (p=0. 86), or *safety stress* (p=0.43)—Table 7-11, and

[5] *density* (*adjusted for street connectivity* and *land use mix*) positively associated with *sense of community* (*β*=0.06, p=**0.044**; ICC=0.04), negatively associated with *neighborhood satisfaction* (*β*=-0.081, p=**0.035**; ICC=0.05), and not associated with *safety stress* (p=0.82)—Table 7-12.

Proximity to food destinations (network distance)

	Waist circumference			Sense of community			Neighborhood satisfaction			Safety stress		
	MODEL 1			**MODEL 2**			**MODEL 3**			**MODEL 4**		
	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value
Level 3												
Intercept	100.43	2.8152	0.000	3.7504	0.1955	0.000	2.1753	0.2170	0.000	2.1693	0.2051	0.000
%Poverty	0.0251	0.0616	0.685	-0.0040	0.0041	0.335	0.0050	0.0051	0.333	0.0063	0.0049	0.207
%African American	0.0086	0.0244	0.724	-0.0071	0.0015	**0.000**	0.0074	0.0019	**0.000**	-0.0023	0.0022	0.301
Residential stability	0.1026	0.0684	0.139	0.0143	0.0037	**0.000**	-0.0132	0.0048	**0.009**	0.0017	0.0047	0.713
Level 2												
Proximity to food destinations (network)	0.0014	0.0007	**0.043**	0.0000	0.0000	0.555	0.0000	0.0000	0.469	-0.0001	0.0001	0.063
Level 1												
Age	0.1598	0.0551	**0.004**	0.0104	0.0025	**0.000**	-0.0142	0.0028	**0.000**	-0.0085	0.0036	**0.019**
Gender	-2.1143	1.2463	0.090	-0.1322	0.0851	0.120	0.1060	0.0901	0.240	0.1180	0.0868	0.175
Labor force	-0.1126	1.5113	0.941	-0.0140	0.0766	0.856	-0.0109	0.0872	0.901	-0.1057	0.1200	0.381
Length of residency	0.0482	0.0544	0.377	0.0112	0.0026	**0.000**	-0.0115	0.0029	**0.000**	-0.0061	0.0038	0.106
Hispanic	-0.0138	2.9648	0.996	-0.1782	0.1482	0.232	0.1415	0.1637	0.389	0.3251	0.2184	0.150
White	-1.2546	1.6600	0.452	-0.0781	0.1349	0.567	0.0223	0.1392	0.874	0.0818	0.1543	0.597
Other	-1.8171	4.2002	0.674	-0.3327	0.2316	0.152	0.5629	0.2643	**0.033**	-0.2803	0.2934	0.341
Income												
0 – 45K	3.7012	2.2509	0.100	0.1220	0.1189	0.306	-0.0147	0.1395	0.917	0.3466	0.1186	**0.004**
45K – 75K	2.1842	1.9571	0.265	0.0343	0.1236	0.781	0.0662	0.1372	0.629	0.3121	0.1376	**0.024**
75K – 162K (referent)	-1.1266	2.1845	0.606	0.0183	0.1070	0.865	0.0809	0.1182	0.494	-0.0434	0.1059	0.682
ICC		0.0004			0.06			0.01			0.008	

Table 7-8 **Model 1 shows the weighted three-Level regression model of *waist circumference* and proximity to food destinations at the network distance (environmental variable at Level-2), adjusted for socio-demographic (Level-1), and neighborhood context variables (Level-3): main effect. Models 2-4 show similar analyses with sense of community, neighborhood satisfaction, and safety stress as the outcome variables.**

Proximity to food destinations (airline distance)

	Waist circumference **MODEL 1**			Sense of community **MODEL 2**			Neighborhood satisfaction **MODEL 3**			Safety stress **MODEL 4**		
	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value
Level 3												
Intercept	100.459	2.7899	0.000	3.7507	0.1954	0.000	2.1748	0.2168	0.000	3.7464	0.1928	0.000
%Poverty	0.0241	0.0619	0.698	-0.0040	0.0041	0.334	0.0050	0.0051	0.330	-0.0040	0.0041	0.337
%African American	0.0123	0.0240	0.610	-0.0071	0.0015	**0.000**	0.0074	0.0018	**0.000**	-0.0071	0.0015	**0.000**
Residential stability	0.0988	0.0685	0.154	0.0142	0.0037	**0.000**	-0.0131	0.0048	**0.009**	0.0144	0.0037	**0.000**
Level 2												
Proximity to food destinations (airline)	0.0015	0.0008	0.057	0.0000	0.0000	0.609	0.0000	0.0001	0.467	0.0000	0.0000	0.609
Level 1												
Age	0.1609	0.0544	**0.004**	0.0104	0.0025	**0.000**	-0.0142	0.0028	**0.000**	0.0103	0.0025	**0.000**
Gender	-2.1197	1.2379	0.087	-0.1319	0.0851	0.121	0.1056	0.0902	0.242	-0.1312	0.0847	0.122
Labor force	-0.1355	1.4772	0.927	-0.0139	0.0767	0.857	-0.0106	0.0873	0.904	-0.0218	0.0778	0.780
Length of residency	0.0476	0.0535	0.374	0.0112	0.0026	**0.000**	-0.0115	0.0029	**0.000**	0.0112	0.0026	**0.000**
Hispanic	0.0088	2.8999	0.998	-0.1798	0.1480	0.228	0.1424	0.1636	0.386	-0.1829	0.1446	0.208
White	-1.1844	1.6532	0.475	-0.0785	0.1346	0.564	0.0227	0.1390	0.871	-0.0629	0.1340	0.641
Other	-1.9431	3.8262	0.619	-0.3337	0.2318	0.152	0.5643	0.2645	**0.033**	-0.3471	0.2246	0.123
Income												
0 – 45K	3.6581	2.2270	0.100	0.1212	0.1189	0.309	-0.0138	0.1393	0.922	0.1307	0.1201	0.278
45K – 75K	2.1955	1.9496	0.261	0.0341	0.1239	0.783	0.0662	0.1376	0.630	0.0400	0.1239	0.747
75K – 162K (referent)	-1.1602	2.1547	0.590	0.0179	0.1071	0.868	0.0813	0.1183	0.492	0.0265	0.1077	0.806
ICC		0.0006			0.06			0.01			0.08	

Table 7-9 **Model 1 (main effect) shows the weighted three-Level regression model of *waist circumference* and proximity to food destinations at the airline distance (environmental variable at Level-2), adjusted for socio-demographic (Level-1), and neighborhood context variables (Level-3). Models 2-4 show similar analyses with sense of community, neighborhood satisfaction, and safety stress as the outcome variables.**

Clustering of food destinations

	Physical activity			Sense of community			Neighborhood satisfaction			Safety stress		
	MODEL 1			**MODEL 2**			**MODEL 3**			**MODEL 4**		
	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value
Level 3												
Intercept	2.0727	0.2880	0.000	3.7513	0.1953	0.000	2.1720	0.2160	0.000	2.1680	0.2062	0.000
%Poverty	-0.0057	0.0057	0.321	-0.0040	0.0041	0.335	0.0049	0.0051	0.337	0.0063	0.0051	0.219
%African American	0.0000	0.0023	0.989	-0.0068	0.0016	**0.000**	0.0067	0.0018	**0.001**	-0.0036	0.0023	0.134
Residential stability	0.0048	0.0054	0.378	0.0137	0.0037	**0.001**	-0.0121	0.0048	**0.015**	0.0037	0.0048	0.438
Level 2												
Clustering of food destinations (½ mile radius; 1/32nd mile bundle)	5.9067	2.4131	**0.016**	0.5334	1.4016	0.704	-1.4948	1.6067	0.354	-1.2828	1.7264	0.459
Level 1												
Age	-0.0171	0.0054	**0.003**	0.0105	0.0025	**0.000**	-0.0143	0.0028	**0.000**	-0.0087	0.0037	**0.019**
Gender	-0.0911	0.1463	0.536	-0.1316	0.0853	0.123	0.1057	0.0902	0.242	0.1159	0.0863	0.180
Labor force	0.4133	0.1411	**0.004**	-0.0115	0.0766	0.881	-0.0142	0.0883	0.873	-0.1136	0.1203	0.348
Length of residency	0.0079	0.0039	**0.048**	0.0111	0.0026	**0.000**	-0.0113	0.0029	**0.000**	-0.0059	0.0038	0.116
Hispanic	-0.1773	0.2117	0.407	-0.1812	0.1479	0.224	0.1433	0.1632	0.382	0.3388	0.2216	0.140
White	-0.0457	0.2200	0.837	-0.0790	0.1339	0.559	0.0206	0.1373	0.881	0.0858	0.1598	0.593
Other	0.4115	0.4003	0.308	-0.3306	0.2330	0.157	0.5623	0.2697	**0.037**	-0.2747	0.2968	0.356
Income												
0 – 45K	-0.4120	0.2486	0.117	0.1211	0.1165	0.299	-0.0152	0.1390	0.914	0.3488	0.1196	**0.004**
45K – 75K	-0.4745	0.1871	**0.017**	0.0334	0.1236	0.787	0.0665	0.1373	0.628	0.3178	0.1386	**0.022**
75K – 162K (referent)	-0.2468	0.2184	0.275	0.0174	0.1059	0.870	0.0816	0.1183	0.491	-0.0431	0.1054	0.682
ICC		0.090			0.060			0.100			0.020	

Table 7-10 **Model 1 (main effect) shows the weighted three-Level regression model of *physical activity* and clustering of food destinations (environmental variable at Level-2), adjusted for socio-demographic (Level-1), and neighborhood context variables (Level-3). Models 2-4 show similar analyses with sense of community, neighborhood satisfaction, and safety stress as the outcome variables.**

Space syntax measures: distance to "main streets", average city-wide connectivity, and average city-wide integration

	Waist circumference MODEL 1			Sense of community MODEL 2			Neighborhood satisfaction MODEL 3			Safety stress MODEL 4		
	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value
Level 3												
Intercept	99.7220	2.8678	0.000	3.7361	0.1911	0.000	2.1877	0.2115	0.000	2.1934	0.1971	0.000
%Poverty	0.0086	0.0602	0.887	-0.0018	0.0041	0.658	0.0021	0.0052	0.686	0.0039	0.0049	0.434
%African American	0.0032	0.0313	0.920	-0.0047	0.0019	**0.018**	0.0037	0.0022	0.103	-0.0057	0.0026	**0.032**
Residential stability	0.0431	0.0727	0.555	0.0111	0.0039	**0.006**	-0.0086	0.0046	0.068	0.0078	0.0043	0.075
Level 2												
Distance to "main streets"	0.0001	0.0007	0.910	0.0000	0.0000	0.884	0.0000	0.0000	0.602	0.0000	0.0001	0.818
Average city-wide connectivity (½ mile radius)	-0.4116	0.2877	0.155	-0.0458	0.0188	**0.016**	0.0654	0.0280	**0.021**	0.0732	0.0259	**0.006**
Average city-wide integration (½ mile radius)	13.6943	7.1581	**0.058**	0.0563	0.4280	0.896	-0.0904	0.5034	0.858	-0.4254	0.5389	0.431
Level 1												
Age	0.1670	0.0559	**0.003**	0.0107	0.0025	**0.000**	-0.0145	0.0028	**0.000**	-0.0091	0.0037	**0.015**
Gender	-1.9532	1.2508	0.119	-0.1200	0.0845	0.156	0.0895	0.0902	0.321	0.1006	0.0841	0.232
Labor force	0.1121	1.5546	0.943	-0.0057	0.0759	0.941	-0.0236	0.0874	0.787	-0.1238	0.1215	0.311
Length of residency	0.0380	0.0552	0.491	0.0107	0.0026	**0.000**	-0.0109	0.0029	**0.000**	-0.0051	0.0038	0.182
Hispanic	-0.3886	2.8342	0.892	-0.1734	0.1487	0.248	0.1293	0.1630	0.429	0.3543	0.2206	0.124
White	-1.6622	1.6554	0.318	-0.0749	0.1351	0.583	0.0171	0.1359	0.900	0.0901	0.1584	0.572
Other	-2.1835	4.2130	0.615	-0.3273	0.2213	0.141	0.5558	0.2427	**0.022**	-0.2768	0.2956	0.351
Income												
0 – 45K	4.0550	2.2879	0.076	0.1321	0.1182	0.265	-0.0220	0.1398	0.875	0.3301	0.1163	**0.005**
45K – 75K	2.3491	2.0049	0.242	0.0523	0.1219	0.668	0.0462	0.1338	0.730	0.2867	0.1372	**0.037**
75K – 162K (referent)	-0.7411	2.1650	0.732	0.0239	0.1052	0.821	0.0762	0.1168	0.514	-0.0551	0.1059	0.603
ICC		0.004			0.07			0.07			0.02	

Table 7-11 **Model 1 (main effect) shows the weighted three-Level regression model of *waist circumference* and average city-wide integration adjusted for distance to "main streets" and connectivity (environmental variables at Level-2) and for socio-demographic (Level-1), and neighborhood context variables (Level-3). Models 2-4 show similar analyses with sense of community, neighborhood satisfaction, and safety stress as the outcome variables.**

Urban planning measures: density, street connectivity, and land use mix

	Physical activity MODEL 1			Sense of community MODEL 2			Neighborhood satisfaction MODEL 3			Safety stress MODEL 4		
	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value
Level 3												
Intercept	2.0606	0.2869	0.000	3.7589	0.1903	0.000	2.1600	0.2093	0.000	2.1642	0.2096	0.000
%Poverty	-0.0069	0.0063	0.281	-0.0034	0.0041	0.412	0.0045	0.0050	0.376	0.0060	0.0051	0.242
%African American	-0.0032	0.0029	0.276	-0.0056	0.0019	**0.004**	0.0052	0.0021	**0.019**	-0.0038	0.0025	0.127
Residential stability	0.0079	0.0059	0.186	0.0131	0.0038	**0.001**	-0.0112	0.0047	**0.021**	0.0038	0.0044	0.393
Level 2												
Density (1/4 mile)	-0.1050	0.0543	**0.055**	0.0600	0.0296	**0.044**	-0.0807	0.0378	**0.035**	-0.0095	0.0416	0.819
Street connectivity (1/4 mile)	0.0405	0.6950	0.954	-0.3554	0.2228	0.113	0.0020	0.4435	0.996	0.0151	0.4325	0.973
Land use mix (1/4 mile)	0.0912	0.3674	0.804	-0.0641	0.3366	0.849	0.4419	0.2642	0.097	0.2917	0.2558	0.257
Level 1												
Age	-0.0168	0.0053	**0.003**	0.0102	0.0025	**0.000**	-0.0139	0.0028	**0.000**	-0.0087	0.0036	**0.017**
Gender	-0.1020	0.1480	0.494	-0.1276	0.0831	0.125	0.0993	0.0884	0.262	0.1152	0.0877	0.189
Labor force	0.4089	0.1400	**0.004**	-0.0057	0.0765	0.941	-0.0232	0.0878	0.791	-0.1177	0.1205	0.332
Length of residency	0.0090	0.0039	**0.024**	0.0108	0.0026	**0.000**	-0.0109	0.0029	**0.000**	-0.0059	0.0038	0.126
Hispanic	-0.1405	0.2209	0.528	-0.2190	0.1364	0.112	0.1909	0.1480	0.199	0.3491	0.2270	0.135
White	-0.0517	0.2238	0.819	-0.0929	0.1374	0.506	0.0378	0.1376	0.784	0.0949	0.1584	0.551
Other	0.3908	0.4054	0.340	-0.3060	0.2279	0.181	0.5324	0.2645	**0.044**	-0.2901	0.2993	0.334
Income												
0 – 45K	-0.4149	0.2468	0.112	0.1175	0.1203	0.330	-0.0029	0.1421	0.984	0.3523	0.1202	**0.004**
45K – 75K	-0.4909	0.1834	**0.013**	0.0375	0.1229	0.760	0.0672	0.1364	0.622	0.3180	0.1379	**0.021**
75K – 162K (referent)	-0.2422	0.2135	0.273	0.0193	0.1075	0.858	0.0845	0.1199	0.481	-0.0473	0.1056	0.654
ICC		0.05			0.04			0.05			0.02	

Table 7-12 **Model 1 (main effect) shows the weighted three-Level regression model of *physical activity* and density at the ¼ mile adjusted for street connectivity and land use mix (environmental variables at Level-2) and for socio-demographic (Level-1), and neighborhood context variables (Level-3). Models 2-4 show similar analyses with sense of community, neighborhood satisfaction, and safety stress as the outcome variables.**

7.5.2. Relationships between the proposed mediating variables and the outcome variables of overall physical activity and waist circumference

The final step prior to testing for mediation is to run 3-Level regression models to test whether the mediating variables show significant relationships with the outcome variables of *physical activity* and *waist circumference.* Table 7-13, Models 1-3, indicate that there is no significant association between the mediating variables—*sense of community* (p=0.76), *neighborhood satisfaction* (p=0.37), and *safety stress* (p=0.53)—and *overall physical activity*. Table 7-14, Models 1-3, show that the mediating variables—*sense of community* (p=0.76), *neighborhood satisfaction* (p=0.62), and *safety stress* (p=0.94) have no significant association with *waist circumference.*

This demonstrates that there is no evidence linking any of the neighborhood perception variables (*sense of community, neighborhood satisfaction,* and *safety stress*) to the outcome measures of *physical activity* or *waist circumference*. Therefore, not all the conditions were met to test for the mediating effects of neighborhood perceptions on the relationships between the built environment and *physical activity*. In answer to research question 4, perceptions of the psychosocial environment do not mediate the associations between the built environment and physical activity.

	Physical activity								
	MODEL 2			MODEL 2			MODEL 3		
	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value
Level 3									
Intercept	2.0664	0.2914	0.000	2.0718	0.2916	0.000	2.0763	0.2934	0.000
%Povery	-0.0065	0.0066	0.327	-0.0067	0.0065	0.311	-0.0066	0.0066	0.316
%African American	-0.0018	0.0026	0.490	-0.0020	0.0026	0.441	-0.0015	0.0024	0.538
Residential stability	0.0074	0.0058	0.206	0.0079	0.0059	0.186	0.0070	0.0057	0.219
Level 1									
Sense of community	-0.0191	0.0618	0.757						
Neighborhood satisfaction				0.0533	0.0597	0.373			
Safety stress							0.0348	0.0551	0.529
Age	-0.0170	0.0053	**0.003**	-0.0164	0.0053	**0.003**	-0.0169	0.0054	**0.003**
Gender	-0.0965	0.1483	0.518	-0.0998	0.1485	0.505	-0.0980	0.1477	0.510
Labor force	0.4157	0.1405	**0.004**	0.4172	0.1397	**0.003**	0.4202	0.1424	**0.004**
Length of residency	0.0088	0.0040	**0.029**	0.0092	0.0040	**0.023**	0.0088	0.0040	**0.030**
Hispanic	-0.2067	0.2142	0.340	-0.2113	0.2163	0.334	-0.2115	0.2150	0.330
White	-0.0650	0.2199	0.769	-0.0647	0.2200	0.770	-0.0661	0.2224	0.768
Other	0.3911	0.4060	0.340	0.3673	0.4008	0.364	0.4065	0.4034	0.318
Income									
0 – 45K	-0.4132	0.2492	0.116	-0.4138	0.2488	0.117	-0.4287	0.2519	0.108
45K – 75K	-0.4841	0.1854	**0.015**	-0.4880	0.1856	0.015	-0.4958	0.1875	0.014
75K – 162K (referent)	-0.2476	0.2169	0.271	-0.2523	0.2166	0.262	-0.2470	0.2167	0.272
ICC (at Level-1)		0.05			0.05			0.05	

Table 7-13 **Weighted three-Level regression model of *physical activity* and sense of community, neighborhood satisfaction, and safety stress (mediating variables at Level-1), adjusted for socio-demographic (Level-1), and neighborhood context variables (Level-3)**

	Waist circumference								
		MODEL 1			MODEL 2			MODEL 3	
	Coef	STD	p-value	Coef	STD	p-value	Coef	STD	p-value
Level 3									
Intercept	100.3257	2.8044	0.000	0.1594	0.0570	0.006	100.4977	2.7973	0.000
%Poverty	0.0262	0.0614	0.671	-2.0496	1.2415	0.099	0.0228	0.0619	0.714
%African American	0.0265	0.0246	0.286	-0.0148	1.5229	**0.992**	0.0214	0.0236	0.368
Residential stability	0.0726	0.0716	0.315	0.0423	0.0541	**0.435**	0.0829	0.0708	0.247
Level 1									
Sense of community	0.7645	0.7796	0.327						
Neighborhood satisfaction				-0.3101	0.6241	0.619			
Safety stress							0.0417	0.5760	0.943
Age	0.1560	0.0556	**0.006**	0.1594	0.0570	**0.006**	0.1640	0.0565	**0.004**
Gender	-1.9794	1.2386	0.110	-2.0496	1.2415	0.099	-2.0917	1.2580	0.096
Labor force	0.0047	1.5247	0.998	-0.0148	1.5229	0.992	-0.0071	1.5347	0.996
Length of residency	0.0372	0.0555	0.503	0.0423	0.0541	0.435	0.0462	0.0544	0.396
Hispanic	-0.4003	2.9158	0.892	-0.4825	2.9246	0.870	-0.5306	2.9277	0.857
White	-1.3110	1.6361	0.425	-1.3673	1.6218	0.401	-1.3758	1.6121	0.396
Other	-1.6214	4.2781	0.712	-1.7000	4.3070	0.701	-1.8722	4.2923	0.672
Income									
0 – 45K	3.5479	2.2321	0.112	3.6399	2.2426	0.105	3.6215	2.2099	0.101
45K – 75K	2.0430	1.9498	0.296	2.0885	1.9571	0.287	2.0484	1.9645	0.298
75K – 162K (referent)	-1.1316	2.1715	0.602	-1.0889	2.1876	0.618	-1.1140	2.1830	0.610
ICC (at Level-1)		0.005			0.005			0.005	

Table 7-14 **Weighted three-Level regression model of *waist circumference* and sense of community, neighborhood satisfaction, and safety stress (mediating variables at Level-1), adjusted for socio-demographic (Level-1), and neighborhood context variables (Level-3)**

Chapter 8
DISCUSSION AND LIMITATIONS

8.1. Summary of findings

The following section highlights some of the important findings discussed in the previous two chapters. The findings are presented as themes, each of which can be investigated in more depth in future research. They are presented following the order of the independent measures similar to the structure of Chapter 6 and Chapter 7. Within each environmental measure, the pedestrian movement outcomes are generally discussed first, followed by the physical activity outcomes.

8.1.1. Overall observations

- *The built environment measures are more strongly linked with pedestrian movement than with pedestrian movement + sedentary behaviors*

- *Destination measures show stronger associations with pedestrian movement, pedestrian movement + sedentary behaviors, and overall physical activity as compared to space syntax measures and urban planning measures*

- *Space syntax measures show a stronger relationship with waist circumference than destination measures, while planning measures show no significant relationship with waist circumference*

8.1.2. Destination measures

- *The destination grouping "all destinations without parks" is the indicator most highly associated with pedestrian movement for the proximity to, number of, and clustering of destination measures and the number of destination bundles*

- *Generally speaking, parks in the Detroit neighborhoods are associated with less pedestrian movement*

8.1.2.a. Proximity to destinations

- *Proximity to destinations is associated with higher pedestrian movement*

- *Proximity to multiple destination types is more related to pedestrian movement at the network distance, whereas individual destination types show associations at both the airline and network distances*

- *Closer proximity to food destinations following the network distance is associated with lower waist circumference of residents*

- *Proximity to commercial destinations is related to both pedestrian movement and pedestrian movement + sedentary behaviors*

- *Proximity to educational destinations is associated with higher pedestrian movement*

8.1.2.b. Number of destinations

- *Regardless of the type of destination, a higher number of destinations located within a ¼ mile radius from sample blocks is associated with higher pedestrian movement and, to a lesser extent, pedestrian movement + sedentary behaviors*

- *The number of destinations does not have a significant relationship with either overall physical activity or waist circumference among neighborhood residents*

8.1.2.c. Clustering of destinations

- *For most destination types, higher clustering is associated with less pedestrian movement and pedestrian movement + sedentary behavior*

- *Higher clustering of food destinations is related to higher pedestrian movement and higher pedestrian movement + sedentary behavior*

- *Higher clustering of food destinations is associated with higher overall physical activity of neighborhood residents*

- *Higher number of destination bundles are associated with more pedestrian movement but not with physical activity of residents*

- *The 'number of destinations' confounds any observable effect of clustering*

8.1.3. Space syntax measures

- *Street spaces that are more integrated into the city have lower pedestrian movement and higher waist circumference*

- *Street spaces that are highly connected locally, but less integrated into the city, have more pedestrian movement and pedestrian movement + sedentary behavior*

- *"Place chains" located on main avenues are associated with higher pedestrian movement*

- *Street network connectivity and street network integration show better associations with pedestrian movement, pedestrian movement + sedentary behavior, and waist circumference at the ½ mile radius*

- *Areas with a smaller destination reach have higher pedestrian movement*

8.1.4. Urban planning measures

- *Higher density at the ¼ mile and ½ mile radius levels is associated with higher pedestrian movement*

- *Blocks with higher density have higher levels of pedestrian movement and pedestrian movement + sedentary behaviors*

- *Higher density is related to lower overall physical activity of residents*

- *Street connectivity and land use mix are not associated with physical activity nor waist circumference outcomes of residents*

- *The combination of higher density, higher street connectivity, and more land use mix is more strongly related to higher pedestrian movement than the measures individually*

8.1.5. Psychosocial environment measures

- *Sense of community, neighborhood satisfaction, and safety stress do not mediate the impact of the built environment on overall physical activity or waist circumference*

8.2. Discussion of overall findings

At the outset of this dissertation, research questions were developed around the idea that both place factors and space factors work together to enhance or inhibit human actions in the environment. An attempt was made in the analysis to spell out the independent and combined contributions of each set of factors. The results give some indication that tight connections exist between measured space and measured place and the two reinforce each other to affect *pedestrian movement* and *physical activity* outcomes.

The findings from this study are generalizable to other parts of the city of Detroit because of the weighting that was applied, but it is not necessarily the case that the findings can be directly extrapolated to other cities or contexts. Detroit presents its own set of dynamic relationships, issues, challenges, and solutions. However, the findings from this study do allow for a critical investigation of how and whether prominent 'best practices' in urban design and planning can contribute to socially and environmentally sustainable neighborhood changes in low density environments.

8.2.1. The difference between pedestrian movement and physical activity findings

The percentages of variance explained by the built environment measures on the outcomes of *pedestrian movement* and *physical activity* differ greatly. All the independent measures explain much higher variance on the *pedestrian movement* outcomes than on the *physical activity* outcomes. A possible reason for this is that *pedestrian movement* and *sedentary behaviors* were observed in the actual environments from which the built environmental measures were developed. Therefore, there is a direct connection, making it likely that the built environment affected the observed *pedestrian movement* outcomes.

On the other hand, general *physical activity* refers to health behaviors that are less dependent on the environments in which people live. It is believed that *physical activity* and other health outcomes are not "determined" by any single causes—of which the built environment is only one—but rather that multiple influences cumulate to produce these outcomes. There is ample evidence to suggest that the environment plays an important role in *physical activity* and health outcomes (Brownson et al., 2001; Frumkin, 2003; Jackson, 2003; Lawrence, 2002), but the independent influences of biological, personal, social, and economic influences are other important contributing factors. The measures of overall *physical activity* are therefore likely to reflect a combination of influences, whereas the measures of *pedestrian movement* are more likely to reflect the influences of the environment. See a similar discussion in Parker (2001, p. 480).

8.2.2. More pedestrian movement than sedentary behavior

Findings from analysis of the objective *pedestrian movement* data indicate that most of the environmental variables have stronger relationships with *pedestrian movement* than with *pedestrian movement* + *sedentary behavior*. According to this finding, people use the Detroit areas more for movement than for sedentary uses such as sitting, standing, or socializing.

This perhaps suggests that the *pedestrian movement* observed in these areas reflects transportation walking trips, in other words, people walking with a purpose without stopping or lingering. Although it cannot be definitely stated that people in the sample areas walk more for transportation than recreational purposes, questions about these types of *physical activity* were included in the 2008 HEP survey, allowing the opportunity for further analysis to be conducted. Other factors that may also contribute to the low levels of observed *sedentary behavior* are safety concerns, fear of harassment by the authorities, or few visible opportunities in the environment for sedentary behaviors to occur.

Recent city projects, spearheaded by the Michigan Trails and Greenways Alliance (MTGA)[26], are in the process of planning and building greenways and bike paths throughout the city of Detroit, including throughout the sample neighborhoods. These greenways connect open spaces and major attractions throughout the city. The data from this research suggesting that the physical environment is related to pedestrian

26 http://www.michigantrails.org/projects/detroit-trails/

movement within the neighborhoods sheds positive light on this initiative of aiding walking and biking through the city. As one participant remarked in a focus group about neighborhood physical activity: “We have more segregation and polarization…[the greenways will] bring people together. That’s powerful!” ("Healthy Environments Partnership: Focus group summaries," 2006, p. 3)

8.3. Discussion of research question 1

The four destination measures included in this dissertation were *proximity to destinations*, *number of destinations*, *clustering of destinations* and the *number of destination bundles*. The destination category *all destinations without parks* was the strongest indicator of *pedestrian movement* in each of these destination factor groups. One of the reasons why this combined measure shows the strongest associations with *pedestrian movement* outcomes is that people may be more likely to walk from where they live if they are surrounded by a greater variety of destinations. A destination measure that consists of a combination of different types of destinations is probably more likely to meet people’s preferences and therefore enhance walking than measures of specific types of destination. In this category of measures, the most significant indicator of pedestrian movement is the *number of all destinations without parks bundles*.

8.3.1. The relationship between parks and pedestrian movement

As mentioned above, the destination category *all destinations without parks* is more predictive of pedestrian movement than the *all destinations* category, in which parks is included. This finding is consistent with other research indicating that parks do not contribute to more walking and/or higher *physical activity* outcomes (Cerin et al., 2007;

Forsyth et al., 2008b; Lee & Moudon, 2004b; Lee & Moudon, 2006a; McCormack et al., 2008; Moudon et al., 2007).

However, some of the earlier walkability research such as Addy et al. (2004), Brownson et al. (2001), King et al. (2003), and Pikora et al. (2003) indicates that access to parks is associated with higher *physical activity* and/or walking. These studies often relied on respondent reports, people's perceptions of walk-enhancing uses, or expert panel ratings rather than on objective measures of the environment or objectively measured *physical activity*. The positive assessment of parks and walking in these studies possibly reflect respondents' best intentions (but not their actions), differences in the quality of parks, or expert beliefs about good urbanism. Another likely reason for differences in findings related to parks and walking is related to the size, quality, and attractiveness of the parks being studied (Giles-Corti et al., 2005; Moore et al., 2008). Maintaining parks and open spaces is a huge expense for city governments or municipalities, and city services related to parks are sometimes the first to be neglected in areas where the property-tax revenues are lower.

Detroit residents' descriptions of their physical environment provide insight to understand how people feel about parks in the city. The Healthy Environments Partnership conducted a series of eight focus groups in 2006 to understand how residents perceive the impact of their neighborhoods on their health. Participants reported on aspects of the environment that helped and hindered physical activity. When talking about parks, people reported that those parks that were in good condition and had activities for youth and other people present helped to facilitate physical activity (see Figure 8-2).

However, they also reported that some parks were poorly maintained with a lack of equipment or were perceived as unsafe (see Figure 8-1). For example, one respondent stated, *"I will not let my kids go to the parks...the wooded areas are dangerous. Why take the risk if you don't have to"* ("Healthy Environments Partnership: Focus group summaries," 2006, p. 2). This statement and others from the focus groups suggest that the characteristics of certain parks in Detroit and people's perceptions of their parks may deter pedestrian movement. Complete analysis of these statements and on the particular characteristics of parks in Detroit that may encourage or hinder physical activity and pedestrian movement has not yet been conducted. Further research in this area may help to better explain the connection between parks and walking and physical activity

As Moudon et al. (2006c) point out, planning theories from the early 20th century supported the placement of schools, community centers, and open spaces right in the heart of a community. Today, however, many neighborhood centers consist predominantly of commercial and retail functions. A current direction in New Urbanism, which considers parks an important common denominator of stable communities, harks back to planning theories from a century ago (Talen, 2006). It appears as if not all parks are equal; the few popular public parks in Detroit are smaller, well-kept, and with plenty of amenities. They have clear boundaries separating areas for different activities and are in visual proximity to the surrounding land uses. Further research is needed to provide a systematic understanding of the relationship between the qualitative characteristics of parks and walking and to understand the role that these public open spaces play in diverse communities.

Figure 8-1 Lack of city maintenance of parks located in/close to the Detroit neighborhoods

Figure 8-2 Well-maintained parks in the Detroit neighborhoods[27]

8.3.2. Proximity to destinations

Proximity to destinations measures showed associations with both *pedestrian movement* and *physical activity* outcomes, although the strength of the associations with *pedestrian movement* outcomes was weaker than that of the *number of destinations* and *number of bundles* measures. The combined (*all destinations* and *all destinations with parks*) measures of the proximity to destinations are more strongly associated with *pedestrian movement* at the network distance. The proximity to specific destination types, on the

27 Image on the left was retrieved from Google Maps on July 10, 2010

other hand, is associated with *pedestrian movement* at both the airline and network distances. This finding is hard to interpret and more research is needed to understand how airline and network distances relate to different types and combinations of destinations. The difference between airline and network distances may be inconsequential, since the difference in explained variance between analyses of network and airline distances of the *proximity* measures is so minimal.

8.3.2.a. Proximity to educational destinations and pedestrian movement

The measures of proximity to destinations suggest higher *pedestrian movement* in and around respondent blocks that are within closer proximity to educational destinations at both the network and airline distances. This finding supports the tradition in walkability research of looking at the proximity to schools that goes as far back as Clarence Perry's "neighborhood unit" (1929). Other studies have found more transportation walking if residents live closer to schools, are surrounded by a higher number of schools (McCormack et al., 2008), or if there is a higher number of smaller schools in denser areas (Braza et al., 2004). Contrary to the above findings, Moudon et al.'s (2006c) study questioned the role of educational uses in walking after finding a negative association between the presence of schools in their King County study areas and walking. They showed that having more than 5 schools within 1 kilometer of homes deterred walking.

An informal observation by the author during the 2006 systematic neighborhood observation data collection found large numbers of children participating in after-school walking, reflecting the above findings. In 2007, large-scale planned school closings by the Detroit Public School (DPS) system shuttered the doors of large numbers of schools. This merely continued a trend of school closings over the past 10 years.

Figure 8-3 Track-walkers at a school that recently closed its doors

Despite these circumstances, recent observations were made of people using the outdoor facilities of boarded-up schools for recreational purposes; people of all ages were seen walking or running the track, alone or part of walking groups (Figure 8-3). The high visibility fenced in areas, proximity to houses, and the quality of amenities may be some of the attractors. It should be noted that no association was found between the proximity of educational destinations and *physical activity* outcomes. How school closings and these alternative uses of Detroit's public schools are likely to affect the *physical activity* and *pedestrian movement* of residents is a topic for future research.

8.3.2.b. Proximity to food stores and waist circumference

In her article "New Urbanism and the challenges of designing for diversity", Kristen Day poses the question:

> "When urban designers attempt to accommodate walking, … do they imagine 'walking' primarily as 'strolling'—a leisurely accompaniment to window-shopping and coffee on a weekend morning? Or is 'walking' imagined as essential transportation for grocery shopping, errands, and travel to work for families without cars or drivers' licenses?"
>
> (Day, 2003, p. 89)

The analysis from this research gives some indication that a fair number of Detroit residents may walk for daily domestic purposes (Figure 8-4). Nowhere in the analysis was this indication as clear as with walking and *physical activity* associated with food-relates uses (grocery stores, supermarkets, convenience stores, drug stores, gas stations with food, non-fast food restaurants, fast-food outlets, and liquor stores[28]). Although not conclusive, the results show that respondents in closer proximity to food stores (following the distance along streets), have lower *waist circumferenc*es. Noted, the explained variance of this relationship is rather weak.

Figure 8-4 Walking to supermarkets, grocery stores and other food destinations

28 Liquor stores in the Detroit neighborhoods often carry food-related items.

A similar finding also shows a positive relationship between the proximity to food stores and *pedestrian movement* at the network distance and airline distances. Shortening walking distances such as cutting through vacant lots (following “desire lines”) is a common strategy for finding the most efficient path on foot in Detroit, as in other cities. This suggests that walkers may find routes to destinations including food stores that are actually closer to airline distance than walking along streets. A few local projects, such as *“The Walking Project”*[29] by Erika Block and Hilary Ramsden, celebrate these walking behaviors in Detroit.

The interpretation of why people seem to have lower *waist circumferenc*es when they live closer to food stores is somewhat murky. Perhaps living closer to food establishments makes it more likely that people will choose to walk, and therefore reap the health benefits of increases in their *physical activity* (French et al., 2001). Other research supports this idea that proximity to food stores can increase walking (Berke et al., 2007; Lee & Moudon, 2006b; Moudon et al., 2006c), but the link to overall *physical activity* is less clear (King et al., 2003). Another reason for the lower waist circumferences is perhaps that there is greater access to healthier choices by living closer to a food resource in the neighborhood (Zenk et al., 2005).

Although no association was found between the proximity of food stores and reported *physical activity*, the clustering of food destinations was positively associated with higher overall *physical activity*. This finding, when combined with the research showing that proximity to food stores can increase walking, provides some evidence that food destinations contribute to higher physical activity as a result of walking.

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29 http://www.walksquawk.org/home.asp

8.3.2.c. Proximity to commercial environments and sedentary behavior

Although all the other proximity to destinations measures show stronger relationships with *pedestrian movement* than with *pedestrian movement* + *sedentary behaviors*, the proximity to commercial destinations is an exception. The relationship between the proximity of commercial destinations and *pedestrian movement* and *pedestrian movement* + *sedentary behavior* adds support to comparable findings from other research that suggest that proximity and availability of retail shops and food stores, individually and in clusters, affect walking (Berke et al., 2007; King et al., 2003; Lee & Moudon, 2006b; Moudon et al., 2006c).

During the 2006 neighborhood observations, people were observed standing and lingering outside of grocery stores, liquor stores, supermarkets, barbershops, gas stations with food markets, and car repair shops. The literature in urban design and pedestrian activity promotes the belief that pedestrian activity contributes to social interaction by bringing people in close contact with each other while strolling (Duany et al., 2000; Fishman, 2005; Katz, 1993; Kim & Kaplan, 2004; Leccese & McCormick, 2000). This dissertation research suggests that residents in the Detroit neighborhoods find a place of respite and opportunities for social interaction at prominent commercial establishments in their areas.

A common occurrence in the Detroit neighborhoods is groups of people having informal gatherings on street corners or on vacant properties in full view of a high-activity area such as the entrances to commercial establishments. The author observed these gatherings of people to also strike up conversations with passersby (Figure 8-5). This is in line with findings from *The Social Life of Small Urban Spaces* (1980); William Whyte studied public spaces in New York City and found that people choose to sit right in the middle of the action instead of in isolated corners. Another element of good urban spaces that Whyte suggests was also observed: movable chairs. In the Detroit neighborhoods, sitting areas were observed in close proximity to commercial establishments.

Figure 8-5 Gatherings near commercial areas

A final type of sedentary use in these commercial areas is the informal vendors that find a place on the sidewalks or the edges of small parking lots next to commercial destinations. In some cases, selling of fresh fruits and vegetables and/or other domestic items attract others to gather around and make conversation.

8.3.3. Number of destinations

The results in this dissertation show that the number of destinations and number of destination bundles are the strongest indicators of *pedestrian movement,* and to a lesser extent *pedestrian movement* + *sedentary behavior*. All of the destination categories (*all destinations*, *all destinations without parks*, *commercial*, and *food destinations*) showed significant positive relationships with the above-mentioned outcomes. These findings are consistent with previous findings of a positive relationship between the number of destinations and increased transportation walking (McCormack et al., 2008).

The number of destinations and number of destination bundles relate accessibility to the degree of choice: the more destinations, the greater the variety and the higher the accessibility. Although proximity to destinations describes a more localized connection between home and destinations than the number of destinations, the two measures are somewhat related: people are more likely to walk to destinations if they have more destinations in close proximity.

The literature provides additional explanations for why the number of destinations is important. It is likely that the more destination choices people have available around them, the more likely they are to pay attention to the destinations, and therefore to find the places that fit their tastes and needs. Prior research has shown that people often see their choices as more limited than what is "objectively" available to them in the environment (Handy & Clifton, 2001; Moudon et al., 2006c). Along similar lines, Cerin (2007) observed that perceptions are critical to walking, reporting that the perceived number of destinations within a 5-minute walk increased participant's overall weekly minutes of walking. Moudon et al. (2006c) shows that sufficient-walkers (people who walk for 150+ minutes per week) did not report having a grocery store within walking distance, while they actually had 2.46 grocery stores in a ½ mile radius.

This phenomenon may also occur in Detroit. Urban residents from more diverse areas may not find memorable and distinct places that fit their needs as easily as do the more homogenous sample of residents from the Walkable and Bikable Communities (WBC) study in King County, WA (Moudon et al., 2006c). Also, since people's needs and wants differ, two people in the same location may evaluate accessibility of that place differently (Handy & Niemeier, 1997). By increasing the number of destinations available, everyone is closer to places that they might want to walk to.

Findings from this dissertation analysis show that the number of destination measures is most predictive at the ¼ mile radius. This may suggest that a threshold exists between the number of available destination choices and the perceived distance to those destinations. In the Detroit areas, this threshold appears to be around a ¼ mile radius, since the ¼ mile radius was more predictive than the ½ mile radius. These findings are suggestive rather than conclusive; larger and smaller radius areas need to be tested in future analysis to verify this observation.

In a study in King County, WA by Moudon et al. (2006c), threshold distances to destinations were estimated using objectively measured distances to destinations and reports of walking from sufficient walkers (explained above) and non-walkers. In this dissertation research, specific distances based on the proximity to destinations and higher levels of pedestrian movement are not reported. However, the threshold distances reported by Moudon et al. may inform an explanation for why the number of destinations at the ¼ mile turned out more predictive than at the ½ mile in this dissertation research. The estimated average distance to restaurants, grocery stores, retail, churches, schools, offices, mix use buildings, and sport facilities that distinguished walkers from non-walkers in the King County study ranged between 0.18 – 0.37 miles. Only the more specialized facilities such as grocery store/restaurant clusters, daycare centers, libraries, and museums, attracted people over longer distances of between 0.5 – 0.8 miles. The threshold distances to the more common destinations (0.18 – 0.37 miles) is consistent with the fact that in this dissertation research, the ¼ radius level is most significantly related to *pedestrian movement* for the number of destinations measures.

No indication was found that the factors of *number of destinations* and *number of destination bundles* are likely to affect the reported *physical activity* or the *objective waist circumference* of respondents in the sampled areas. This finding differs from King et al. (2003) who showed a positive relationship between the number of destinations and reported walking and objective pedometer readings for older women. Two limitations of the King et al. study makes comparison with this dissertation research difficult. First, the analysis relied on respondent reports of the number of destinations that people walk to, rather than objectively measured number of destinations. The sample also consisted of 229 postmenopausal Caucasian women from Pittsburgh, which limits the generalizability to other population groups in other urban areas.

8.3.4. Clustering of destinations

8.3.4.a. Clustering of all destinations

The *clustering of destinations* measures suggest characteristics of the destination environment different from those suggested by the other destination measures. Similar to the measures of the *proximity to destinations*, all the *clustering of destinations* measures at the ½ mile radius were significantly associated with both *pedestrian movement* and, more importantly, *pedestrian movement + sedentary behavior*. Other than the *clustering of food destinations*, all the clustering measures showed negative associations with the *pedestrian movement* outcomes.

In addition, it was found that except for the clustering of food destinations, the *number of destinations* confounds the effects of clustering. It is likely that as the *number of destinations* increases, destinations become less clustered. This contradicts the logical expectation that as the number of destinations increases, the extent of clustering would also increase. Although the analysis performed for this dissertation is limited in fully explaining the extent of this observation, it is likely that the clustering of destinations is not as important of a factor in the Detroit areas as may be the case in other contexts. The following discussion suggests some evidence for how to think about clustering in the Detroit areas.

As Detroit's first ring suburbs developed into a fairly equal distribution of population across land, business and service establishments serving these populations followed suit, distributing fairly equally as well. As the population steadily declined starting in the 1950's, so did the number of destinations that formerly served these populations. The population shrinkage across space did not occur equally, as is shown by Figure 8-6 with residential uses in black and "all destinations" in red. As people moved out of sections of the city, the destinations soon followed suit. The fewer destinations left behind in an area of population decline may begin to rely on the presence of proximate destinations to attract people over longer distances; in a sense, they "join forces" with other destinations to keep their doors open. In other words, the fewer destinations, the more clustering. It is probable that what is being observed in the data is the result of this unique urban process occurring in Detroit.

The confounding effect suggests that the unique urban context of Detroit may contribute to other destination factors surfacing as more important than the *clustering of destinations*. Further research is needed to unravel the urban processes specific to

Detroit, and measurement in other cities is needed to determine if *clustering of destinations* in general supports *pedestrian movement* outcomes.

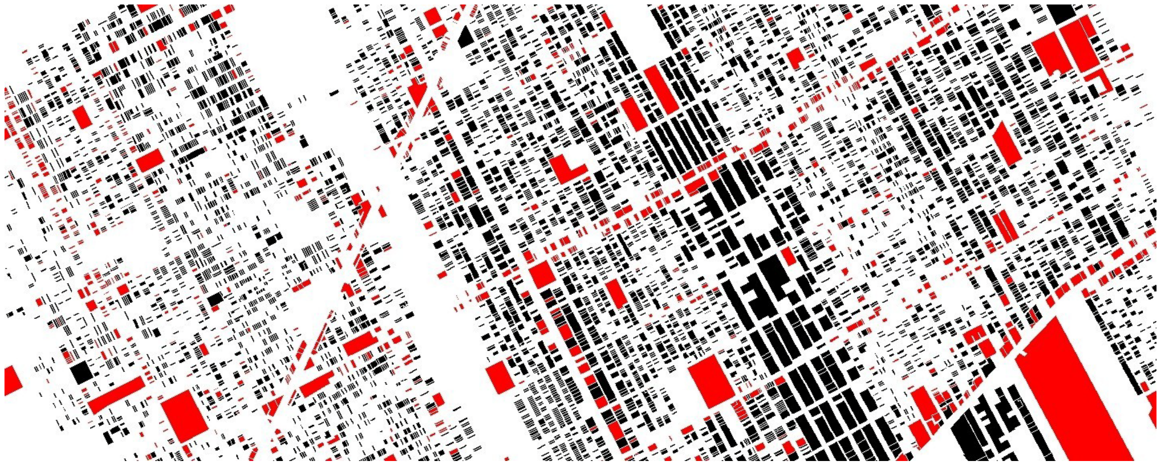

Figure 8-6 Occupied residential land uses shown in black and "all destinations without parks" in red, compiled from the 2002/2003 land use parcel map

8.3.4.b. Clustering of food destinations

In contrast with the findings from the other clustering measures discussed above, the *clustering of food destinations* shows a positive relationship with *pedestrian movement* and especially *pedestrian movement + sedentary behavior*. Commercial areas in the Detroit neighborhoods offer concentrations of food and retail establishments that provide food products and basic domestic necessities.

Some of the areas in Detroit with large numbers of food establishments clustered in the same area were informally observed to have lively street activity. Other forms of sedentary behaviors in public areas around food destinations are related to private vendors and roadside stalls from nearby food establishment that spill out onto the sidewalks (Figure 8-7). It is likely that these venues conducive to *sedentary behavior* also become attractive places for nearby residents to walk to.

Figure 8-7 Street vendors near commercial areas

Results from the analysis indicate that the higher *clustering of food stores* is also significantly associated with higher levels of overall *physical activity*, after adjusting for individual-level socio-demographic characteristics and neighborhood contextual factors such as the length of residency, percentage poverty, and percentage African American in the surrounding block groups.

8.3.4.c. Number of bundles

The *number of bundles* measures were tested to further investigate the relationship of clustering with the *pedestrian movement* outcomes. Whenever destinations are located close together and converge into clusters of destinations, they become prominent urban places in themselves, such as business streets, neighborhood main streets, or shopping complexes. Findings from this analysis show that the *number of bundles* measures, along with the *number of destinations* measures, are the strongest indicators of *pedestrian movement* as compared to the other physical environment measures. This suggests that destinations perhaps contribute to the making of distinctive neighborhood places, facilitate multi-purpose trips, and attract people over longer distances.

Urban designers have suggested that for destinations to provide the most benefit to public space in the surrounding area, it is critical to reinforce the connections between public space and the people who live and work around it (Talen, 2006; Thompson, 2002)—author's interpretation of what Talen considers public places. For example, a consideration of the qualitative aspects of commercial establishments may suggest that large window shopfronts rather than closed-off facades may encourage natural surveillance, sense of ownership and control of public space, and/or aesthetic and visual interest. An interesting anecdotal observation was made of the destinations in the Detroit neighborhoods: it is more common for stand-alone businesses to have no visual contact with the street, and very limited or no signage indicating the name and type of business. In contrast, businesses in more pedestrian-friendly, vibrant parts of the neighborhoods have plenty of visual contact to the sidewalks and bright attractive signage (Figure 8-8).

Figure 8-8 **Stand-alone business establishment in a neighborhood (left) and shops in a clustering of destinations (right)**

Bundles of destinations in the Detroit neighborhoods consist of commercial areas where people conduct everyday routine shopping trips and errands. On the one hand, commercial areas can be perceived to attract outsiders and undesirables rather than being venues for residents to freely linger and connect with others. In his book *Sidewalk,* Michel Duneier suggests that the function of commercial public space can be life changing. He describes how informal vending is a source of livelihood and great pride for Hakim, a vendor on a sidewalk in Greenwich Village who becomes one of his public acquaintances. Duneier says this about Hakim:

> "As a vendor of black books, he decided, he would have work that was meaningful—that sustained him economically and intellectually. He began by working for one of the other vendors for a few days, and then borrowed money from a former roommate to start his own table." (p. 24)

Destinations that are concentrated in bundles are also more likely to become obvious venues for community activities—clusters become places. As Lee and Moudon (2006b) report using King County data, the larger the buffer sizes (radius areas) that make up a destination bundle, the more complex the destination mix. This is supported by findings from this dissertation research showing that the 1/16th mile bundles rather than the 1/32th mile bundles are more associated with *pedestrian movement*. In addition, the *all destinations without parks* bundle showed the strongest associations with *pedestrian movement*. Lynch (1960) describes a cluster as an urban "node" that concentrates enough choice in one location for it to become both uniquely identifiable and an orientation device for making the city more comprehensible (or legible). Later, he suggests: "[the neighborhood center] is motivated not only by considerations of convenient walking distance, but above all a social ideal" (Lynch, 1981, p. 394). The *clustering of all destinations without parks* may be considered an urban "node."

8.4. Discussion of research question 2

Findings from the analysis indicate that the destination measures of *number of destinations*, *number of bundles*, and *clustering of destinations* show stronger relationships with *pedestrian movement* and/or *physical activity* outcomes than space syntax measures. On the other hand, the space syntax measures revealed findings about the relationships of the spatial environment, especially the city-wide characteristics of space, with *pedestrian movement* and *physical activity* outcomes that are not shown with localized destination measures. The two types of measures quantify and suggest different dimensions of the relationships between the built environment and the outcomes. This notion builds support for the overarching goal of this dissertation of considering measurable dimensions of space and place as mutually reinforcing.

Recent research in space syntax has investigated the intricate spatial relationships of typical American cities which show important differences from the European cities previously researched. It has been shown that the way in which spaces in the city are configured has important implications for how land use patterns relate to the movement of people (Peponis et al., 2008; Peponis et al., 2006; Peponis et al., 1997). Space syntax research that focuses specifically on lower-density cities with more uneven distributions of populations and land uses than what is typical of European cities has shown that the same spatial principals apply, although contextualized differently. The relationships between spatial characteristics, land use distribution, and movement are not fixed, but rather function as a dynamic, interacting system (Peponis et al., 2008; Peponis et al., 2007; Peponis et al., 2006; Stahle et al., 2006).

Similarly, this dissertation analysis supports the idea that the characteristics of space are linked to the dynamic processes of place-making and behavior in places. The findings demonstrate that the configuration of space, as defined theoretically and empirically through space syntax theory, continuously interacts with land use patterns to facilitate *pedestrian movement* and *physical activity* outcomes.

8.4.1. Street network integration and pedestrian movement

Findings from this research show that the more integrated streets are into the layout of the city, the lower the *pedestrian movement* and *pedestrian movement + sedentary behavior*. Other studies, on the other hand, have shown positive correlations between *street network integration* and *pedestrian movement* and transportation walking (Baran et al., 2008; Hillier, 1996a; Hillier & Hanson, 1984; Hillier et al., 1993; Penn et al., 1998; Peponis et al., 2008; Peponis et al., 1997; Read, 1999). Although the finding from this dissertation seems to be at odds with earlier findings from the space syntax literature, comparisons cannot be made due to differing city contexts.

Baran et al. (2008), for instance, found that higher *street network integration* is related to higher transportation walking in a comparative study of a neotraditional and a conventional suburban community. This study differs from the Detroit study in that Baran's two study areas are self-contained areas and the study did not consider the larger city structure.

A study by Peponis et al. (1997) in the city of Atlanta included both pedestrian and vehicular movement in the analyses. They demonstrated that *pedestrian movement* and vehicular movement differ depending on whether integration refers to the city or to neighborhood sub-areas. The study found higher *pedestrian movement* for streets more highly integrated into the city, but also reported a higher variability in *pedestrian movement* on less integrated streets. This observation may also play a role in Detroit.

Another study by Peponis et al. (2007) suggests that any land uses other than residential gravitate towards two types of blocks: some uses are attracted to small blocks and dense areas, while other uses are drawn to large blocks with less dense street networks. The street layout has important implications for how these land uses distribute throughout the city; city blocks that consolidate into large blocks, for instance, concentrate higher volumes of vehicular traffic on fewer streets. As suggested earlier in this dissertation, years of reconfiguring the city layout of Detroit have turned the already highly-integrated avenues into hierarchically dominant spaces that are likely to favor the car and truck over the pedestrian (see section 5.2.2). One way to consider this finding is that some of the highly integrated streets that are associated with lower observed *pedestrian movement* carry large amounts of the vehicular traffic, while discouraging pedestrian traffic. In other words, higher levels of *integration* do facilitate urban movement, but it is vehicular rather than *pedestrian movement*.

Anecdotal observations support this idea that street spaces that are well-integrated into the spatial structure in Detroit support primarily vehicular traffic and may serve as a deterrent to walking. As one participant during the HEP focus groups remarked in response to a question that asked about deterrents to walking: “So much traffic—cars driving up and down the streets real fast. Especially in the summer…” ("Healthy Environments Partnership: Focus group summaries," 2006, p. 2). It may be that these highly integrated streets (or spatial outliers) in Detroit expose pedestrians to too much of the city buzz and vehicular through traffic, which may contribute to uncomfortable, edgy experiences. Appleyard (1981) once suggested that the lack of pedestrian scale, high volumes of four to six lane traffic speeding by, and a lack of protective urban features such as trees, planters, shrubs, safe crossings, and medians may all contribute to public space that feels more like an edge than a center of community activity.

Figure 8-9 show a typical highly integrated street (outlier) close to the sampled areas in Detroit. The avenue in the two images shows typical views of these main streets, with cars and trucks travelling at high speeds and few opportunities for pedestrians to cross safely. The qualitative characteristics of these main avenues and their relationships to *pedestrian movement* in the surrounding communities are an important topic for further research.

Figure 8-9 Main avenues with high integration values and few pedestrian amenities to support the comfortable, safe crossing of pedestrians (right)

In addition to a significant negative association with *pedestrian movement*, higher city-wide street integration was also found to be associated with higher *waist circumference* after *connectivity* and *distance to "main streets"* were accounted for.

8.4.1.a. "Main streets" and "place chains"

It is likely that higher *integration* may positively affect *pedestrian movement* on a more localized neighborhood level after the negative effects of spatial outliers are accounted for. This does not mean that pedestrians avoid these highly integrated street spaces all together; these streets act as the arteries of the city, bringing together a variety of copresences (foot, car, bus, and truck traffic) and making them difficult to avoid.

The visual exposure that businesses on these arteries gain from their location draws people from all across the city. Findings from this dissertation suggest that blocks within closer proximity to destinations on these arteries (*distance to "place chains")* have higher *pedestrian movement*. Interestingly, the relationship between the *distance to "place chains"* and higher *pedestrian movement* becomes insignificant after adjusting for the *number of all destinations without parks* located on these main streets. This suggests that pedestrians are less likely to frequent neighboring blocks if the main streets have fewer destinations located on them. The full extent of these findings has not yet been fully explored or quantitatively tested. Figure 8-10 shows an example of one of the main avenues in Detroit. The *distance to "place chains"* measures, which represents the closest distance to the destinations located on the main avenue, turned out more predictive than the *distance to "main streets*" measure.

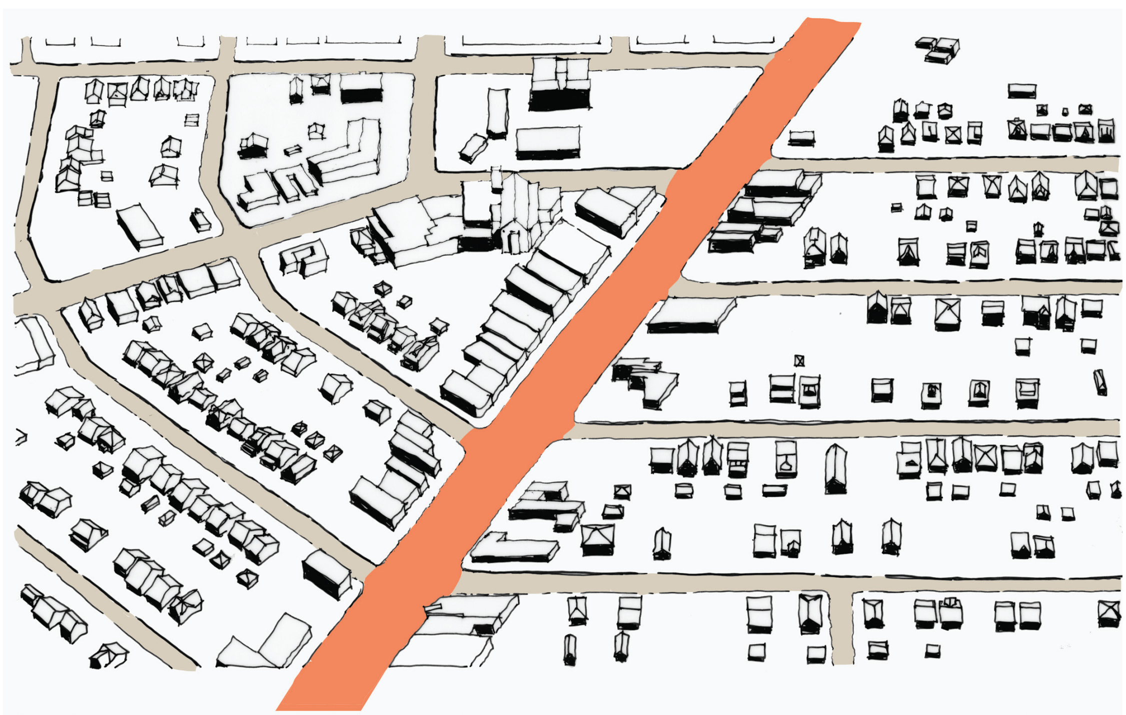

Figure 8-10 Diagram showing a typical main avenue in the city of Detroit

8.4.2. Street network connectivity, reach, and destination reach

Initial statistical models in this dissertation showed lower *pedestrian movement* and *pedestrian movement + sedentary behavior* on more connected streets. This finding is inconsistent with previous research in both urban planning and space syntax demonstrating more walking for areas with denser street connections and street connectivity (Baran et al., 2008; Cervero & Kockelman, 1997; Frank & Engelke, 2001; Frank et al., 2005a; Handy, 1996a; Handy et al., 2003; Handy, 1992, 1996c). Other studies in space syntax showed that *street network connectivity* has the most significant correlations with *pedestrian movement* (Desyllas & Duxbury, 2001). This puzzling finding reversed after adjusting for *city-level integration*. This suggests that the association between higher *pedestrian movement* and more connected streets exists in smaller neighborhood enclaves that are somewhat disconnected from the bigger structure of the city.

Considering the quality of some of the integrated streets discussed in the previous section, it seems plausible that micro-ecologies may develop in some areas. These areas are internally focused street systems that are highly connected to all the local streets and therefore improve access to local places in the proximate area. However, these street systems are at the same time less integrated into the larger city structure, potentially cutting down on the through movement of strangers. Figure 8-11 is a representation of one of the locally connected areas in the city of Detroit, showing the *clustering of destinations* along the streets that are more connected locally. This interpretation seems especially plausible considering that *street network connectivity* showed a stronger relationship with *pedestrian movement* + *sedentary behavior* than with *pedestrian movement* alone, suggesting that this more local spatial environment provides similar opportunities for lingering as the *clustering of destinations* along major local streets.

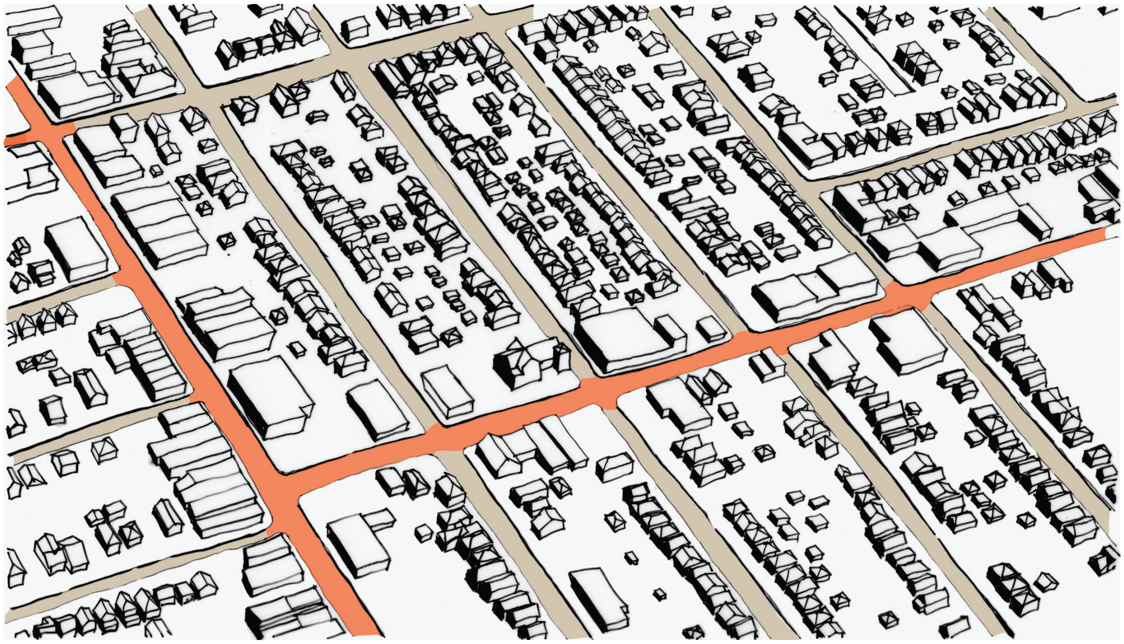

Figure 8-11 **Diagram of an area in Detroit showing a street network that is highly connected locally with destinations located on the two most highly connected streets**

Another finding that adds to this interpretation is that higher *pedestrian movement* is associated with sample blocks that have smaller *destination reaches*. A smaller *destination reach* means that a smaller footprint of streets in all directions is needed to reach the highest *number of destinations*. Findings of *metric reach* were insignificant, suggesting that the impact of local *street network connectivity* on *pedestrian movement* is reinforced by the destinations that are located within the area. *Destination reach* to commercial destinations showed the strongest association with *pedestrian movement*.

8.5. Discussion of research question 3

8.5.1. Density, land use mix, and street connectivity

Of the three urban planning measures, *density* showed the most significant relationships with *pedestrian movement* and *pedestrian movement* + *sedentary behavior*. This finding is consistent with other findings about the importance of *density* in predicting pedestrian behaviors (Boer et al., 2007; Cervero & Kockelman, 1997; Frank & Engelke, 2001; Frank et al., 2008; Frank et al., 2005a; Lee & Moudon, 2006a; Moudon et al., 2007; Rundle et al., 2007). The other two measures of *land use mix* and *street connectivity* showed very weak or no relationships with the *pedestrian movement* and *physical activity* outcomes. The weak relationships with *street connectivity* is surprising since the local spatial environment has been a major topic of interest in community design (Joseph & Zimring, 2007; Saelens et al., 2003b; Schumacher, 1986; Siksna, 1997; Southworth & Ben-Joseph, 1995; Southworth & Ben-Joseph, 1997; Southworth & Owens, 1993).

Findings from this dissertation research suggest that measures of the spatial environment relate to the specific city context and occur at multiple city scales. The common urban planning measure of *street connectivity* may over simplify the dynamic relationships of the spatial environments in cities such as Detroit. The application of space syntax measures in this dissertation has yielded more predictive results on *pedestrian movement*, *pedestrian movement* + *sedentary behavior*, and *waist circumference*. Therefore, it is proposed that space syntax measures can provide more detailed descriptions of the spatial characteristics of the environment than the urban planning measure of *street connectivity*.

The insignificant results of *land use mix* on *pedestrian movement* and *physical activity* outcomes limits the extent to which the destination environment can be described in terms of land uses. Other researchers have proposed that *land use mix* measures are important in understanding vehicular travel behavior, pedestrian behavior, *physical activity*, and health outcomes (Cervero, 1989; Cervero & Kockelman, 1997; Ewing & Cervero, 2001; Frank et al., 2008; Frank et al., 2006; Kelly, 1994; Powell, 2005; Rundle et al., 2007). Findings from this dissertation research show that the use of destination measures, as previously suggested by Moudon et al. (2006b), are an effective alternative to understanding the links between the built environment and *pedestrian movement*, and *physical activity*.

The analyses of the three planning measures point to the interrelationship of the factors. Consistent with previous research, *density* seems to have an independent influence on *pedestrian movement*. *Street connectivity* (the number of streets divided by the number of intersections) and *land use mix* (entropy score indicating the degree of mix) did not show any relationships with *pedestrian movement* until all three measures were combined in a regression model. This suggests that the three factors work closely together; higher *density*, higher *land use mix*, and higher *street connectivity* in combination are conducive to pedestrian activities. This finding supports Cervero and Kockelman's (1997) original proposal about the link between the 3Ds (density, diversity, design) and pedestrian behavior.

Throughout this dissertation, the colinearity of density, land use mix, and *street connectivity* previously observed in other studies is seen as a limitation to unraveling the independent effects of the built environment on *pedestrian movement* and *physical activity*. Frank et al. dedicated a number of publications to disentangling the three factors (see Frank et al. 2005a, 2007, 2008). Cervero and Kockelman (1997) recognize the problems associated with the colinearity of these measures, but they propose that the 3Ds capture the multi-sided dimensions of the built environment.

In this dissertation research, the low prediction of *land use mix* and *street connectivity* helps to isolate the independent influence of *density*. This might be useful in future research in the Detroit areas. However, the results also show that a description of the environment solely along the lines of *density* limits the ways in which the physical environment can be understood and relationships can be tested. More details regarding the findings related to *density* are included next.

8.5.2. Density and physical activity

In addition to being significantly related to *pedestrian movement, density* also emerged as a marginally significant indicator of *physical activity*. However, the relationship indicated by the statistical analyses show lower overall *physical activity* for respondents living in more dense areas. Since this finding is at odds with most research, it raises important questions about the physical context of the Detroit areas. Two explanations are proposed:

The observation of lower *physical activity* as *density* increases in the Detroit study areas may point to the possibility that residents associate higher density areas with concerns about safety because high density areas may be perceived to attract more strangers. If this is the case, then the higher *pedestrian movement* and *sedentary behavior*s observed in higher density areas may be counting strangers rather than locals. Residents may participate in less walking due to their fear of strangers, resulting in lower overall *physical activity*.

Another possible explanation relates to the way density was measured in this research. The sporadic distribution of residential units throughout the city resulting from depopulation of the city over the past few decades is reason to question the effectiveness of the *density* measures at the ¼ mile and ½ mile radius areas. Even though the ¼ mile radius *density* in the Detroit neighborhood is correlated with block-level *density* (0.504, p<.001), the ½ mile *density* is not correlated with either block *density* or the ¼ mile *density* measures. This suggests that aggregated *density* measures are potentially problematic in the context of the Detroit neighborhoods.

It may be that both aspects mentioned above have some bearing on lower reported overall *physical activity* in higher density areas. More research is needed to better understand the pathways involved in these findings. Future analysis can be done using the 2008 Healthy Environment Partnership data that includes more specific questions regarding recreational, transportation, and work-related walking.

8.5.3. Density and sedentary behavior

Block level *density* was the only urban planning measure that is more predictive of *movement* + *sedentary behavior*s than of *pedestrian movement* alone. The *density* of the center block indicated higher *pedestrian movement* + *sedentary behavior* on both the block and the surrounding rook. This finding suggests that a large majority of sedentary activities in residential areas occur in the center blocks where respondents and their neighbors live, which then potentially spills over into the surrounding blocks. This may mean that residents are more likely to stay close to home and are not as likely to venture too far out. While conducting the neighborhood observations in 2006, people were frequently observed sitting, standing, and talking on or around front porches and sidewalks that were in proximity to occupied homes. Other activities observed include on-street car repairs or children playing on the sidewalks or streets.

8.6. Discussion of research question 4

8.6.1. Sense of community, neighborhood satisfaction, and New Urbanism

The results from this dissertation found that there are no mediating effects of *sense of community* or *neighborhood satisfaction* on the relationships between the built environment and *physical activity* and *waist circumference*. The examination of whether social factors mediate the role of the environment on *physical activity* outcomes has particular relevance for recent movements such as New Urbanism. A prominent notion in New Urbanism is that well-designed environments can promote *psychosocial outcomes*, which in turn promote *physical activity.* In light of the hundreds of neotraditional developments being built in the United States and around the world and the wide application of these principals in retrofitting existing communities, a better understanding of their performance in terms of encouraging positive perceptions such as *sense of community* and *neighborhood satisfaction* is needed.

The concept of social capital is relevant here. A concept introduced by Robert Putnam, social capital fosters *sense of community*, stimulates norms of reciprocity and trust, and facilitates cooperation between residents for mutual benefit (Putman, 2000). It is further proposed that residents are more likely to use outdoor space if they feel that others are watching out for them and willing to intervene on their part (Sampson et al., 1997). People that feel comfortable [and safe] to use outdoor space are also more exposed to opportunities for social contact and neighboring (Lund, 2003). This in turn builds *sense of community* and *neighborhood satisfaction* and people are more likely to organize around neighborhood issues. Social contact and the management of safety issues in activity-friendly environments may also have trickle down effects, facilitating healthy behaviors and aiding the dissemination of health information (Foster et al., 2007).

However, the findings from this dissertation indicate no relationship between the built environment and psychosocial perceptions nor between psychosocial perceptions and *physical activity* outcomes for those measures with a main effect. This calls into question the generalizability of the above notions to all kinds of neighborhoods and suggests that further investigation is needed.

8.6.2. Safety stress

Results from the analysis show that *safety stress* also does not show a mediating relationship with the built environment and *physical activity* outcomes. However unlikely this finding appears, it is consistent with other studies (Carver et al., 2005; Cervero & Duncan, 2003; Timperio et al., 2004).

As Schulz et al. (2008) suggest, stress is a complex and dynamic process influenced by a multitude of contextual (social and physical) and individual characteristics. In a series of focus groups in the Detroit areas coordinated by the Healthy Environment Partnership, people reported that characteristics of the physical environment do contribute to chronic physical stress (Israel et al., 2006). There was some agreement among participants that safety is a main concern in their neighborhoods. In another set of eight focus groups conducted by HEP asking residents about the impact their neighborhood environment and its perceived barriers may have on their *physical activity*, one participant remarked: “I think security has a lot to do with our physical activity in the neighborhood” ("Healthy Environments Partnership: Focus group summaries," 2006, p. 3).

These reports differ from the results in this dissertation showing that there is no relationship between the built environment, *safety stress*, and *physical activity* outcomes. Similar to the earlier discussion about the difference between people's reported perceptions of parks and the objectively-measured reality of parks discouraging walking, self-reports do not always match objectively-measured results. In the case of safety, it may be that residents do have concerns about safety, but that they do not actually change their *physical activity* patterns as a result; they still may engage in some level of *physical activity* by walking to nearby places out of necessity despite their fears.

8.6.3. Perceptions as moderating variables

One possible reason why no mediation was found is that the *psychosocial perceptions* may play a moderating rather than a mediating role. Kim and Kaplan's (2004) framework for identifying the dimensions of *sense of community* that relate to the physical environment and other dimensions of *sense of community* that relate to the psychosocial environment is relevant here. According to Kim and Kaplan, close-knit neighborhood ties are one aspect of the psychosocial environment of a neighborhood. These social ties can develop independent of associations with the built environment, especially where the physical environment is not as rich in the physical features that could facilitate these perceptions to develop. The close-knit ties that are more likely to develop among long-term residents (Festinger, 1950; McMillan & Chavis, 1986) may also buffer some of negative perceptions of the physical environment and contribute to higher levels of *sense of community* and *neighborhood satisfaction*. Therefore, instead of the neighborhood perceptions of *sense of community*, *neighborhood satisfaction*, and *safety stress* mediating relationships of the built environment and *physical activity*, they may moderate these relationships.

8.7. Study limitations

As discussed in the next chapter, this dissertation has a number of implications relevant to theory, design, and practice. It is hoped that a contribution has been made in the fields of urban design, practice, architecture, and public health, among others. Before going on to discuss implications, however, it is important to present the limitations of the study. The limitations are presented in bullet point format, with the limitation in bold followed by the explanation.

- **Data sources from two points in time:** Survey data, objective environmental data, and neighborhood observational data were combined from different points in time even though the analysis remained cross-sectional. Checks were conducted for all the main environmental variables to assess for any significant changes in environmental conditions between 2002 (when the survey was conducted and the data for the built environment measures was compiled) and 2006 (when the pedestrian observations were made), and there was very little change in the physical environment during this period. However, the possibility that qualitative environmental conditions may have changed and therefore confound the analysis cannot be completely ruled out.

- **Cross-sectional research:** Because the analysis in this dissertation was cross-sectional, the direction of the associations can only be inferred. It is reasonable to expect that on a day-to-day basis, the built environment would be more likely to impact people's *physical activity* and *pedestrian movement* outcomes rather than the other way around. On the other hand, people are agents as well as subjects. Over time, the *physical activity* and *pedestrian movement* choices that individuals make could have an impact on the built environment. For example, a businessman may decide to open a shop on a street where he has seen many people walking, thus changing the destination environment. The hypothesized directions will need to be tested with longitudinal data in order to fully grasp the sequence of relationships or make any causal statements.

- **Self-reported overall physical activity:** The *physical activity* scale from the 2002 HEP survey was constructed from self-reported responses. Studies have shown that self-reported data on *physical activity* outcomes is not always reliable. Instead, direct measures of health outcomes or measures of objective *physical activity* levels through accelerometers or geographic positioning system devices are recommended (Ellaway et al., 1997; Frank et al., 2008; Frank et al., 2005a; Papas et al., 2007).

- **Overall physical activity outcome lacks specificity:** Another limitation of the *physical activity* scale is the lack of specificity in the questions about the type of exercise that respondents engage in. Questions were not framed specifically for understanding respondents' *physical activity* outcomes in their local neighborhood. Although this is an apparent limitation, it also assures very conservative estimates of the potential impact of the physical environment on *physical activity* outcomes. Some researchers, such as Forsyth et al. (2008b), suggest that the effects of the built environment on *physical activity* are often overestimated and thus increasing overall *physical activity* through the designed environment is a much bigger challenge than ordinarily assumed (see section 4.9 for a review of how the literature conceptualizes *pedestrian movement* and *physical activity*). The more recent 2008 Healthy Environment Partnership survey included specific questions about leisure and transportation walking, and will enable a better understanding of the specific *physical activity* behaviors of residents within their neighborhoods.

- **Conceptual difference between pedestrian movement and physical activity outcomes:** It is not possible in this study to connect respondents' reported *physical activity* with the measure of observed *pedestrian movement*. The *physical activity* measures pertained only to residents of the study areas, whereas the pedestrian observations counted everyone: residents and visitors alike. Therefore, the two main outcome variables could not be used in the same analyses and they were instead examined separately. On the other hand, the inclusion of measures of overall *physical activity* and ecological measures of neighborhood *pedestrian movement* provides insight into two different dimensions of *physical activity*.

- **No distinctions between different types of walking:** Just as the observations of *pedestrian movement* could not distinguish between residents and visitors, they also did not distinguish between different purposes of walking. It has recently been suggested that it is important to distinguish between total physical activity and walking for specific purposes, such as transportation walking and recreational walking (Forsyth et al., 2008b; Forsyth et al., 2007).This study did distinguish between *physical activity* and *pedestrian movement*, but it did not differentiate between transport and recreational walking. The motivations for these two types of walking are quite different, so it is likely that they have different relationships with built environment factors. Accounting for different types of walking would offer a more nuanced understanding. Analysis using the dataset from the 2008 HEP survey will perhaps enable more direct connections between specific environmental characteristics and specific walking outcomes to be made.

- **Complexity of contributing factors to physical activity:** The analysis indicates low predictions of individual environmental variables on *physical activity* outcomes. In examining this finding, it is helpful to consider the fact that contributing factors to higher levels of *physical activity* are complex and multidimensional; the links between the built environment and *physical activity* are not necessarily as clear cut as some studies in the field of walkability research seem to suggest. Instead, the environment is but one of many causes that can add to better lifestyle choices and behaviors and better health outcomes. Forsyth (2008b) suggests that although research findings are not always consistent and the environment may seem to matter only to a small degree, it is clear that the built environment nonetheless does matter for walking—what is less clear is how much it matters for *physical activity.* As Karen Franck suggests, a greater understanding of the context in which environmental transactions take place can guide the investigation toward understanding multidirectional pathways and causes. She suggests that researchers can maintain vigilance by not overestimating the influence of the environment by underestimating other influences or assuming that the environment has only direct effects on behavior (Franck, 1984, p. 411).

- **Waist circumference as an indicator of physical activity:** This study applied waist circumference as a physical activity outcome measure. Similar to the discussion above explaining that the built environment is only one contributing factor to physical activity, physical activity itself is only one contributing factor to waist circumference. Other factors such as diet and genetics also play a role in people's waist circumferences. Using waist circumference as an indicator of physical activity therefore does not consider the role of these other factors.

- **Analyses conducted using mostly single variables:** There may also be limitations to the way the analyses were conducted. Statistically insignificant findings of the relationships between the neighborhood environment variables and *physical activity* outcomes may have been affected by the inclusion of various individual level and neighborhood social context variables in the models. However, no more than one or two environmental variables were entered into the regression models at a given time. To maximize the statistical power of the regression models testing environmental variables and *pedestrian movement*, no more than two or three variables were entered in a single regression model. This limits the analysis to looking at mostly single associations and not multi-faceted relationships.

- **Reliability of objective environmental data:** There are also a few drawbacks with the objective environmental data. Assessor's land use parcel data was used to describe the land use characteristics of the neighborhoods. This data was not collected specifically for the purpose of this research project, and missing or incorrectly coded values on some of the parcels may have biased the results. Throughout the course of the analysis, however, less than 0.01% missing values were found for the entire city of Detroit, and a visual assessment of the parcel maps showed even fewer missing values in the study areas.

- **Difficulty of measuring the environment:** The environmental variables themselves had some limitations, although they were taken into account as much as possible by the analysis. One example is that the environmental measures were vulnerable to outliers, particularly the spatial variables. To account for this, outliers were sometimes excluded from the analysis and at other times, new measures such as *distance to "main streets"* were created to analyze the outlying cases.

- **Unit of analysis:** Deciding which unit of analysis to use for the environmental factors can be problematic. For example, determining a unit of analysis for *density* was initially problematic. Housing unit *density* was first calculated at the rook, ¼ mile, and ½ mile levels, consistent with the literature. Assessment of the *density* distribution at the block level, however, indicated that the above-mentioned levels might reduce the between-unit variability too much. It was therefore also decided to calculate the block level *density*.

- **Colinearity of the environmental measures:** The environmental variables are often highly interrelated. To ensure that this did not negatively impact the results, variable correlations were always tested before entering multiple variables into a regression model. Variance inflation factors were calculated to determine which correlated variables to exclude from the regression models. Another possible concern was the fact that multiple respondents were located within close proximity of each other. To reduce the effects of multicolinearity, only block level means were used at the neighborhood level (Level-2) in multi-level analyses.

- **Lack of qualitative data:** This dissertation was conducted using quantitative research methods. As discussed earlier, there are many advantages to utilizing objective data sources, and the same can be said about using quantitative methods. On the other hand, the subjective dimension can be useful for assessing people's attitudes, preferences, and perceptions of the built environment. Qualitative inquiry is particularly important in supplementing the understanding of place characteristics. A more nuanced interpretation of the findings may have been possible had qualitative methods also been incorporated.

- **Generalizability:** Finally, one cannot be certain of the generalizability of the results because not all cities or regions have environmental conditions or populations similar to that of the study areas or Detroit as a whole. According to HEP's weighting scheme, the sample of 919 individuals was adjusted to reflect the city-wide population distribution in order to make inferences to the city population possible. This dissertation presents the findings from the three areas of Detroit as a "case study" of the relationships between environmental measures and *physical activity* and *pedestrian movement* outcomes. The intent is to suggest broad implications for urban design practice and research that will need to be further tested in other cities.

Chapter 9
IMPLICATIONS FOR THEORY, DESIGN, AND RESEARCH

Building on the discussion in section 1.2 about the importance of this dissertation research, this chapter outlines implications for theory, design, and research. It is first proposed that this dissertation has relevance for design theory by formulating a few ideas pertaining to design process and typologies. The following section concentrates on ways in which this research may be useful to urban design and planning practice by presenting a condensed summary table of the findings, touching on opportunities related to destination bundles, and outlining the value of this research as it relates to New Urbanism. The final section in this chapter discusses the implications for future research.

9.1. Implications for design theory

Although sometimes ambiguous, a distinction can be made between design solutions/applications and design processes. Design solutions refer to the use of descriptive representations of the environment—scientific or anecdotal, visual or narrative—that designers *'think of'* when they design; they are the sources of knowledge that designers use to solve design problems in the hope that the actual outcomes align with the intended outcomes. Bill Hillier has stated that architects rely predominantly on normative (tried-and-true) representations rather than analytical (scientific) representations to guide future design decisions (Hillier, 1996b). The "Summary of findings" (section 8.1) and "Practical suggestions for urban design and planning" (section 9.2.1) presented in the beginning of this chapter describe representations of the environment that can be useful in what to *'think of'* when designing.

Design processes, on the other hand, refer to the mental concepts, methods, and structures that designers *'think with'* to tackle a design problem. For example, designers use visual mappings, relational diagrams, and/or massing models to help structure the multiplicity of considerations in a design. This research suggests that space and place patterns are generative tools that can help the designer organize her thinking. They are the tried-and-true versions of the "napkin sketch" without constricting the designer to specific formal expressions. Patterns and structures do not give design solutions; instead, they are generative frameworks that encourage a variety of solutions depending on how the designer or design/client collaboration chooses to assemble and relate the elements in a given context.

A valuable example demonstrating generative frameworks is Christopher Alexander's *A Pattern Language* (Alexander, 1977). He used predictive research findings and beliefs about good design to develop a series of 253 practical patterns useful for developing interior, architectural, and urban solutions. His diagrams describe what he suggests to be the invariant features that exemplify good places. These diagrams highlight the relationships between spatial and experiential elements and are supplemented by proposed qualities that contribute to a sense of place. The patterns in his book suggest a hierarchy of elements, some universal and others more specific to unique qualities that distinguish different places. By underlining the inescapable and consistent properties in the pattern, each diagram becomes a generative design tool rather than a static description of place. The degree to which each pattern is supported by previous empirical testing is also indicated by rating the empirical backing of each pattern with zero, one, or two asterisks.

Some of Alexander's critics question the extent to which he truly captures universal properties through his patterns; instead, they suggest that he simply assembles fragments of "*personal idiosyncratic, stylistic preferences*" (Broadbent, 1973, 1979; Sime, 1985). Nonetheless, his patterns offer visual descriptions of a design process rather than images of a design solution that designers become fixated with. They also describe lasting qualities of places which the designer can interpret in innovative and creative ways to uniquely 'situate' the design in a physical setting rather than hard-to-interpret abstractions.

9.1.1. Typologies: conceptions of place and space for urban design

In their article "Suburban Clusters: The Nucleation of Multifamily Housing in Suburban Areas of the Central Puget Sound," Moudon & Hess (2000) build a strong case for the focus on typologies. They describe the all too common mix-use suburban clusters as a type that has all the necessary conditions to be retrofitted to support walkable neighborhood design. The 'suburban clusters' describe typologies of high land use mix, concentration of uses and people, and connections with the surrounding suburbs, all amounting to an urban fabric that may also encourage walking. To get a better understanding of the nature of typologies, a few characteristics need to be reviewed.

In the simplest explanation, typologies are about types of buildings, neighborhoods, place settings, or cities. It is about the study of typical spaces and structures that belong to recognizable types or classes. The idea of "recognizable" suggests an important characteristic of types; it suggests not an arbitrary categorization of like-composites of the built landscape, but classification systems that have meaning to people's understanding of their surroundings. The work of Groat suggests that one of the fundamental ways in which people find meaning in architecture is by identifying the built environment by way of 'types'. She found that people consistently categorize buildings into their most likely types, and interestingly, the correct identification of the building type may not be as important as the role that buildings appear to fulfill (Groat, 1982; Groat & Canter, 1979).

Types are a combination of a complex set of elements that underlie processes and transformations of physical and spatial structures in buildings, neighborhoods, and cities into coherent descriptions. Since they have descriptive qualities conceived from the built landscape, they point out the relevance of social and cultural life. Moudon suggests that if defined correctly, types can become structuring concepts tested against the reality of city building (Moudon, 1994, p. 308).

Because the generation of types happens through everyday life, the types are dynamic and flexible, constantly reconfigured by human-environment forces. Bill Hillier et al. (1984) suggest that without rule-sets [such as typologies] the designer is left to make decisions and assimilate ideas without guidance on priorities or patterns of application: "the designer's field becomes *more* complex and *less* structured" (p. 250).Therefore, typologies are a method for prioritizing multidimensional properties and qualities of the environment as they evolve over time.

A book chapter by Anne Vernez Moudon, "Getting to know the built landscape: typomorphology" (1994) is one of the few comprehensive descriptions of cross-continental schools of thought on typologies that developed in the fields of geography, urban planning, and architecture. She writes that 'typologies' have been defined for buildings, public spaces, urban fabric, the city (Caniggia, 1963; Muratori, 1959), schools, town plans, building fabric, land utilization (Conzen, 1968), and street patterns (Moudon, 1992b), to name a few.

One criticism of some of these examples is that they can become distinct visual categories of built form rather than convincing tools for urban analysis; Moudon (1992b) includes Aldo Rossi's *The Architecture of the City* (1982) into this critique. The Muratori School, on the other hand, emphasized that the typological process is the tool to understanding the city. They view urban form and structure as the aggregate of many ideas, choices, and actions becoming expressed in physical form. It is perhaps for this reason that Moudon points out "*that typologies have been developed more fully in Italy than anywhere else*" (p. 291). Using analytical findings from type studies as the point of departure anchors design processes in reality. Typologies in urban analysis imply the exploration of the relational aspects of streets, neighborhoods, and cities.

This dissertation research generally supports an 'ecological' approach. The configurational descriptions of space (space syntax techniques) and place (objective destination measures) are two analytical tools for further research. Descriptive tools of space and place also allow for analysis across various scales. Although this dissertation focuses on the scale of the neighborhood and people's walkable ranges, other space/place descriptions can focus on the city level (Bonnes et al., 1990; Hillier & Hanson, 1984), public spaces (Gehl, 2001; Low & Lawrence-Zúñiga, 2003; Mehta, 2007), or the building level (Hanson, 1998).

Types can become good analytical, descriptive, and generative tools if their description of structures and patterns remains open-ended enough. For example, Coates and Seamon (1993) point out that even though Christopher Alexander's *Pattern Language* illustrates 253 patterns, forms and relationships, they are far from complete. Patterns may be revisited or new ones created from scratch depending on the design issues at hand. Patterns are never complete and can become part of an ongoing dialogue between architect, client, user, builder, and site (Seamon, 2000).

One of the main differences between the research and design processes is the ongoing isolating of factors in research and the combining of factors in design. This is one of the main reasons that designers often have a hard time translating research into design; getting it right on a single dimension does not necessarily imply that a design works as a larger whole. Ecological perspectives are useful in guiding the broader application of findings into the design process. It is critical to continually assess the implications of a single variable on an ever-expanding context as the design process refines a design project. Typologies can play a dominant role in bridging the gap between research and design.

9.2. Implications for urban design and planning practice

9.2.1. Practical suggestions

The following summary table of the findings from this research is intended to make useful suggestions for the design of neighborhoods in Detroit. Some environmental characteristics are shown to facilitate pedestrian movement, sedentary behaviors, and physical activity. The level of prediction is indicated with one (*), two (**), or three (***) stars, one showing the weakest relationship and three showing the strongest.

[***] A three star rating shows that highly significant relationships were observed in the Detroit neighborhoods, recommended for design.

[**] A two star rating shows that significant relationships were observed in the Detroit neighborhoods.

[*] One star shows that weak relationships were observed and applications of this finding is thought provoking, but it is not intuitively clear how it should be applied in design: more research is needed.

Overall findings of destination environments in Detroit				
Built environment characteristic	**Effect on outcome**	**Strength of relationship**	**Type of destination**	**Detail**
Destination type	↑PM	***	[All destinations without parks]	
Destination types	↑PM	**	[All Destinations] [Commercial] [Educational] [Food]	
Park destinations	↓PM	**	[Parks]	
Proximity to destinations				
Closer distance	↑PM	**	[All destinations without parks]	"following streets" and "as the crow flies"
Closer distance	↑PM	**	[All destinations]	"following streets"
Closer distance	↑PM	**	[Educational]	"following streets" and "as the crow flies"
Closer distance	↑PM ↑SB	**	[Commercial]	"following streets" and "as the crow flies"
Closer distance	↑PM ↑PA	**	[Food]	"following streets" and "as the crow flies"
Number of destinations				
More destinations	↑PM ↑SB	***	[All destinations without parks]	Sum at ¼ mile radius
More destinations	↑PM ↑SB	**	[All destinations] [Commercial] [Educational] [Food]	Sum at ¼ mile radius
Clustering of destinations				
More Clustering	↑PM ↑SB ↑PA ↓WCI	**	[Food]	"following streets"
Number of destination bundles				
More destination bundles	↑PM	***	[All destinations without parks]	1/16th mile size
More destination bundles	↑PM	**	[All destinations] [Commercial] [Educational] [Food]	1/16th mile size

Street network characteristics				
Higher city-wide integration	**↓PM**	**		Average of ½ mile area
Higher local connectivity + lower city-wide integration	**↑PM**	*		Average of ½ mile area
Higher city-wide integration	**↓WCI**	*		Average of ½ mile area
Closer distance to "place chains"	**↑PM**	*		
Closer distance to "main streets"	**↑PM**	*		
Destination reach				
Smaller footprint of streets	**↑PM**	**	[Commercial]	
Smaller footprint of streets	**↑PM**	*	[All destinations] [All destinations without parks]	
Planning measures				
Higher density	**↑PM** **↑SB**	***		Average at ½ mile Average at ¼ mile
Higher density	**↑SB** **↑PM**	***		Average at block
Higher density	**↓PM**	*		Average at ¼ mile
Higher combined density, land use mix, and street connectivity	**↑PM** **↑SB**	*		Average at ½ mile Average at ¼ mile

Key points:

These measures of the built environment are more associated with pedestrian movement than with physical activity

Some areas, such as commercial destinations and food destinations, encourage sedentary behavior

Food destinations can encourage higher physical activity and lower waist circumference

↑	**Higher**
↓	**Lower**
PM	**Pedestrian movement**
SB	**Sedentary behavior**
PA	**Physical activity**
WCI	**Waist circumference**

***	*Strongly significant contribution —highly recommended for design*
**	*Significant contribution —recommended for design*
*	*Weakly significant contribution —approach carefully in design: more research needed*

Table 9-1 Summary table of practical suggestions for urban design and planning

9.2.2. Implications for *New Urbanism*

As a response to urban sprawl and suburbanization, the New Urbanism movement formed in the 1980s to address issues of car dependence and traffic congestion, the erosion of sense of community and place, and the social and economic segregation of women, children, and social classes (Talen, 2005). A wide range of publications describe how dense housing, highly connected streets, mixed modes of transportation, mixed housing, and building design promote social interaction and street safety through 'natural surveillance': citizens with eyes on the street (Calthorpe, 1995; Foster et al., 2007).

As the name suggests, New Urbanism—also called neotraditional development—promotes a return to town planning principals of pre-World War II America. With values described in a document called the *Charter of the New Urbanism (2000),* the group aspires to creating livable neighborhoods that foster sense of community, place identity, and environmental sustainability (Calthorpe, 1995; Katz, 1993). New Urbanists can be seen as building upon the ideals introduced by Jane Jacobs: design that encourages a diversity of uses and building types, small blocks and lot sizes, and walk friendly places (Jacobs, 1961). However, the movement has been criticized for its stylized solutions to complex urban issues, utopian idealism, restrictive coding systems, exclusionary design, and a lack of socioeconomic diversity in the planning process (Day, 2003; Fishman, 2005).

In response to the successes and failures of New Urbanist planned communities, Emily Talen wrote a refreshing article "Design for Diversity: Evaluating the context of socially mixed neighborhoods." She suggests that if planners and designers are to support and promote socially diverse neighborhoods, they need to become more acquainted with the form of diverse places. She found places such as “inner-ring, ‘blue-collar’ suburbs, often having the characteristics of strong edges, grids with commercial corridors, and mixed housing types,” to be useful examples of existing cities that have to some extent proved their longevity (Talen, 2006, p. 1). Similar findings from this dissertation raise issues with how or if assumptions of New Urbanism—to a certain extent the norm in planning and design—are embodied in the Detroit neighborhoods. This dissertation research addresses a gap in the literature by investigating existing, socially diverse communities.

9.2.3. Clustering destinations creating opportunities to make places

For urban designers, one of the main purposes of encouraging more destinations, or more mix of uses, is to increase the number of available public spaces for residents. In the United States, streets have a social purpose; both the streets and the destinations provide venues for chance encounters (Appleyard, 1981; Hillman et al., 1980; Lynch, 1981; Southworth & Ben-Joseph, 1997; Whyte, 1980). As Langdon (1994) suggests, places give “heart” to a community and strengthen the bonds between people by creating a sense of place and promoting the notion of community.

The New Urbanists fully embrace the ideal of community in works by Calthorpe (1995), Duany and Plater-Zyberk (1992; 2000), Langdon (1994), and Katz (1993); they take it one step further by formalizing a taxonomy of design goals, design elements, and form applications suggested to promote aspects of “togetherness”. Their ideals developed largely from interpretations of works by Jacobs (1961), Whyte (1988), and Krier (1984) suggesting a fine-grain urban texture by having small and frequent public destinations and open spaces dispersed throughout the neighborhood. This complexity of land uses provides a rich texture of public and private spaces in the city that accommodates a cross-section of relationships between neighbors, friends, acquaintances, and strangers (Jacobs, 1961).

The findings from this dissertation show higher *pedestrian movement* in areas with more destinations (Chapter 6, Figure 3-4 and 3-5). It appears as if destinations in the study areas function exactly as destinations should: they attract people. A great piece of insight from Jane Jacobs may shed some light on these relationships: “[o]bjects in cities—whether they are buildings, streets, parks, districts, landmarks, or anything else—can have radically differing effects, depending upon the circumstances and contexts in which they exist” (Jacobs, 1961, p. 574). Destinations in Detroit seem to attract the attention of residents because they play such an important role in residents’ everyday lives. Destinations are also important in creating public space for residents.

Destination bundles in existing suburban settings are also attracting renewed interest among planners and researchers. For example, Moudon and Hess studied 85 post-war neighborhood clusters in the Puget Sound. Their suburban neighborhood clusters developed out of a different historical context than the destination clusters in the Detroit areas; the clusters in the Puget Sound consist predominantly of commercial, educational, and multifamily uses that sprung up in zones next to the high traffic arterials where suburbanites would have found single-family housing lots less attractive.

However, like most of the Detroit neighborhood bundles, the clusters in the Puget Sound had no formal plan that guided the initial overall design. Land parcels are often very large (around 40 acres), street connections are limited, and a large thoroughfare gathers the uses in a linear fashion. In addition, the concentration of traffic on a single arterial does not handle traffic well. The combination of large parcels, high traffic volumes, and lack of access to the surrounding areas deter walking (Moudon & Hess, 2000).

The importance of Moudon and Hess's observations is that despite the unintentional way in which these public spaces have developed over the years without any formal planning or design criteria, their significance is starting to be recognized on even a regional level. The form-based, land use, and spatial composition of the clusters show a number of similarities with Perry's Neighborhood Unit (1929), which is one of the most important models espoused by the designers and planners of neotraditional developments. Their analysis also differs in important ways from Perry (please refer to Moudon and Hess (2000) for a more detailed discussion). They describe the neighborhood clusters (NCs) to have the following characteristics which may also have relevance for thinking about destination bundles in Detroit:

1. NCs are comparatively high density and are fairly integrated with the surrounding neighborhoods.
2. They have retail and residential uses in close proximity to yield a good mix of land uses, and they encourage walking at least to some extent.
3. NCs are more likely to attract a range of housing types in close proximity, including multifamily and rental properties, drawing populations that are more diverse.
4. Although the neighborhood clusters are imperfect realizations of vibrant, walkable public spaces, they have all the right underpinnings for attracting high density uses, employment opportunities, and formal attempts to retrofit them into prominent regional centers. Many issues including traffic control, street and sidewalk connectivity, and around-the-clock usage are mentioned as potential

aspects in need of improvement. Despite their haphazard growth processes and pitfalls, Moudon and Hess (2000) suggest that the neighborhood clusters in the Puget Sound hold promise for socially and environmentally sustainable urban development.

The bundles of destinations in the Detroit neighborhoods do not face the same challenges as the suburban neighborhood clusters in the Puget Sound. The broad outlines of vibrant neighborhood bundles in the city of Detroit are already in place; they have a fundamental structure of "urbanity" that may simplify the retrofitting of these environments into sustained urban spaces. They have all the right urban hardware already in place: strong urban form, street connectivity, and mix of uses (see figure Figure 9-1).

Figure 9-1 Neighborhood clusters can become distinctive urban places

Neighborhood residents can also play a crucial role in such a process that focuses on the revitalization of destination bundles as neighborhood public spaces. At a public meeting in Detroit, a former cancer survivor and long-term resident of the city shared her story. She described how she is trying to make her street the best street in her neighborhood by paying the neighborhood kids a few bucks to plant flowers. Asking the kids to take care of their hard work over time, she says, teaches them to care for, respect, and be committed to their street and neighborhood. As an old-time Detroiter, she is one who knows that change does not come fast, but this is her way of giving back. In her words, her efforts are paying off, because she is taking back her neighborhood "one block at a time."

9.2.4. Neighborhood clusters facilitating public custodianship

Strengthening neighborhood clusters may contribute to feelings of communal ownership of facilities and services and provide not only chances for informal and involuntary encounters, but informal control of space. Jane Jacobs suggests that the peace of sidewalks and streets "is not kept primarily by the police, necessary as police are…[but] by an intricate, almost unconscious, network of voluntary controls and standards among the people themselves, and enforced by the people themselves" (Jacobs, 1961, p. 40).

Oscar Newman suggests: "[t]he areas most usually identified as safe are heavily trafficked public streets and arteries combining both intense vehicular and pedestrian movement; commercial retailing areas during shopping hours; institutional areas; and government offices" (Newman, 1972, p. 109). He further suggests that both victim and criminal assume that assaults will not be tolerated by witnesses (shopkeepers and other shoppers) on a well-trafficked area and that the escape route of the criminal is more difficult in an "informally patrolled" area. Strangers help the locals keep the peace along with the most important custodians of public space: the shop owner, the dry cleaner, the barber, and the street vendor.

In one of his research studies, Newman compared reports stating that certain concentrated commercial and institutional areas are perceived as safe with reports from areas that have the opposite perception; Newman found that people consider staff members of the establishments and institutions crucial to maintaining order and safety in the area. Shopkeepers, security guards, and librarians, he explains, have a high stake in ensuring safety not only for their businesses and institutions, but also for the adjoining areas. Architectural features such as windows, visibility, and sight lines are important in facilitating public custodianship of space (Newman, 1972).

Community activities also facilitate a public life of respect and trust, an aspect of social life that is different from the private life and things discussed with a close neighbor. The social lives that develop around neighborhood public spaces are of a very specific nature. The relationships between locals and strangers, the meanings of encounters, and shared trust are all critical components that contribute to the success of public space. According to Jacobs, the difference between getting advice from a grocer or a neighbor is a matter of city privacy (anonymity). A good grocer shows feelings of good-will and will help out while showing no personal interest for someone's private affairs. Good establishments are places with opportunities for public contact, but with no strings attached. For another description of public custodianship, please refer to Mitchell Duneier's (1999) ethnographic book, *Sidewalk.*

As an example, Jacobs offers a vignette of her experiences living on Hudson street, a mixed neighborhood in New York City. For streets to be successful, she suggests, they need well-defined boundaries, not boundaries that keep people out, but well-defined demarcations between public and private spaces. Although commerce that attracts people also gets blamed for attracting the unwanted, she notes that "impersonal city streets make anonymous people, and this is not a matter of [a]esthetic quality nor of a mystical emotional effect in architectural style. It is a matter of what kinds of tangible enterprises sidewalks have, and therefore of how people use the sidewalk in practical, everyday life" (p. 74).

9.3. Future directions for research

The previous two sections focused on the implications that this dissertation has for urban design practice and theory. Turning now to urban design research, this next section offers ways in which the findings from this study may inform the research community. The same format is used here as with section 8.7 discussing the limitations: the future directions are presented in bullet point format, with the suggestion in bold followed by an explanation.

- **Application of destination measures:** Destination measures are intuitive, practical, and descriptive, and were found to be highly associated with pedestrian movement and physical activity outcomes. They are also easily translatable across disciplines and shared among different groups of people. A focus on destinations allows the researcher to concentrate on particular *place settings* that residents value and helps to engage urban planners, architects, clients, and residents with various aspects of the environment. This enables the researcher to become familiar with the important issues that anchor these communities to their places. Further development and application of destination measures can be explored in future research.

- **Combined use of destination and space syntax measures:** This research builds on a growing body of literature investigating the relationships of land use characteristics and spatial characterizations of the environment (Peponis et al., 2008; Peponis et al., 2007; Peponis et al., 2006; Stahle et al., 2006). The findings support the idea that the mere presence of destinations is not enough to describe how the designed environment affects outcomes, for the arrangement of destinations is also an important factor. Destination factors and space syntax factors work together to explain how urban settings function. Future research integrating destination measures with spatial measures can continue to explore and verify the combined effect of destinations and spatial layout.

- **Ecological approach:** A greater understanding of how the design of street spaces and the qualities of destination places connect people to destinations and destination bundles will allow professionals and residents to consider the physical environment as a cohesive whole. Critical aspects of design such as access, layout, and arrangement are to be considered simultaneously. Such an approach avoids the isolation of individual environmental variables and allows for a more meaningful characterization of the environment. This research helped lay a foundation for more investigation in this area.

- **Development and use of typologies:** Descriptions and models that combine both spatial and destination characteristics into singular representations have the potential to become analytical, descriptive, and generative tools. More cohesive and visual descriptions of neighborhood environments will be another future task. The development of environmental typologies that combine environmental characteristics into visual descriptions may be useful (discussed in section 9.1.1).

- **A focus on both place and space:** One of the main conclusions in this dissertation suggests that human outcomes occur through the dynamic interactions between space and place. Each aspect drags along characteristics of the other. Certain research questions may be best investigated by emphasizing either spatial properties or destination characteristics, but in general, a 'both-and' approach is indicated. It is suggested that future research investigate both constructs at the same time in order to more fully grasp environmental effects.

- **Participatory research:** Members of the Healthy Environments Partnership and community members were engaged with this project throughout the developmental, methodological, and interpretative stages. This allowed the project to be attuned to interest groups within these communities, stimulating co-learning among the author, residents, other researchers, and community interest groups. Future research may benefit from also conducting their investigations in a participatory manner. Please refer to Israel et al. (1998) for a detailed review of community-centered, participatory, and collaborative research approaches.

- **Accounting for colinearity:** Previous research has suggested that environmental factors believed to encourage walking and physical activity are highly colinear (Lee & Moudon, 2006b). Findings from this dissertation have yielded promising results for avoiding colinearity by focusing on different environmental characteristics than the urban planning measures of density, land use mix, and street connectivity. Further explorations are needed to continue to investigate how to address the issue of colinearity.

- **Use of objective measures:** This study builds on recent developments in the physical activity literature that use objective descriptions of the physical environment (Badland et al., 2008; Berke et al., 2007; Frank et al., 2005a; Lee et al., 2005; Leslie et al., 2007; Moudon et al., 2006c; Troped et al., 2001). The rationale for using objective measures is supported by findings indicating a poor agreement between perceptual and objective measures (McGinn et al., 2007a; Moudon et al., 2006c). Objective examinations of the built environment that determine which factors are related to people's walking behaviors are also of interest to those who design and construct the built environment: designers and planners (Forsyth et al., 2008b). This research suggests that objective measures can provide meaningful descriptions of peoples' environments and should be utilized in research.

- **Importance of including qualitative data:** Despite the benefit of using objective measures, findings from this study would have been more difficult to interpret if not for the extensive data on residents' perceptions, attitudes, and behaviors published elsewhere ("Healthy Environments Partnership: Focus group summaries," 2006; Israel et al., 2006). Neighborhood physical features are likely to have different meanings depending on the specific area and population. Future research may focus on collecting more qualitative data specifically related to people's perceptions of their neighborhood environments.

- **Usefulness of objective data sources:** Objective data sources are becoming more readily available. These sources include detailed maps, high quality aerial photographs, and other Geographic Information Systems data that are often available free of charge. These existing objective data sources help the researcher gather information without putting additional strain on communities. Contact sessions with communities can then be directed toward other research activities such as gathering qualitative feedback, engaging residents to frame important issues, and interpreting findings. In addition, objective data can be a useful tool for communication between researchers, residents, developers, community organizations, and government officials. It is recommended that researchers utilize these data sources.

- **Syntax 2D software:** The Syntax 2D software developed at the University of Michigan's A. Alfred Taubman College of Architecture and Urban Planning holds promise for providing spatial characteristics of visual fields that are not described by the environmental measures used in this dissertation. This software enables the quantification of visual fields along neighborhood streets and captures various aspects of visibility such as the area, occlusivity, and perimeter of the visual field. Measurement of these visual fields may contribute to an understanding of, for example, how people's sense of safety is affected by what they see—or do not see—when they walk down streets.

- **Next steps:** Due to the cross-sectional nature of the analysis, this dissertation research is descriptive rather than predictive. This suggests that the ideas, findings, and interpretations need further research to isolate the specific causes and processes. Nonetheless, a foundation has been laid to explore these issues further. Next steps are proposed:

    1. Similar research questions and hypotheses can be tested using 2008 HEP survey data. This survey includes all the relevant questions from the 2002 survey and added more specific questions related to transportation walking, leisure

walking, walking within the neighborhood, and work-related walking. The future analysis can then be compared with the findings from the analysis using the 2002 survey, while more specific pathways such as specific walking purposes can add another layer to the description of localized walking.

2. A sub-sample of the 2008 sample included the same respondents as in 2002. Opportunities for longitudinal analysis on general physical activity, health, and neighborhood perception outcomes are possible. For example, the time lag between 2002 and 2008 may be enough to track significant changes on a few of the environmental variables; time 1 - time 2 comparisons can parse out the contributions of these land use changes on physical activity outcomes.

3. This analysis suggested no mediating effects of neighborhood psychosocial perceptions on the relationships between environmental measures and physical activity outcomes. It is possible that only certain aspects of people's overall physical activity are affected by their perceptions of the neighborhood. Data that is more specific to the type of physical activity may show different results. In the discussion section, the author alluded to some of these more specific connections. Future analysis looking at different purposes of walking such as transportation, leisure, or work-related, may identify more direct connections between neighborhood perceptions and activity outcomes.

9.4. Conclusion

This dissertation contributes to understanding the links between the built environment and physical activity outcomes. In particular, it seeks to inform urban designers and planners how different environmental characteristics contribute to neighborhood settings supportive of pedestrian movement and other physical activity outcomes. It is suggested that both destination factors and space syntax factors can greatly enhance mainstream planning measures, which are often highly aggregated. The destination and space syntax factors can better address certain elements of the designed environment such as the arrangement, the detailed composition, and the characteristics of places and spaces.

Of all the measures analyzed in this dissertation, the destination measures showed the strongest associations with pedestrian movement. Some space syntax measures, such as integration, connectivity, and distance to “main streets” showed strong associations with pedestrian movement, but other measures in this group did not. Contradicting previous research, this study showed overall low predictions of the planning measures, with the exception of density. Planning measures of density, diversity, and design are often abstract and hard to interpret and need care in how they are operationalized in research and translated into practice.

This investigation explores ways of developing simpler environmental measures and characterizations of the built environment that could be more easily translated into design practice. The belief is that these grouped measures internalize some predictive relevance. Having such predictive measures and diagrams at the fingertips of creative experts could unlock the crucial organizational, structural, and experiential aspects that guide the design of active neighborhoods. In turn, this may also help researchers, designers, and community members communicate more effectively during the planning and design processes.

Finally, this dissertation engages in a broader theoretical discussion of space and place. By applying the theories to selective empirical measurement, a deeper understanding of the theories of space and place is explored. The research proposes multifaceted relationships between the elements of space and place: street layouts, land uses, and the density of people. These findings indicate that space and place are independent and interdependent constructs that constantly reinforce one another. It is hoped that this dissertation research will serve as a stepping-off point for future research to continue exploring these relationships.

Appendix A
CORRELATION TABLE

Correlation table of physical environmental measures and pedestrian movement outcomes, not adjusted for age

	Pedestrian movement (block)	Ped. Mov. + Sed. Beh. (block)	Pedestrian movement (rook)	Ped. Mov. + Sed Beh. (rook)
Destination measures				
Proximity to destinations				
All destinations (airline distance)	-0.18182	-0.14482	-0.20374	-0.11544
	0.0298	0.0844	**0.0147**	0.1698
	143	143	143	143
All without parks (airline distance)	-0.25708	-0.21387	-0.23749	-0.16219
	0.0019	**0.0103**	**0.0043**	0.053
	143	143	143	143
Commercial (airline distance)	-0.29063	-0.28177	-0.17667	-0.18433
	0.0004	**0.0007**	**0.0348**	**0.0275**
	143	143	143	143
Educational (airline distance)	-0.20271	-0.21039	-0.34636	-0.3153
	0.0152	**0.0117**	**<.0001**	**0.0001**
	143	143	144	144
Food (airline distance)	-0.26565	-0.19933	-0.3229	-0.30314
	0.0013	**0.017**	**<.0001**	**0.0002**
	143	143	144	144
All destinations (network distance)	-0.21344	-0.17623	-0.25076	-0.16557
	0.0105	**0.0353**	**0.0024**	**0.0473**
	143	143	144	144
All without parks (network distance)	-0.21344	-0.17623	-0.25076	-0.16557
	0.0105	**0.0353**	**0.0024**	**0.0473**
	143	143	144	144
Commercial (network distance)	-0.29595	-0.26646	-0.19845	-0.1991
	0.0003	**0.0013**	**0.0171**	**0.0167**
	143	143	144	144

	Pedestrian movement (block)	Ped. Mov. + Sed. Beh. (block)	Pedestrian movement (rook)	Ped. Mov. + Sed Beh. (rook)
Educational (network distance)	-0.23416	-0.24124	-0.37856	-0.3505
	0.0049	**0.0037**	**<.0001**	**<.0001**
	143	143	144	144
Food (network distance)	-0.26761	-0.20238	-0.32265	-0.29359
	0.0012	**0.0153**	**<.0001**	**0.0004**
	143	143	144	144
Number of destinations				
All destinations (1/4 mile radius)	0.48247	0.28949	0.46295	0.29907
	<.0001	**0.0005**	**<.0001**	**0.0003**
	143	143	144	144
All without parks (1/4 mile radius)	0.50467	0.33113	0.47885	0.33148
	<.0001	**<.0001**	**<.0001**	**<.0001**
	143	143	144	144
Commercial (1/4 mile radius)	0.46626	0.28674	0.43841	0.27502
	<.0001	**0.0005**	**<.0001**	**0.0008**
	143	143	144	144
Food (1/4 mile radius)	0.3483	0.20015	0.34101	0.21905
	<.0001	**0.0165**	**<.0001**	**0.0083**
	143	143	144	144
All destinations (1/2 mile radius)	0.41569	0.29845	0.45321	0.38496
	<.0001	**0.0003**	**<.0001**	**<.0001**
	143	143	144	144
Commercial (1/2 mile radius)	0.41275	0.29662	0.41418	0.32717
	<.0001	**0.0003**	**<.0001**	**<.0001**
	143	143	144	144
All without parks (1/2 mile radius)	0.43134	0.3344	0.44961	0.39243
	<.0001	**<.0001**	**<.0001**	**<.0001**
	143	143	144	144
Food (1/2 mile radius)	0.3009	0.18524	0.291	0.211
	0.0003	**0.0268**	**0.0004**	**0.0111**
	143	143	144	144
Clustering of destinations				
All destinations (1/32 mile bundle; 1/4 mile radius)	-0.03634	-0.129	-0.00531	-0.05391
	0.6665	0.1247	0.9496	0.521
	143	143	144	144

	Pedestrian movement (block)	Ped. Mov. + Sed. Beh. (block)	Pedestrian movement (rook)	Ped. Mov. + Sed Beh. (rook)
All without parks (1/32 mile bundle; 1/4 mile radius)	-0.05624	-0.12944	-0.06723	-0.08633
	0.5046	0.1234	0.4234	0.3035
	143	143	144	144
Commercial (1/32 mile bundle; 1/4 mile radius)	-0.02271	-0.11099	-0.05002	-0.08651
	0.7878	0.1869	0.5516	0.3025
	143	143	144	144
Food (1/32 mile bundle; 1/4 mile radius)	0.14915	0.11206	0.16355	0.20682
	0.0754	0.1827	0.0501	**0.0129**
	143	143	144	144
All destinations (1/16 mile bundle; 1/4 mile radius)	-0.00676	-0.07779	-0.01527	-0.05689
	0.9362	0.3558	0.8558	0.4982
	143	143	144	144
All without parks (1/16 mile bundle; 1/4 mile radius)	0.04487	-0.09641	0.0187	-0.02773
	0.5947	0.252	0.824	0.7415
	143	143	144	144
Commercial (1/16 mile bundle; 1/4 mile radius)	0.13001	-0.05833	0.08443	0.04383
	0.1217	0.4889	0.3143	0.602
	143	143	144	144
Food (1/16 mile bundle; 1/4 mile radius)	0.27985	0.24987	0.29046	0.2943
	0.0007	**0.0026**	**0.0004**	**0.0003**
	143	143	144	144
All destinations (1/8 mile bundle; 1/4 mile radius)	0.00613	-0.07537	-0.01332	-0.05027
	0.9421	0.3709	0.8741	0.5496
	143	143	144	144
All without parks (1/8 mile bundle; 1/4 mile radius)	0.02446	-0.07085	-0.00685	-0.02742
	0.7718	0.4004	0.9351	0.7442
	143	143	144	144
Commercial (1/8 mile bundle; 1/4 mile radius)	0.01331	-0.06832	0.01068	0.00934
	0.8747	0.4175	0.8989	0.9116
	143	143	144	144
Food (1/8 mile bundle; 1/4 mile radius)	0.24771	0.2858	0.17414	0.16193
	0.0029	**0.0005**	**0.0369**	0.0525
	143	143	144	144
All destinations (1/32 mile bundle; 1/2 mile radius)	-0.19764	-0.26084	-0.20137	-0.29895
	0.018	**0.0017**	**0.0155**	**0.0003**
	143	143	144	144

	Pedestrian movement (block)	**Ped. Mov. + Sed. Beh. (block)**	**Pedestrian movement (rook)**	**Ped. Mov. + Sed Beh. (rook)**
All without parks (1/32 mile bundle; 1/2 mile radius)	-0.22562	-0.29135	-0.22506	-0.31577
	0.0067	**0.0004**	**0.0067**	**0.0001**
	143	143	144	144
Commercial (1/32 mile bundle; 1/2 mile radius)	-0.16893	-0.22635	-0.16522	-0.26003
	0.0437	**0.0066**	**0.0478**	**0.0016**
	143	143	144	144
Food (1/32 mile bundle; 1/2 mile radius)	-0.03575	-0.03853	0.04824	-0.01283
	0.6716	0.6477	0.5659	0.8787
	143	143	144	144
All destinations (1/16 mile bundle; 1/2 mile radius)	-0.17438	-0.23926	-0.15985	-0.26418
	0.0373	**0.004**	0.0556	**0.0014**
	143	143	144	144
All without parks (1/16 mile bundle; 1/2 mile radius)	-0.21578	-0.28489	-0.18627	-0.28176
	0.0096	**0.0006**	**0.0254**	**0.0006**
	143	143	144	144
Commercial (1/16 mile bundle; 1/2 mile radius)	-0.20714	-0.27243	-0.17637	-0.27467
	0.0131	**0.001**	**0.0345**	**0.0009**
	143	143	144	144
Food (1/16 mile bundle; 1/2 mile radius)	-0.05223	-0.03105	-0.00499	-0.00882
	0.5356	0.7128	0.9526	0.9164
	143	143	144	144
All destinations (1/8 mile bundle; 1/2 mile radius)	-0.17992	-0.24477	-0.16161	-0.27308
	0.0315	**0.0032**	0.053	**0.0009**
	143	143	144	144
All without parks (1/8 mile bundle; 1/2 mile radius)	-0.21911	-0.28288	-0.18935	-0.28845
	0.0086	**0.0006**	**0.023**	**0.0005**
	143	143	144	144
Commercial (1/8 mile bundle; 1/2 mile radius)	-0.22188	-0.28107	-0.19374	-0.29165
	0.0077	**0.0007**	**0.02**	**0.0004**
	143	143	144	144
Food (1/8 mile bundle; 1/2 mile radius)	-0.19386	-0.07556	-0.20634	-0.20253
	0.0203	0.3697	**0.0131**	**0.0149**
	143	143	144	144

	Pedestrian movement (block)	Ped. Mov. + Sed. Beh. (block)	Pedestrian movement (rook)	Ped. Mov. + Sed Beh. (rook)
Number of bundles				
All destinations (1/32 mile bundles; 1/2 mile radius)	0.46993	0.28123	0.43857	0.29161
	<.0001	**0.0007**	**<.0001**	**0.0004**
	143	143	144	144
All without parks (1/32 mile bundles; 1/2 mile radius)	0.4894	0.31447	0.45399	0.31877
	<.0001	**0.0001**	**<.0001**	**<.0001**
	143	143	144	144
Commercial (1/32 mile bundles; 1/2 mile radius)	0.44879	0.26328	0.42737	0.2737
	<.0001	**0.0015**	**<.0001**	**0.0009**
	143	143	144	144
All destinations (1/16 mile bundles; 1/2 mile radius)	0.51671	0.33329	0.46847	0.31998
	<.0001	**<.0001**	**<.0001**	**<.0001**
	143	143	144	144
All without parks (1/16 mile bundles; 1/2 mile radius)	0.5519	0.38405	0.48102	0.36614
	<.0001	**<.0001**	**<.0001**	**<.0001**
	143	143	144	144
Commerical (1/16 mile bundles; 1/2 mile radius)	0.51629	0.33668	0.44492	0.30999
	<.0001	**<.0001**	**<.0001**	**0.0002**
	143	143	144	144
Space syntax measures				
Street network integration				
Mean city level integration (1/4 mile radius)	-0.27333	-0.28595	-0.29328	-0.27844
	0.001	**0.0005**	**0.0004**	**0.0007**
	143	143	144	144
Mean neighborhood level integration (1/4 mile radius)	0.00526	0.02863	-0.04366	0.11762
	0.9503	0.7343	0.6033	0.1603
	143	143	144	144
Mean city level integration (1/2 mile radius)	-0.32312	-0.29977	-0.3377	-0.30454
	<.0001	**0.0003**	**<.0001**	**0.0002**
	143	143	144	144
Mean neighborhood level integration (1/2 mile radius)	-0.07432	-0.01029	-0.0985	0.08434
	0.3777	0.9029	0.2402	0.3149
	143	143	144	144

	Pedestrian movement (block)	Ped. Mov. + Sed. Beh. (block)	Pedestrian movement (rook)	Ped. Mov. + Sed Beh. (rook)
Distance to "main streets" and "place chains"				
Distance to "main streets"	-0.27112	-0.06827	-0.20608	-0.01325
	0.0011	0.4179	**0.0132**	0.8748
	143	143	144	144
Distance to "place chains"	-0.29438	-0.09955	-0.23392	-0.04486
	0.0004	0.2368	**0.0048**	0.5934
	143	143	144	144
Street network connectivity				
Mean city level connectivity (1/4 mile radius)	-0.10565	-0.11978	-0.09961	-0.02898
	0.2092	0.1542	0.2349	0.7302
	143	143	144	144
Mean neighborhood level connectivity (1/4 mile radius)	-0.06569	-0.04814	-0.04881	0.05829
	0.4357	0.568	0.5613	0.4877
	143	143	144	144
Mean city level connectivity (1/2 mile radius)	-0.14533	-0.12765	-0.12343	-0.03121
	0.0833	0.1287	0.1405	0.7103
	143	143	144	144
Mean neighborhood level connectivity (1/2 mile radius)	-0.07483	-0.06341	-0.06398	0.04755
	0.3744	0.4518	0.4462	0.5714
	143	143	144	144
Reach				
Reach (1/4 mile radius)	-0.04855	0.04181	-0.01534	0.14248
	0.5647	0.62	0.8552	0.0885
	143	143	144	144
Reach (1/2 mile radius)	-0.12912	-0.01261	-0.09413	0.08146
	0.1243	0.8811	0.2618	0.3318
	143	143	144	144
Destination reach				
All destinations (1/2 mile away)	-0.16375	-0.11482	-0.1369	-0.07227
	0.0507	0.1721	0.1018	0.3893
	143	143	144	144
All without parks (1/2 mile away)	-0.19523	-0.17587	-0.16361	-0.12141
	0.0195	**0.0356**	0.0501	0.1472
	143	143	144	144
Commercial (1/2 mile away)	-0.22058	-0.17524	-0.16433	-0.09292
	0.0081	**0.0363**	**0.049**	0.268
	143	143	144	144

	Pedestrian movement (block)	Ped. Mov. + Sed. Beh. (block)	Pedestrian movement (rook)	Ped. Mov. + Sed Beh. (rook)
All destinations (1 mile away)	-0.20324	-0.15575	-0.17523	-0.11551
	0.0149	0.0632	**0.0357**	0.168
	143	143	144	144
All without parks (1 mile away)	-0.21657	-0.20893	-0.17641	-0.14996
	0.0094	**0.0123**	**0.0344**	0.0728
	143	143	144	144
Commercial (1 mile away)	-0.242	-0.20574	-0.17302	-0.09763
	0.0036	**0.0137**	**0.0381**	0.2444
	143	143	144	144
Urban planning measures				
Density Residential density (block level)	0.3069	0.3762	0.3221	0.3137
	0.0002	**<.0001**	**<.0001**	**0.0001**
	142	142	142	142
Residential density (1/4 mile radius)	0.00669	-0.02936	0.02278	-0.0153
	0.9368	0.7277	0.7864	0.8556
	143	143	144	144
Residential density (1/2 mile radius)	0.43829	0.38435	0.50587	0.46771
	<.0001	**<.0001**	**<.0001**	**<.0001**
	143	143	144	144
Land use mix Land use mix (1/4 mile radius)	0.15639	0.09407	0.11933	-0.04431
	0.0621	0.2638	0.1543	0.598
	143	143	144	144
Land use mix (1/2 mile radius)	0.17584	0.09042	0.09702	-0.02669
	0.0357	0.2828	0.2473	0.7508
	143	143	144	144
Street connectivity Street connectivity (1/4 mile radius)	0.17143	0.1849	0.28936	0.31452
	0.0406	**0.0271**	**0.0004**	**0.0001**
	143	143	144	144
Street connectivity (1/2 mile radius)	-0.00939	0.03246	0.10775	0.23107
	0.9114	0.7003	0.1986	**0.0053**
	143	143	144	144

Appendix B
REGRESSION TABLES

Clustering of all destinations at the ½ mile radius

	MODEL 1 Pedestrian movement (block)			MODEL 2 Ped. mov. + Sed. beh. (block)		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.7035	0.7438	<.0001	9.4004	1.5595	<.0001
Age	-0.0316	0.0200	0.117	-0.0770	0.0419	0.069
All destinations (1/32nd mile bundle)	-22.7639	10.4480	**0.032**	-59.8375	21.9048	**0.007**
Adj R-Square		.05			.07	

	MODEL 3 Pedestrian movement (block)			MODEL 4 Ped. mov. + Sed. beh. (block)		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.6629	0.7462	<.0001	9.4119	1.5606	<.0001
Age	-0.0309	0.0200	0.126	-0.0753	0.0419	0.075
All destinations (1/16th mile bundle)	-6.1799	2.9996	**0.042**	-17.1746	6.2733	**0.007**
Adj R-Square		.04			.07	

	MODEL 5 Pedestrian movement (block)			MODEL 6 Ped. mov. + Sed. beh. (block)		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.5232	0.7181	<.0001	9.0368	1.5023	<.0001
Age	-0.0296	0.0200	0.142	-0.0719	0.0419	0.089
All destinations (1/8th mile bundle)	-2.1606	1.0763	**0.047**	-6.0481	2.2515	**0.008**
Adj R-Square		.04			.07	

Table B-1 **Regression models of *pedestrian movement* and *pedestrian movement + sedentary behavior* and the clustering of all destinations consisting of 1/32nd, 1/16th, and 1/8th of a mile destination bundles, adjusted for block and rook level age**

Clustering of commercial destination at the ½ mile radius

	MODEL 1 **Pedestrian movement (block)**			MODEL 2 **Ped. mov. + Sed. beh. (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.3838	0.7072	<.0001	8.6029	1.4870	<.0001
Age	-0.0287	0.0201	0.156	-0.0695	0.0423	0.104
Commercial destinations (1/32th mile bundle)	-11.1222	6.3671	0.084	-30.1751	13.3886	**0.026**
Adj R-Square	.03			.05		

	MODEL 3 **Pedestrian movement (block)**			MODEL 4 **Ped. mov. + Sed. beh. (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.5231	0.6862	<.0001	9.0119	1.4260	<.0001
Age	-0.0301	0.0198	0.133	-0.0731	0.0412	0.079
Commercial destinations (1/16th mile bundle)	-3.6962	1.4820	**0.014**	-10.2062	3.0796	**0.001**
Adj R-Square	.06			0.10		

	MODEL 5 **Pedestrian movement (block)**			MODEL 6 **Ped. mov. + Sed. beh. (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	3.4515	0.6732	<.0001	8.7627	1.4023	<.0001
Age	-0.0287	0.0198	0.150	-0.0695	0.0413	0.095
Commercial destinations (1/8th mile bundle)	-1.5623	0.6111	**0.012**	-4.1739	1.2731	**0.001**
Adj R-Square	.06			0.10		

Table B-2 **Regression models of *pedestrian movement* and *pedestrian movement + sedentary behavior* and the clustering of commercial destinations consisting of 1/32nd, 1/16th, and 1/8th of a mile destination bundles, adjusted for block and rook level age**

	Number of destination bundles								
	MODEL 1 **Ped. mov. + Sed. beh. (block)**			MODEL 2 **Ped. mov. + Sed. beh. (block)**			MODEL 3 **Ped. mov. + Sed. beh. (block)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	4.7398	1.3913	0.001	4.5471	1.3637	0.0012	4.8757	1.3794	0.001
Age	-0.0596	0.0398	0.138	-0.0532	0.0392	0.1777	-0.0540	0.0399	0.179
All destinations bundles (1/16th mile bundle at 1/2 mile radius)	0.0827	0.0187	**<.0001**						
All destinations without parks bundles (1/16th mile bundle at 1/2 mile radius)				0.0871	0.0177	**<.0001**			
Commercial destinations bundles (1/16th mile bundle at 1/2 mile radius)							0.0912	0.0206	**<.0001**
Adj R-Square	0.17			0.2			0.17		

Table B-3 Regression models of *pedestrian movement* + *sedentary behavior* and number of bundles (all destinations, all destinations without parks, and commercial destinations), adjusted for block level age

	Number of destination bundles						Number of destination bundles + Number of all destinations without parks					
	MODEL 1 **Ped. mov. + Sed. beh. (block)**			MODEL 2 **Ped. mov. + Sed. beh. (rook)**			MODEL 3 **Ped. mov. + Sed. beh. (block)**			MODEL 4 **Ped. mov. + Sed. beh. (rook)**		
Variable	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**	**Estimate**	**Std**	**p-value**
Intercept	4.5471	1.3637	0.0012	2.8219	1.3452	0.038	2.7050	1.6907	0.113	0.1368	1.6061	0.932
Age	-0.0532	0.0392	0.1777	-0.0033	0.0406	0.935	-0.0441	0.0391	0.262	0.0202	0.0401	0.617
Number of bundles (all without parks) (1/2 mile radius; 1/16th mile bundle)	0.0871	0.0177	**<.0001**	0.0739	0.0143	**<.0001**	0.0636	0.0218	**0.004**	0.0447	0.0172	**0.011**
Number of all destinations without parks (1/2 mile radius)							0.0239	0.0132	0.074	0.0301	0.0105	**0.005**
Adj R-Square	0.20			0.19			0.21			0.24		

Table B-4 Regression models of *pedestrian movement* + *sedentary behavior* and number of bundles (all destinations without parks), adjusted for the number of all destinations without parks and block and rook level age

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