ABSTRACT

Title of Document: THE RELATIONSHIP BETWEEN NEIGHBORHOOD ENVIRONMENT AND WALKING BEHAVIOR: THE INFLUENCE OF PERCEPTIONS

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Perceptions and other social-psychological factors are key to fully understanding walking. Theorists and designers in the urban planning field have long held that people internalize their environment in very complex ways, but these efforts have rarely been translated into empirical travel behavior research. As a result, there is a lack of understanding of how perceptions are shaped by the environment and the contribution of those relationships in the explanation of walking behavior. This study investigates the relationships between residents' perceptions of their neighborhood environment and corresponding objective measures of the same attributes and ultimately, tests their associations with walking behavior.

The methodology includes a cross-sectional, disaggregate research design that incorporates three major categories of data: (1) objective measures of the environment, including macro-scale and micro-scale features, (2) residents' perceptions of the environment, and (3) walking behavior data. Five areas in Montgomery County, MD are chosen as the study locations because of the variation in social and transportation factors. Six constructs representing major features of the environment (land use/density, pedestrian network, road network, safety from traffic, cleanliness, tree cover) are elaborated in both the objective and perceptual assessments of the environment.

Models of perceptions show that objective measures of the environment and socio-demographic measures are generally not good predictors of perceptions. Perceptions have slightly higher explanatory power than objective measures in models of walking behavior. Different measures of the environment are significant from the objective and perceptual angles: only land use and street network are associated with walking both when measured objectively and through perceptions. The other measures are only significant when measured from one perspective: pedestrian network and cleanliness are significantly associated with walking when measured objectively, while tree cover is significant when measured perceptually.

The results indicate that the traditional methods of assessing the pedestrian environment with regard to walking behavior might not be the most effective way of capturing environmental variables. They underscore the value of trying to understand the impact of perceptions on the relationship between the built environment and walking, which entails more targeted environmental interventions that can better change and improve walkability. Specific recommendations include educating people in assessing their environment and more frequently including perceptual measures of the environment when assessing it for walkability.

THE RELATIONSHIP BETWEEN NEIGHBORHOOD ENVIRONMENT AND WALKING BEHAVIOR: THE INFLUENCE OF PERCEPTIONS

By

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Dedication

This dissertation is dedicated to Benjamin Smith and Julia Livi. Without you, I just couldn’t have done this.

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Chapter 1: Introduction

Walking is an activity almost everyone engages in. For most of history, it was the only way for the majority of people to go about their daily life. Environments were built around that speed of movement, at the "human scale". These environments were meant to be seen from the pedestrian's perspective, and according to urban designers and architects, are generally the types of environments that people enjoy being in. Spaces like these are rife in Europe as well as Asia and Africa, where development happened slowly and well before the advent of the automobile. In Medieval European cities such as Carcassonne, one is better suited navigating the environment on foot rather than in a vehicle: destinations are close by, there is a great complexity of the environment attracting the eye, streets are narrow and curve at sharp angles. In other words, pedestrians perceive environments such as these as pleasant spaces that belong to them. In contrast, trying to drive in these places is an exercise in frustration, as the speed of a car makes wayfinding all but impossible.

Although these pre-automobile environments are considered beautiful both by designers and the countless tourists that flock there, most of the built environment in North America was not designed that way. Instead, much of the environment in the United States was built around the supremacy of the automobile. Although there are distinct advantages to that way of building and traveling, it does make walking much more difficult – and often more unpleasant. This is a problem, as walking has benefits on many levels: it allows people to travel, to exercise and to socialize, all in one simple, low-impact activity. It is also one of the few activities that can be engaged in by almost everyone, including all age groups, genders, and social and economic conditions.

The multifold benefits of walking have led many researchers and designers from multiple fields, in particular travel behavior and public health, to attempt to improve walking conditions and increase walking. However, many barriers have limited the effectiveness of research in this field. First, measuring walking is not as simple as one might like. What constitutes walking? How can it be properly captured?

Second, measurement of the environment is also difficult. In the past, many researchers have relied on macro-level measures (Boarnet and Sarmiento, 1998; Berrigan and Troiano, 2002), but this has often led to mixed results (Crane, 2000) that probably under-evaluates the importance of the environment in walking. Further, what aspects of the environment in particular have the most impact? Measuring the environment more precisely has recently been the focus of many studies, but the effectiveness of these measures is unproven (Handy, 2005). Finally, one component has been lacking in many studies of walking behavior: perceptions of the environment. Although many designers (such as Lynch, 1960) have emphasized the critical importance of perceptions in the relationship between environment and walking behavior, this has not led to many empirical studies to test these relationships, particularly in studies of travel behavior. What is more important in shaping behavior: what is actually in the environment or what one *thinks* is there? Are these two measures of the environment substantially different? What does this mean for planners who want to increase the walkability of their neighborhoods?

Of interest in the present research is to determine the strength and extent of the role of perceptions in the relationship between walking behavior and the built environment. By better understanding the role of perceptions, more accurate methods of measuring the environment can be elaborated, leading to a more targeted intervention in the future.

The Importance of Walkable Design

As stated above, the built environment in the United States is decidedly automobile-oriented. Considering this state of affairs, what is the resulting status quo in the walkability of the built environment? What are the consequences in terms of safety, public health, and society in general? These questions have been addressed in a great deal of research, which is briefly summarized below to give some context regarding the importance of walkable design.

Automobiles are a major issue for walkability on many levels. Vehicle ownership and vehicle miles traveled (VMT) have been on the rise (FHWA, 1990; FHWA, 1995). The increases in car ownership and VMTs entail increased use of fossil fuels and consequently air and water pollution, which in turn cause respiratory and cardiopulmonary problems (King et al., 2002). Automobile crashes are also a major source of concern. In 1998, 5,220 pedestrians died from traffic-related injuries and another 69,000 sustained non-fatal injuries (FHWA 1999). Current design guidelines aim at reducing the incidence and severity of car crashes by straightening roads, widening lanes and turning radii, increasing size and number of light signals, etc. (Untermann, 1987) However, many of these features also serve to increase driving speed and therefore pose more risk of serious injury for pedestrians.

Indirectly, the increased physical threat to pedestrians, as well as the clear design orientation toward automobiles, discourages people from walking (Funder's Network, 2003). Indeed, the road and street design reduces space for both pedestrians and pedestrian amenities in favor of increased space for motorists. As Untermann theorized in his paper (1987), almost all features that increase automobile safety have an inverse or adverse effect on walkability.

In addition to health concerns, the current street design focus on automobiles has quality of life consequences. The democratic nature of streets has been discussed in many contexts. In *Public Streets for Public Uses* (1987), Vernez-Moudon stated that "functions of the street must be expanded to its full social, economic, and environmental significance." Streets are important for pedestrian movement, social interaction, commercial activity and enjoyment of the environment, while car-oriented streets discourage all of these benefits. Francis (1987) states that there needs to be recognition of the social aspect of streets and a renewed focus on the needs of pedestrians.

As the least expensive way to travel, walking is the primary mode of transportation for a large percentage of the population: it was the second most favored travel mode in 1983 and 1990 (FHWA, 1990). Walking is used as a mode of transport four times more than bus, rail, taxi and bicycle (FHWA, 1990). In 1995, eight million U.S. households did not own a car, with large proportions of this category being economically disadvantaged families (FHWA 1995). For these at-risk demographics in particular, walking is both a crucial form of transportation and physical activity. Because so many Americans depend on walking and public transportation for travel, questions of access have been addressed by numerous researchers. Many people depending on walking cannot access basic community and commercial amenities (Murray et al., 1998; Talen, 2002).

In response to alarming statistics about the impact of sedentary lifestyles (U.S. Department of Health and Human Services, 2001; Mokdad et al., 2001; Pratt, 2000; Katzmarzyk, 2000), recommendations have been made to prevent further spread and aid in reduction of obesity, diabetes and cardiovascular disease. Poor diet and lack of physical activity have been shown to be the main causes of the problem. In a 1995 study for the Centers for Disease Control and Prevention (CDC), Pate et al. concluded that U.S. adults should engage in at least 30 minutes of moderate physical activity most days of the week to improve their health. The CDC further found that regular moderate physical activity (such as walking), reduces the risk of dying prematurely (U.S. Department of Health and Human Services, 2001).

Among the moderate physical activity types, consensus has been reached that walking is an excellent option. The American Heart Association has found that walking regularly for 30 minutes or more can improve cardiovascular health (AHA, 2001.) In a study, Manson et al. (2002) found that fast-paced walking was associated with a reduction of risk of cardiovascular disease, as was more vigorous activity. Another study showed that "lifestyle activity" (which can include integration of additional walking in one's lifestyle) provided similar health benefits to gym-based workouts (Kohl et al., 1998; Dunn et al., 1999).

However, not all walking entails a significant health benefit. Walking very slowly (strolling, for instance) for the purpose of walking a pet or with a small child, is insufficient to significantly increase heart rate, and therefore may not substantially aid in improving health. Similarly, very short bouts of walking are not as beneficial. To attain significant health benefits, walking trips at moderate to high walking speed of 10 minutes or more are recommended (TRB-IOM, 2005). Recently, a recommendation of 10,000 steps a day has been widespread (President's Council on Physical Fitness and Sports). Pedometers – devices which measure number of steps taken – are now widely, and inexpensively, available (Cocker et al., 2006).

By changing urban form to be more pedestrian-friendly, planners hope to increase the amount of walking behavior, thus improving public health (Fenton, 2005; Powell et al., 2003). This solution has been particularly emphasized because walking in the built environment can be integrated into the travel routines of many, thereby providing benefits in reducing traffic and increasing sense of safety and community in the process. However, the connection between urban form and walking behavior is still a point of contention and has yet to be shown to be substantial. This has limited the leverage of walking advocates in effecting change in communities nationwide.

Study Motivation & Specific Aims

As highlighted above, increasing walking behavior would have multifold benefits for public health as well as quality of life. Further, increasing walking could indirectly reduce driving, both through driving-replacement and by making the environment more pedestrian-friendly: features that improve the walking environment make it less friendly to vehicles and vice-versa (Untermann, 1987). Walking behavior can only be affected in limited ways through physical planning means: only by changing the environment can transportation and urban planners influence walking behavior. As discussed in the next chapter, existing research has shown links between the environment and walking, although socio-demographics and other variables can be of greater import. The strength and importance of the links between environment and walking are still under debate. As a result, interventions to improve the environment lack precise targeting.

These lacunas in existing research provide the motivation for this study: better understanding of the importance of the built environment will allow for more targeted – and more effective – interventions in the future. The central question is how the *perceived* environment and *objective assessment* of the environment relate to each other, and how *both* are associated with walking behavior. In other words, is the environment experienced directly, or are perceptions (which are filtered and therefore different) more important? Comparing these two methods of environmental assessment is relevant because they are the primary methods in the two main avenues of research in walkability: transportation planning studies tend to use objective assessment while public health studies tend to rely on perceptions. It is likely, and hypothesized here, that measures of perceptions and the objective environment are not highly correlated. If that is indeed the case, which version of the environment will have a stronger impact on walking? On the one hand, the perceived environment is the way we internalize the environment in decision-making. However it is also one step removed from the actual environment because of that internalization. Perceptions are intrinsically value laden: they are as much a result of the individual and his/her experiences as of the environment. Those two points of view have colored the research linking walking to environment, but so far this has not resulted in a comparison of perceived versus objective. Such a comparison would be useful nonetheless since it would clarify whether perceptions or objective assessment, or a combination of both, would yield a stronger link with walking. Assuming that perceptions are significant, it then becomes important to understand not only how perceptions and objective assessment of the environment relate to walking behavior but how they relate to each other. Planners can only act to change the environment. However, by better understanding how the objective environment is translated to perceptions, planners could find how to best alter the environment to affect perceptions with the potential to indirectly influence behavior.

Theoretical Framework

This study aims to build on previous research by examining the relationship between the built environment, walking behavior and perceptions. The aims and focus of this study are informed by the social ecological perspective. The social ecological perspective suggests that behavior results from a complex interaction of the physical and social environments (Stokols, 1996) acting at multiple levels, including the personal, cultural, social, and physical environmental (for example, Sallis et al., 1998; Sallis and Owen, 2002). Much of the research examining the determinants of physical activity behavior has focused on individual- and social-level factors (Frank and Engelke, 2001), such as employment status or presence of children in the home. However, recently, public health researchers and practitioners have paid increasing attention to the potential impact of the physical environment (Handy et al., 2002). The social ecological perspective highlights the importance of the "behavioral setting" or the "physical and social context in which behavior occurs." According to this view, certain settings support or discourage physical activity, including walking (Sallis et al., 1998). This social ecological approach provides a theoretical framework around which the various spheres of influence on behavior can be incorporated.

This study relies on a similar framework to structure the research and identify variables for analysis. Figure 1, a modified social ecological model, shows the hypothesized relationships in a conceptual framework. *It is hypothesized that perceptions differ by personal characteristics as well as by environmental features (1)*. In other words, perceptions are influenced by personal characteristics and may therefore vary across distinct individuals even when encountering the same environment. Although some of these characteristics are easily measurable, such as socio-demographic factors, others are not, such as personality, previous experience, etc.

It is further hypothesized that the importance of personal attributes in shaping perceptions entails that variations in perceptions are different than variations in the built environment (2). This means that features of the environment might be highly correlated in reality but are not perceived that way, for instance.

Finally, it is hypothesized that perceptions as well as the environment both have an association with walking behavior (3). This is supported by existing literature (Crane, 1999; Frank and Engelke, 2001; Pikora et al., 2003). Perceptions filter (Addy et al., 2004) all the factors that are related to walking behavior. However, it is likely that perceptions will be a more strongly related to behavior for some features of the environment (such as sense of safety, for instance), while objective assessment will be a better measure for others (for example McGinn et al, 2007; Hoehner et al., 2005).

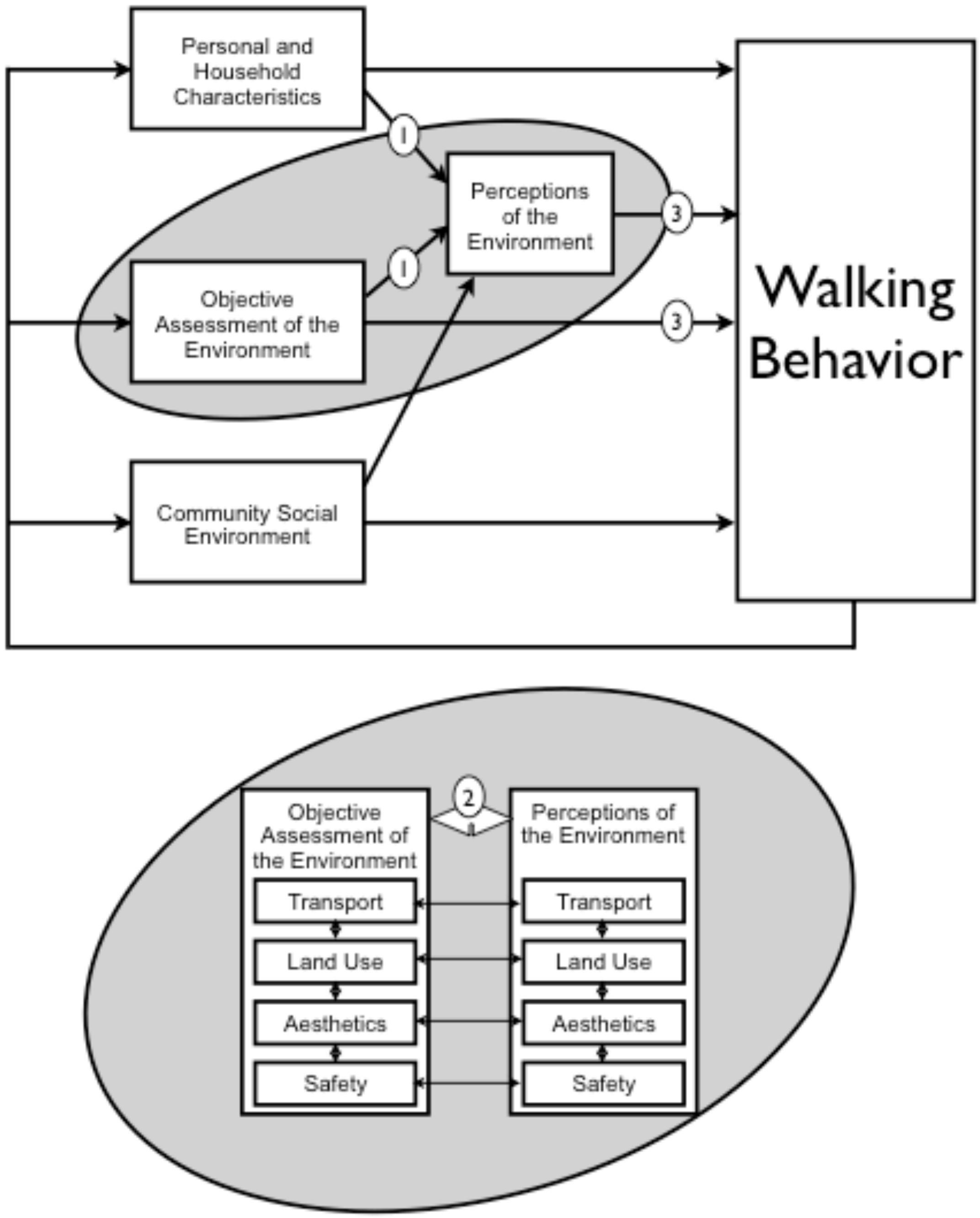


Figure 1: Theoretical Framework

For this study, the relationship of perceptions and objective measures of the environment with walking behavior will be analyzed. In doing so, socio-demographic variables will be considered both at the individual and community level.

Within this framework, the relationship between and among features of the built environment (objectively measured) and perceptions of this same environment is of particular interest. There are a number of features in each major group (objectively measured environment and perceptions of the environment) and these are themselves constructs representing major features of the environment: transportation (pedestrian & motorized), safety, aesthetics (built & natural) and land use. These groups are meant to break up the environment into digestible and coherent pieces. Each category is intended to be comprehensive, with discrete and operationalizable measures. As will be discussed in the following chapters, these particular arrays were chosen because of their demonstrated relationship with walking behavior in existing research both from the travel behavior and public health perspectives. Furthermore, the measures, when taken together, capture a great deal of the walking environment, giving an in-depth picture of micro-level features.

By the nature of this study, there is no need for respondents here to have a theorist's understanding of their perceptions: they are asked simple questions and the overall constructs will be built from factors that have been deemed important in the existing literature. Further, the "matching" that will be done between objective and subjective data need not have a one-to-one relationship as long as they cover the same ground. This means that people could be asked, for instance, if they feel safe from traffic, when the objective data will cover speed of traffic, number of lanes, sidewalk width, presence of buffers, etc.

In the next chapter, the literature relating to walking behavior and the environment will be analyzed and discussed. The relevant literature originates from three major areas: travel behavior research, public health research, and environmental/behavioral psychology. The foci of these fields have been very similar, but the methodologies and measures used to analyze them have not. This has resulted in a very rich but somewhat disjointed literature, which often uses different terms and definitions of the environment and behavior. The literature review will discuss how the different strains of research contribute to the overall knowledge of the environment and walking behavior, and how this particular study enhances this research.

Chapter 3 will discuss the methodology used in this research. This study consists of a cross-sectional research design that examines: (1) the relationship of perceptions of various aspects of the environment with each other, (2) their relationship to the equivalent objectively measured environmental features, and (3) how both perceptions and environment relate to walking behavior while controlling for socio-economic and other variables. The study design involves three major categories of data collected: (1) objective environment data, collected through an audit and secondary archival GIS sources, (2) perceptual data, collected through a survey questionnaire, and (3) walking behavior data, collected through a travel diary and survey questionnaire. Chapter 3 will discuss the three categories of data, location and population, and the analysis plan.

This study involves the construction of indices from the raw data produced by the audit and interview questionnaire. Chapter 4 will discuss the construction of the indices (in the categories of land use, transportation, safety, and aesthetics). This will emphasize the use of theoretical background as well as statistical testing of these indices. Construction and testing of the indices resulted in six indices: land use (both density and diversity), motorized transport, pedestrian transport, safety (from traffic), tree cover and cleanliness/maintenance of the environment.

Results from the analysis will be discussed in Chapter 5. First, the potential usefulness of micro-level measures instead of the macro-level measures commonly used in walkability research will be examined: are the micro-measures measuring the same environmental features as the 3Ds? Results show that both the perceptual and objective micro-level measures are different than the 3Ds, and therefore have potential contributions in assessing the relationship with walking behavior. This will be followed with analysis relating to all three major hypotheses of this paper. First, the relationship between objective and perceptual measures of the environment will be assessed, followed by correlations within each type of data and linear models of perceptions. Finally, indices of perceptions, objective assessment of the environment, and the 3Ds will be included in models of walking behavior. Results from these analyses support all three hypotheses, and will be explored in-depth in Chapter 5.

Chapter 6 will discuss the findings of this study, in particular with regards to their implications for policy, researchers, and practitioners, as well as their limitations and the opportunities for future research. This research contributes to the understanding of how factors of the built environment, as filtered by subjective interpretation, relate to levels of walking behavior. The findings from this study are significant in their contribution to effective design of policy interventions targeted toward both the physical environment and the individual level.

By completing this study at an individual level as opposed to aggregated to community level, a great deal more detail can be gleaned about the impact of micro-level environmental factors. Policymakers should be able, with findings from this study, to streamline their data collection efforts – by being better aware of the environmental factors that affect walking, they can reduce the data collection to only the relevant measures – while better targeting interventions so that they respond directly to the barrier to walking, whether that be in the environment or in perceptions of the same. If some walkability barriers are actually related to perceptions rather than the environment itself, measuring the environment objectively and responding to those findings might not affect change. On the other hand, if those environmental features can be measured perceptually and then responses are based on those findings, more appropriate responses – and more effective results – can be attained. This study emphasizes which environmental features are more effectively measured from each perspective (objective or perceptual) as they relate to walking.

Chapter 2: Review of the Literature

In response to alarming statistics regarding public health (US Department of Health and Human Services, 2001; Mokdad et al., 2001; Pratt, 2000; Katzmarzyk, 2000), recommendations have been made to increase active lifestyles, particularly through low-impact activities such as walking (Pate et al., 1995; Manson et al., 2002; Kohl et al., 1998). Recent studies showing connections between health outcomes and the built environment have sparked interdisciplinary efforts in urban planning and public health to understand the connections between physical activity and the built environment (Frank and Engelke, 2001; Greenwald and Boarnet, 2001; Berrigan and Troiano, 2002; Handy et al., 2002; Ewing et al., 2003). This interest has emphasized the need for comprehensive and detailed environmental measures in order to identify elements of the physical and natural environment that contribute to or detract from physical activity and walking (Kwon et al., 1998; Painter, 1996) as well as increasing recognition that subjective factors shape behavior. Indeed, relationships between the built environment and walking behavior may be indirect, through individuals' perceptions of the environment and shaped by their attitudes (Bauman et al., 2002). Further, the issue of self-selection – people choosing to live where walking is easy or not – complicates this already fraught relationship.

Even with the extensive research stemming from both the public health and travel behavior fields, the existence and extent of a connection between the urban form and walking behavior – and, in a larger context, health – is still debated. This review aims to analyze the different theories and methodologies used in various studies as well as their resulting conclusions in order to identify the limitations of the existing body of research and elaborate avenues of study.

Furthermore, this review will provide an overview of studies that include perceptions and other socio-psychological factors in their analysis. Although the extent to which psycho-social factors are important in the walking/built environment relationship is still debated, they have been emphasized by designers as a crucial factor. The studies that have included them have tended to confirm this theory.

The review will start with a discussion of the travel behavior literature, as this type has dominated research for the past fifteen years. Although travel behavior research has historically been focused on automobiles, it has recently started focusing on pedestrians. The recent developments in the research including the better archival data used, the interest in walking for alternative modes and congestion relief, as well as the recent ties with public health research will be discussed. Although the findings have been mixed, the literature clearly points to gaps and opportunity for more research.

The review will then discuss contributions of public health research in the field. This will include a discussion of the differences in definition and measurement of walking and the environmental measures of interest from the public health standpoint as well as the significant findings of this literature. The ways in which both public health and travel behavior research have refined their measurement of the environment will then be laid out.

A discussion of relevant environmental/behavioral psychology research will follow: although this field is rarely integrated into the travel behavior and public health research focusing on walking and the environment, it adds a great deal of insight regarding the potential importance of perceptions. The contributions of environmental psychology will therefore be discussed. This will be followed by an examination of the ways in which perceptions of the environment have been thoughtfully integrated in the public health and travel behavior literatures and whether perceptions have shown to be significant in the relationship between walking behavior and the environment. The review will concluded by a discussion of the gaps in existing research and needs for upcoming studies.

Definition of Terms

Before commencing discussions of the environment, behavior, and perceptions, it is first important to discuss the meanings of the terms used here: they are not obvious, and there is not complete agreement from field to field as to their meaning(s). Public health and travel behavior research, although they do not focus on the same aspects of behavior and the environment, are relatively consistent in the terminology they use. This is not the case for literature stemming from the design and environmental and behavioral psychology fields. Therefore, it is important to clarify the meaning(s) of the terms used in this study and in the larger literature.

The first major difference to emphasize is the use of the word perceptions. In the psychology fields, this term has an operationalized definition which is very specific: perceptions are the result of sensation and cognition (Lindsay & Norman, 1977). In other words, the environment is first physically sensed (visual, auditory, etc. stimulation) and is then given meaning through cognition (experience) resulting in perceptions. This entails that perceptions are not directly derived from the environment, but that they are rather the result of multiple processes (Lindsay & Norman, 1977). In contrast, travel behavior research and public health do not define perceptions in such a narrow way. Instead, the term perception in these fields is simply taken as the way in which one reacts to the environment (Hoehner et al., 2005; Lee and Vernez Moudon, 2006). Here, the internal processes leading to perceptions are irrelevant and are therefore not assessed.

Regarding the measures of the environment, there is a consensus in the travel behavior and public health fields that safety refers to safety from traffic, not crime, security being the word used for safety from crime (Hanson, 2006; Duncan et al, 2005; Parks & Schofer, 2006). There is also a consensus that environmental features enhancing enjoyment of an area, as opposed to a destination or safety feature, are referred to as aesthetic features. As Handy (2002) states, aesthetic qualities are largely "intangible" and therefore difficult to measure. The definition of aesthetics in the travel behavior and public health fields is generally not overt, but rather taken as a given, and is often defined as the sum of its parts (Lee and Vernez Moudon, 2004; Owen et al., 2004). For instance, Pikora (2002) refers to factors such as trees, garden maintenance, building maintenance, cleanliness and pollution.

In sharp contrast, the environmental psychology field ascribes a very specific set of characteristics to the term aesthetics. Where the travel behavior and public health field take aesthetics as undifferentiated perceptions of specific parts of the environment, environmental psychology delves into the formation of perception of aesthetics. As a result, they differentiate between symbolic and associational aesthetic values, between properties of the object and sensation and cognition of the subject

(Nasar, 1988). This level of detail allows for a much deeper understanding of the way aesthetic judgments take place. However, this is not the standard in travel behavior and public health literature, nor is necessary or feasible in the research discussed here. Therefore, the public health and travel behavior definition of aesthetics – as limited as it is – will be used here.

Finally, the term walkability is often used in both public health and travel behavior research. The meaning of this term is not self-evident, and although it is used in numerous papers (Belden, 2003; Brownson et al., 2004; Heath et al., 2006), it generally goes undefined. In contrast to many other researchers, Abley (2005) does extensively discuss the term and defines it as "the extent to which the environment is walking friendly". However, as Abley (2005) notes, the features of the environment which make it walking friendly are not agreed upon, and finding which ones are significant is the goal of much research from the public health and travel behavior fields. The term walkability will be used in this paper consistent with its use in the relevant literature.

The Travel Behavior Approach

The research regarding walking and the environment has emerged from two main fields: travel behavior and public health. Although there have been recent efforts to integrate these two disciplines, there are still major divisions in existing studies as the emphasis of researchers from the two disciplines have not coalesced.

Travel behavior research is now well established, and forms one of the main avenues of research in walkability. Travel behavior studies have been widespread, especially during the last fifteen years, as reviewed for example in Badoe and Miller

(2000). However, they have yet to provide any kind of consensus regarding the relationship between the environment and travel: although various aspects of the environment have shown in most studies to be related to travel, results have been mixed and there is still no consensus regarding which environmental features should be considered when relating travel behavior to the environment.

Early studies of the built environment/transportation relationship mostly focused on automobile travel generation. At interest were the environmental measures encouraging or discouraging driving. For instance, Boarnet and Sarmiento (1998) looked at the relationship between land use at the neighborhood level and non-work auto trips to find whether the neighborhood was associated with this type of travel (which is theorized to function differently than work trips). They modeled non-work auto trips as a function of density, street network (percentage of four way intersections) retail employment density, service employment density, and socio-demographic measures. They found that land use measures were insignificant almost across the board and emphasized the need for more research with more appropriate measurement methods.

In a similar study, Cervero and Kockleman (1997) modeled vehicle miles traveled and mode choice as a function of built environment measures and socio-demographic measures. Unlike Boarnet and Sarmiento (1998), they did not focus on non-work vehicle trips, and they did find associations between auto trips and the environment: they found that land use, density and pedestrian oriented design reduce auto trips and encourage non-auto travel. However, their results were somewhat marginal: with low R squares of less than 0.2 for all models. Another similar study by

Cervero (2002) used Montogmery County, Maryland to look at mode choice as a function of environment. Because of data limitations, only driving alone, carpooling and transit were measurable in this study. Cervero found land use, and to a lesser extent urban design, are significant in influencing mode choice.

These studies, as well as many similar ones, use a similar methodology (Crane and Crepeau, 1998; Dieleman, et al., 2002, for instance). They tend to use travel surveys administered through various means and then model either driving or mode choice as a function of the built environment, usually at the neighborhood level, and socio-demographic measures. Although the details of the environmental measures are different from study to study, they tend to belong to three categories otherwise known as the "3Ds": density, diversity and design. Density measures generally include population density, residential density etc. Diversity generally includes various measures of land use including Herfiendhal index, dissimilarity index, Entropy index, commercial densities (for instance measured through retail employment), etc. Finally, the design measures can include 3-4 way intersections, grid pattern, proportion of streets with sidewalks, etc. As cited in many of these studies (Cervero, 2002; Boarnet and Sarmiento, 1998, for example) this methodology entails some limitations, in particular related to the available data: diaries as well as land use measures can be insufficient in some areas and reduce the usefulness of results. Overall, as discussed in reviews of these types of studies (Badoe and Miller, 2000; Frank, 2000; Crane; 2000), results are still mixed: although many studies find relationships between travel behavior and the 3Ds, in particular for land use mix and density (Frank, 2000), results tend to be significant but somewhat marginal when other personal factors are accounted for.

Over the last ten years, the focus has shifted to include walking behavior as well as driving. Mode choice in general has become a major focus of travel behavior literature. The difficulty for many studies tackling mode choice is the sometimes less than ideal fit between the goal of assessing walkability and the aggregation at which behavior and the environment can be measured. As a result of these methodological limitations, some studies (Cervero, 2002, for example) cannot look at walking at all. However, studies have increasingly included walking as a travel mode, and travel diaries have used more detail in measuring travel behavior. For example, the distance measurements used have tended to decrease with time (from mile increments to 1/4 mile, or even less) which has made the measure of walking much more efficient.

Transportation-oriented papers conceive of walking as a mode of transport. As a result, walking is often equated with automobiles and public transportation. It is important to note that this has consequences regarding the behavior analyzed in the studies. Papers that focus on walking as a mode of transport (Such as Craig et al., 2002; Crane and Crepeau, 1998), be they interested in work or non-work walking behavior, do not include walking that does not have a destination, such as walking to exercise or to walk a pet. In addition, the papers focusing on mode choice (for example, Cervero and Kockelman, 1997; Crane, 1996) only take into consideration walking as a replacement of driving behavior. This implied relationship between walking and driving also means that many studies use a single data collection method for both, generally in the form of a travel diary, which is often calibrated for automobile travel. This often leads to underreporting of walking behavior (as respondents are not prompted to remember routine trips, which are easily forgotten) and poorly adapted scales of time and distance (such as one-mile or five minute increments, which are too large to capture walking behavior effectively).

The Public Health Approach

Although the field of travel behavior has been a leading discipline in studying walking behavior, it has by no means been alone in this venture. Public health research has also dominated in examining walking behavior, albeit from a very different perspective. Public health literature has traditionally focused on aggregate levels of physical activity and public health outcomes (Pate et al., 1995; Katzmarzyk et al., 2000). In this context, studies originally were less interested in episodes of behavior as opposed to regular patterns. For instance, the type of physical activity (especially within categories such as "vigorous" or "moderate") would not be as important as the physical activity taking place at all. This also entailed a reduced interest in environment: where the behavior occurred was not very important. In other words, whether someone exercised in a gymnasium doing free weights or in their neighborhood bicycling or walking was not considered important, as long as their overall physical activity satisfied health requirements (Kohl et al., 1998; Dunn et al., 1999; Brownson et al., 2000). Just like in travel behavior, however, this original approach has been greatly refined. Today, public health studies focus specifically on types of physical activity, and since the environment is particularly important in terms of walking, this also has been integrated in the public health literature, as discussed below. The public health literature is crucial in any discussion of walking behavior, but the differences from the travel behavior field, as they relate to definitions of walking as well as measures of the environment, are still noteworthy.

Unsurprisingly, papers stemming from public health research that address walking are primarily concerned with walking as physical activity. Berrigan and Troiano, for example, assessed the association between urban form and physical activity in a 2002 study. In this study, they used home age as a proxy of environmental characteristics (older neighborhoods with older homes being characterized by denser, more mixed design) and associated this with walking behavior and overall physical activity as collected from a national health survey (NHANES). Using logistic regressions, they found that people in older homes walked more than those living in newer homes. This study in itself is closer to an exception, as it used objectively assessed environment, as discussed below.

Many studies focus on physical activity in terms of intensity (for example Giles Corti & Donovan, 2002), with walking considered "moderate" intensity. In many of these studies, a positive outcome would be achieving goals of levels of overall activity, where walking is just one option among many (Brownson et al., 2000). This definition of walking is broader than that of the travel behavior field, but it is problematic in assessing the environment: the location of the walking behavior is not necessarily part of the questionnaire. Furthermore, this can also be problematic in terms of discrete trips. International Physical Activity Questionnaire (IPAQ), for example, which is used in numerous studies (Ainsworth et al., 2000; Craig et al., 2003), does not ask about specific walk trips but rather about average number of trips and average duration. These issues explain why the definition of walking in public health research has evolved over time to be much more specific. Like research stemming from travel behavior, which found that thinking of walking as equivalent to driving does not aid in its analysis, public health research has refined its measures of walking to reflect its unique nature. This has meant that they have tended to merge in their measures of walking over the last few years, and is reflected in the interdisciplinary studies that have emerged (Handy, 2002).

Another difference between public health and travel behavior research, especially in earlier studies, is the type of environmental measures captured in each. Although public health research is hardly monolithic, many studies over the years have used perceptual measures of the environment. Most public health oriented studies use perceptions of the environment instead of objective assessment of the same. For instance, Addy et al. (2004) modeled physical activity and walking (collected through the Behavioral Risk Factor Surveillance System) as a function of perceived social and environmental supports. Using a phone interview, they found that social supports and some aspects of the perceived environment (like sidewalk access) were associated with regular walking behavior. Similarly, Humpel et al. (2004) modeled walking for different purposes (collected through the International Physical Activity Questionnaire) as functions of the perceived environment. The perceived environment here was derived from the Neighborhood Environment Walkability Survey, and formed into four indices: aesthetics, accessibility, safety, and weather. They found that men and women have different relationships with walking and that weather and aesthetics were significant. The importance of the weather index as used in this study, however, could be overstated due to the Australian study area, where extreme heat is a common issue. This approach – a physical activity survey to capture behavior and questionnaire to capture perceived environmental features, followed by multiple regressions – seems to be a standard from the public health field (De Bourdheaudhuij et al., 2005 and Brownson et al., 2001, for example).

However, as travel behavior and public health studies have tended to merge over the last few years, there has also been a confluence of methods in assessing both the environment and behavior. For many studies, the large numbers offered by national surveys of physical activity (like the BRFSS) have led to their extensive use (in Ewing et al., 2003 and Brownson et al., 2000, for example). The advantage is a larger sample for more robust analysis. The weaknesses include limited information regarding to walking. For instance, the BRFSS does not distinguish walking in the built environment to walking on a treadmill, for example, even though these two types of walking entail very different relationships with the built environment. Furthermore, surveys like the BRFSS are recalled self report, which have limited reliability. Some newer studies integrating public health and transportation researchers also make use of larger-scale objective environmental assessment. Ewing et al., as discussed in their 2003 paper, for instance, developed a sprawl index derived from secondary GIS data to classify over five hundred US counties. They found that residents of compact counties were more likely to walk than their counterparts in sprawled counties after controlling for demographic characteristics.

As methods become more standardized from the public health and travel behavior fields, it seems likely that the understanding of walking will increase. Already, different qualities of walking have been assessed (for instance walking for transportation, leisure, etc.) (Humpel et al., 2004) and environmental measures are captured at a smaller aggregation. In particular, the many studies now conducted by teams of public health and transportation researchers are trying to bridge the gap between their respective foci. This study aims to increase these links.

Refining Measures of the Environment

The recent interest on the relationship between the built environment and various forms of physical activity or travel behavior, including walking, has resulted in a need for appropriate environmental measures. Originally, these measures were relatively crude (Crane, 1996) as discussed above. However, as the public health and travel behavior fields have advanced, so have their measures of the built environment. In this type of assessment in particular, their efforts have often developed in tandem. The advances in environmental data are discussed here.

Many studies focus on macro-level features and observe their impact on travel modes and/or general public health. For instance, Crane (1996) uses density, land use mix and street pattern (grid versus cul-de-sac) whereas eighteen characteristics (including traffic threats, safety from crime, for example) are used in Craig et al. (2002). Another study, by Berrigan and Troiano (2002), uses neighborhood age as a proxy of walkability. As discussed above, Ewing et al. (2003) developed a county-based sprawl index. These features are worth including, and their use has shown environmental effects at the aggregate, macro-level, but their limitations are also obvious.

These measures are very crude and limited in what they can say about the environment that is important to pedestrians. First, the spatial aggregation of the data used in most studies looking at density/land use mix/street pattern limit their effectiveness. Because walking is a slow activity (most people walk in the range of 3-4 miles per hour), density or land use as measured at the block group or census tract level will not really provide a good measure of how pedestrians experience their environment. Additionally, these measures are very limited in their scope. They do not capture enough facets of the environment as it relates to walking. For instance, land use mix will matter little if there are no pedestrian facilities present. By the same token, density will not be sufficient to encourage walking if the area is unsafe either from crime or traffic. However, the widespread availability of these data has led many researchers to use them rather than attempting the time consuming and cost-intensive task of collecting micro-level data.

Recent studies have attempted to add to the traditional environmental measures (land use/density/road network) with other relevant items, particularly those that are at the pedestrian scale. However, the availability of these micro-level measures is problematic, as they are not generally available in archival GIS data. Thanks to software such as Google Earth, it is now possible to measure some micro-level features of the environment without fieldwork. However, this is still both work-intensive and limited in the data that can be collected. A number of researchers have also sought to measure micro-level features through the development and testing of various audits

These audits have often focused on features of the environment as they relate to specific activity, such as walking (Clifton et al., 2007). Vernez-Moudon and Lee (2003) present a review of several of these environmental audit instruments from urban design, planning, transportation and public health, which are designed to capture the physical environmental factors related to walking and bicycling. Almost all of these audits use a segment-based system which breaks up the environment according to street segments defined either by intersections, length or both. Deciding which factors to include in an audit, on the other hand, is particularly difficult in walkability studies. Indeed, the importance of each environmental factor has not been tested and, combined with the difficulty in acquiring these data, has discouraged researchers from fully committing to furthering this line of research.

The lack of standard in the factors analyzed in audit tools (Emery et al., 2003; Shriver, 2003; Pikora et al., 2002) shows that this line of research is still in its infancy. In addition, the relative weight of each feature has not been fully ascertained, and this remains an ongoing problem in walkability research. Finally, the method of aggregation to be adopted for these measures once they are collected is also unsure. A few recent studies have emerged (McCormack, et al., 2006) that used data reduction techniques to increase the usability of these audits, but there is still much to be done in this line of research. However, even with the lack of standards regarding measures to be captured and aggregation technique, the advances in measuring micro-level features of the environment are encouraging. Audits have shown very positive reliability (Clifton et al., 2007) and are now being used by multiple researchers to further explore the relationship between built environment and walking behavior.

Nonetheless, even as current research is developing better ways to capture environmental data related to walking behavior, there are still some important flaws. In particular, the mediating importance of psycho-social factors in the built environment/walking behavior relationship has not yet been fully ascertained even though there is increasing recognition that subjective factors shape behavior and mediate actions. Although theorists have tried to address these issues, empirical studies have been slow to follow.

The Importance of Psycho-Social Factors

Understanding the environment is undoubtedly important to advance the understanding of behavior, but it is incomplete without a paired understanding of people's interaction with the environment and society. People are not merely machines that have perfect understanding of what goes on around them and rational reactions and behaviors derived from the understanding. Instead, people behave in accordance with emotions as well as thoughts, and the way they feel, their preconceptions, mood, attitude and other psychological factors color everything they interact with. Furthermore, people do not react in a vacuum but rather within a social framework where the psychological factors of others – especially family and friends – matters a great deal as well. All of this perhaps seems obvious, but it is infinitely complex, and has deep, far-reaching consequences in how people behave. At interest here is how this relates to walking behavior. It seems common sense to expect that people's psychological characteristics as well as social environment would have an impact on this behavior as well as all the others. In particular, the way people internalize the environment they interact with would seem to be inextricably linked to the reactions – and therefore behaviors – that result. This has been the subject of interest for a number of researchers, designers, sociologists and others, as discussed below.

Designers' Perspectives

Theorists and designers in the urban planning and design fields have long held that people encounter, internalize, and understand their environment in very complex ways (Appleyard, 1981, Kaplan and Kaplan, Eds., 1978). Lynch, Appleyard and others, for instance, tried to schematize the parts of the environment most important to people. These sketches show environments perhaps not as they are but closer to how they are perceived (Appleyard et al., 1964). Reviews such as Kameron's (Ittelson, Ed., 1973) show that many studies have demonstrated that perceptions of laypeople are very different from those of designers and that perceptions also vary a great deal between individuals. In this review of experimental studies of environmental perceptions, Kameron (1973) discusses perceptions of architectural forms, cities, highways and streets and natural environments. He finds that according to many studies, "architects perceive the world in ways quite different from those of the general public" and that what they intend for spaces is not necessarily how people respond to them. For instance, designers are interested, among other things, in the "character" of a space while non-designers are only interested in "friendliness" and "coherence". Furthermore, when it comes to cities rather than buildings, Kameron (1973) finds that numerous studies emphasize the importance of attitudes, past experiences, and expectations in perceptions by the public. This review of experimental studies of perceptions underlines the importance of personal characteristics, including experience, in determining perceptions and of the resulting wide range of perceptions possible for the same environment.

Further, a number of designers, theorists and sociologists have looked specifically at the needs and perceptions of pedestrians. William Whyte (1980, 1988) for example, has discussed the importance of human scale, shop windows and architectural features (as opposed to "blank walls") and overall street cleanliness – among others – to attract pedestrians. In his books, he discusses the overall feeling as well as specific features of the street that – according to him, through his observational qualitative research – makes for pleasant and therefore used streets. From the writings of Whyte, but also Untermann (1984, 1987), Appleyard (1964, 1981) and others, it is clear that the needs of pedestrians are specific, due to the speed and scale of a pedestrian, as opposed to a driver. Many of these designers have attempted to tease out the specific parts of the environment that impact pedestrian activity, as seen, for example, in Public Streets for Public Use (1987.)

One clear lesson from these authors is that to adequately describe the environment, one needs extensive training not only to see what is there but also to bring out what is important (Lynch, 1960). Understanding of concepts such as *legibility* (ease with which the spatial structure of a place can be understood and navigated), *imageability* (the quality of a place that makes it distinct and memorable) or *enclosure* (degree to which streets and other public spaces are visually defined by buildings, trees and other elements) and, particularly, being able to operationalize them, is no easy task. However, these concepts are often used to characterize the environment in terms of design. The difficulty in measuring these concepts was made clear in Ewing et al. (2006). To characterize the environment according to categories ranging from *tidiness* (maintenance, cleanliness) to *transparency* (being able to perceive the environment beyond the edge of the street), Ewing et al. had to recruit an "expert panel" consisting of urban planners and designers.

On the other hand, the more widely used objective ways of measuring the environment (such as measuring density, street network or sidewalk width) is also beyond most laypeople. Few, if any, people can easily respond to: "how common are curb cuts in your neighborhood?" Many probably do not even know what curb cuts are. It is more than likely that most people cannot put such details about their environment into words, and experience the environment in a more aggregate manner. For instance, most people do not know the density of sidewalks in their neighborhood. However, with well-developed questions, it is possible to tease out peoples' interaction with their environment. Furthermore, this "nebulous" perception should not necessarily be considered negative: instead it means that people understand their space as a more holistic than compartmentalized environment. Unfortunately, the interest from designers in understanding how people internalize their environment has not resulted in much empirical study from the travel behavior and public health fields.

On the contrary, as shown above, many studies (Crane, 2000; Boarnet & Sarmiento, 1998) have parsed the environment in more and more specialized ways that do not necessarily share anything with the way people engage the environment. For instance, it is unlikely that the average person walking down the street can talk about the number of travel lanes or the zoning of the area. It seems that this disconnect between measurement of the environment and the understanding of how people interact with it is ever growing. This points to a need to bridge the gap in research between measurement of perceptions and measurement of the environment, and to empirically test the importance of perceptions.

Environmental & Behavioral Research

Environmental and behavioral psychology is mainly interested in better understanding, operationalizing and quantifying people's interaction with their environment. Unlike urban designers, psychologists come at the problem not from the environment and its features but rather from people and more specifically their cognitive qualities. In other words, instead of wondering how the environment looks in someone's eyes, the question is how and why people see things the way they do. Much of this type of analysis – that which is interested in brain function, for example – is beyond the scope of this study. However, there is some understanding of the way people internalize their environment from the environmental psychology field that does inform how one can better understand how behavior and environment are related.

Environmental psychology studies, in part, have grown out of designers' interest in the internalization of the environment, as a perceptual, cognitive, affective, and social function. There is a large body of literature in this field (e.g.: Nasar, Ed., 1988; Kaplan and Kaplan, 1978; Altman and Zube, Eds. 1989). Writers and designers such as Rapoport have discussed such wide-ranging issues as personal space (Aiello and Thomson in Wohlwill et al., Eds., 1980), territorial behavior (Brower in Wohlwill et al., Eds., 1980), sacred space and symbolism (Rapoport, 1990). Findings from these studies have confirmed designers' ideas that perceptions of the environment are extremely complex, as interactions with the environment take place both in cognitive and emotional ways, and therefore people of different backgrounds, experiences and cognitive abilities (for instance children vs. adults) will have different reactions to environments. Further, perceptions of specific environments will differ depending on whether they are associated with positive emotions or not. For instance, Herman et al. (1995) found that estimates of distance to destinations depended on whether those destinations were liked or not: positively-associated destinations were thought to be closer than they actually are, although this effect lessened as the subjects became more familiar with their surroundings.

The nature of the studies in this field entails small samples of participants responding to in-depth questionnaires. For instance, in Nasar (in Nasar, Ed., 1988), the perceptions of residential environments are reached through a complex multi-step process that includes the ordering of photographs into groups and three waves of rating according to multiple bipolar scales. This kind of assessment is not comparable to objective assessments of the environments (as the scales are again in terms of ornate-plain, colorful-dull, etc.), instead trying to gain a deeper understanding of the nuances of perception. This kind of time-consuming study allows for an in-depth view of perceptions and the emotions as well as cognitive processes associated with internalization of environmental data.

In another study, Nasar (in Nasar and Preiser, Eds., 1999) uses scales such as “pleasant-unpleasant” and “interesting-boring” to rate the environment. Again, these scales are calibrated to assess various aspects of the environment directly through the emotions they cause: instead of what is there, the questions ask about what is felt when those environments are observed. These types of studies, although they capture the emotions of perception, do not allow for the direct comparison with objective assessments of the environment: it would be impossible to operationalize words such as these so that they represent specific parts of the environment. They also tend to use manufactured "environments" that are sharply controlled and are often only photographs shown to respondents. For instance, Stamps (2005) looked at five aspects of enclosure in a study assessing the relationship between enclosure and sense of safety. In it, Stamps used slides of artificial scenes created from city site plans with computer-aided design (CAD). The five measures of enclosure were then correlated with sense of safety as well as socio-demographics and showed that the "lightness" measure was most strongly correlated with safety. The artificiality of the settings used in many of these studies allow the isolation and measure of specific environmental features, but they are not very well suited for actual neighborhood environments, which are much more complex. That said, this field of research emphasizes designers' thoughts regarding the importance of perceptions in assessing the built environment.

Another branch of environmental psychology comes from the psychological rather than design track. The literature coming from this perspective is interested in the internal processes that cause certain perceptions of environmental features. Again, this literature emphasizes the complexity of perceptions of the environment. For instance, Haber and Hershenson, in The Psychology of Visual Perception (1973) discuss sensory processes, sensory coding mechanisms, and cognitive functions regarding perceptions of colors, movement, scale, and spatial relationships. However, the usefulness of this literature to assess the importance of perceptions in the relationship between the built environment and walking behavior is limited. Indeed, the internal processes causing perceptions are largely irrelevant and are not measurable in a study that does not have a clinical component.

However, it is interesting to note that both designers and psychologists agree regarding the qualities of the process of perceptions. It is not directly derived from the environment, but rather takes multiple (very rapid) phenomena, from observing (seeing) to internalizing (perceiving) to understanding (giving meaning). Although this is outside the scope of this paper, it seems that different portions of the environment might go through more change in this process than others. For instance, it may be that perceptions of safety are more "distorted" through this process of seeing and understanding the environment than perceptions of more value-neutral items such as land use.

At this point in the research of walkability, it seems clear that the design and psychology researchers are not on the same track as those in the public health and travel behavior fields. The lack of agreement regarding the terminology makes this obvious, as discussed earlier in this chapter. While the different tracks are likely inevitable due to the differing foci of the disciplines, it is still unfortunate that the extensive knowledge of perceptions from the design and psychology fields has mostly not spilled over in travel behavior and public health research. This study, as others in the last few years, is attempting to take better advantage of the role of perceptions to illuminate the relationship between environment and walking.

The Integration of Psycho-Social Factors

As psychologists and designers have postulated, socio-psychological characteristics are a key factor in understanding how people interact with their environment. What people see can – and often will be – quite different than what is actually there. The ways in which those perceptions will be distorted are not random, but the studies discussed above show how complex the factors are and how incomplete the understanding of how perceptions form remains. However, this does not quite bridge the gap from environment to behavior. Instead, much of the psychology literature stops before behavior at the perceptions stage. This is not necessarily a flaw of that type of research but rather a reflection of the locus: cognition. Nonetheless, from a transportation, urban planning or public health perspective, the focus instead lies in the last step: behavior. Indeed, the reason for the interest and many studies from these fields is that the relationship between environment and behavior has been shown to be mixed (as shown in reviews like Crane, 2000; Badoe and Miller, 2000), and that perceptions might well be a way to gain a more complete understanding of that relationship. Some recent studies, discussed below, attempt to bring behavior, environment and perceptions together. This is one of the rising interests from travel behavior as well as public health, and will hopefully lead to better analysis, and eventually better policy, in walkability.

To fully understand any behavior, the way people come to that behavior needs to be assessed. Social psychologists have demonstrated that attitudes, for instance, hold a major role in shaping behavior (Ajzen and Fishbein, 1980). However, these findings have rarely been extended to interaction with the environment: the external variables complicate the model considerably. In these rare studies, attitudinal variables have had better explanatory power in models of travel behavior than land-use characteristics. For instance, Kitamura et al. (1997) examined the effects of land use and attitudes on travel behavior. Looking at five San Francisco area neighborhoods, Kitamura et al. modeled travel behavior in terms of environmental measures (objective), socio-demographic measures and attitudes (such as "pro transit", "suburbanite", "urban villager") built from a few questions (e.g.: Urban villager: Having shops and services within walking distance . . . would be important. Too much valuable agricultural land is consumed to supply housing. I use public transportation when I cannot afford to drive.) This study found that although the objectively measured environment and socio-demographic measures were both significant in the models of travel behavior, attitudinal measures tended to have more explanatory power.

As discussed above, perceptions have been associated with physical activity in a number of studies, originating mainly from the public health branch of research (Clifton and Livi, 2004; Giles-Corti & Donovan, 2002; Humpel et al., 2004; Troped et al., 2001). Nonetheless, the types of perceptions are very varied among the studies (distance to destinations, safety, physical barriers, etc.) and the relationship among the subjective factors has not been tested. Most often, these perceptions are not compared to their objectively measured counterpart (for instance, actual presence of sidewalks versus perceived presence of sidewalks, actual safety versus perceived safety etc.)

Instead, the subjective assessment of the feature is treated as a proxy (Addy et al., 2004): indeed, these are less cumbersome to collect in some cases than objective measures of micro features. There are also a number of qualitative studies that observe perceptions of the environment and their relationship to physical activity, especially in targeted socio-demographic groups (Young et al., 2002) but again these do not compare perceptions to objective measurements of the environment.

Only in a few recent studies have efforts been made to integrate both perceptions of the environment and objective assessment of the same in relation to walking behavior. Leslie et al. (2005) compared perceptions of the walkable environment in two neighborhoods with objectively different characteristics. Applying the NEWS questionnaire, they developed indices (density, land use mix, street connectivity, walk facilities, aesthetics, safety from crime, safety from traffic) and found that perceptions of most of these (density, land use mix, street connectivity, walking facilities) were significantly related to the objective environment. Similarly, Saelens et al. (2003) also used the same methodology, although they used only a small sample (N=52) and only controlled for age and educational level. They found that perceptions were consistent with the neighborhood features, and that the perceptions of the environment were significant for transportation walking but not leisure based walking.

Kirtland et al. (2003) also compared objective assessment to perceptual assessment, using secondary GIS data and a questionnaire. Their focus was more on the recreational environment than transportation (there were no questions regarding destinations or aesthetics, for example). Unlike Leslie et al., Kirtland et al. found overall “fair to low” agreement between objective and perceptually measured environment (Kappa statistics between -0.07 and 0.25). The discrepancies in the results might be due to the scale of the comparisons: Leslie et al. only compared two neighborhoods while Kirtland et al. had a much smaller aggregation for their objective environmental data. This might indicate that people have a good idea of their overall neighborhood environment but that their perceptions are more nebulous and altered at smaller aggregation.

Troped et al., in a 2001 study, looked at rail trail use as a function of both perceptual and objective environmental features. In a mail survey, they asked respondents to rate barriers to the rail trail: both streets and topography. Analysis was conducted with two multiple logistic regressions: one with perceptual environmental measures and one with objective measures of the same. They found that the environment was similarly associated with use of the rail trail both from the perceptual and objective assessment.

Hoehner et al. (2005) further elaborated this kind of study. The study environment was characterized using the St Louis University environmental audit. Perceptions were captured using a NEWS type questionnaire administered over the phone, and behavior was captured with the IPAQ questionnaire. This study found that both objective and perceptually measured land use, recreational facilities and some transport features were significantly associated with physical activity, and that there were not major differences between the perceived and objective environments.

In their analysis derived from NEWS data, Hoehner et al. (2005) employed disaggregate measures. For instance, instead of "land use", they looked individually at five land use related questions (for example "many destinations within walking distance", "count of specific destinations.") and compared them to their equivalent objective measures. In contrast, in their analysis using the same questionnaire, Saelens et al. (2003) constructed indices in seven categories (land use, density, pedestrian facilities, street network, aesthetics, safety from crime and safety from traffic) by calculating the mean of questions within each category. Humpel et al. (2004) also formed indices from the NEWS and other questionnaires with use of PCA Varimax analysis. As a result, they formed four indices: aesthetics, accessibility, safety and weather. However, their measures were perhaps better suited for the Australian environment where the study was conducted: weather is not as important in most US states, or at least not important in the same way.

McGinn et al. (2007) compared perceptions to objective measures of the environment, but they did not use micro but rather only macro-level measures of the environment. However, their study did show that perceptions were as – and sometimes more – important as objective measures of the environment in determining physical activity. This again points to the importance of including perceptions in this line of research. Another study, by Hoehner et al (2005) also includes both subjective and objective measures of the environment in models of physical activity. However, this study does not explore the relationship between the objective and subjective measures to find how they relate to each other independently of the physical activity model.

Discussion

How does the environment relate to walking behavior and how do perceptions fit in this relationship? Even with longstanding interest and a flurry of recent studies that have attempted to untangle these relationships, it is still very unclear how these three factors interact.

There is rich literature linking the environment to walking behavior, although results have overall been mixed (Crane, 1996; Boarnet and Sarmiento, 1998; Krizek, 2000). This is due, in part, to the overly aggregated and limited measures of the environment available to researchers: it is difficult to accurately assess relationships when the measures are not always sufficient. For instance, many studies rely of environmental measures that are too highly aggregated – to neighborhoods, zip codes or even towns – and others have measures of behavior that are not well adapted to walking – like measuring travel in mile-long or 10 minute intervals. These problems are being overcome in the most recent studies: measures of travel are being honed to capture more trip detail, and micro-level measures of the environment are being captured through the use of various audits (reviewed in Vernez-Moudon and Lee, 2003) to garner more detailed information about the environment.

However, even with these recent improvements the degree of importance of the environment related to walking remains unclear: personal characteristics tend to be more highly associated with travel behavior, physical activity and walking (Cervero and Kockleman, 1997; Addy et al., 2004). When the environment is significant in predicting travel/physical activity behavior, it is most often marginally so. Further, the aspects of the environment most relevant for walking are also still debatable: although most studies agree on the importance of access, density, safety and aesthetics, their relative importance is unclear and the way to assess them is also in contention.

Psychology and design literature has shown the complexity of perceptions of the environment and has emphasized the alterations that take place from the objective environment to perceptions of the same. This literature generally belongs to two categories: the papers written by designers and sociologists, and those written by psychologists and other researchers focusing on mental processes. Like the divide between the public health and travel behavior literature, these two branches of environmental psychology literature have very different foci and methods. The more scientifically oriented literature, authored by psychologists, is interested in the cognitive functions that cause particular perceptions (e.g.: Haber and Hershenson, 1973). These studies have underlined the importance of attitudes and experience in giving the environment meaning. In other words, these studies emphasize that perceptions of the same environment can differ widely depending on the person experiencing it. However, these studies are of limited value in terms of the environment because they are really more interested in brain function: the actual features of the environment tend to be highly controlled and often simplified to allow targeted analysis of cognition.

The other branch of environmental psychology, more commonly authored by designers or sociologists, is much more interested in the actual environment as well as the perceptions, rather than the mental mechanisms that cause perceptions. This includes visual preference studies, for example (Stamps, 2000; Fisher and Nasar, 1995.) These papers have found that perceptions are often different than objective assessment of the environment and have focused on some general personal characteristics, such as gender, that seems related to those differences in perceptions. This literature is much more relevant to the environment/behavior relationship as a result, but it also has some shortcomings. The main issue is the separation from behavior: most studies of this kind focus on perceptions and environment, but do not take into account the way perceptions then relate to behavior. Furthermore, literature of this type generally does not look at assessments of the environment that can be completed by laypeople on a wide scale or that can be compared to objective assessments of the same. Hence, although these visual preference studies are important from a psychological perspective, their controlled experiment setting does not aid in understanding how people internalize their environment as a whole and how this in turn is associated with behavior. Nonetheless, these studies clearly show the value of perceptions, and researchers should try to integrate this discipline into the environment/walking behavior relationship.

Finally, there have been recent efforts to bring all factors of this complicated issue together: perceptions, the environment, and behavior. These efforts have mainly risen out of the public health and travel behavior fields, as increasingly studies have become interdisciplinary, integrating foci of both fields. These studies have tried to integrate perceptions mainly by comparing two "objectively different" study areas (Saelens et al., 2003; De Bourdeaudhuij et al., 2005). This has tended to show that perceptions do in fact differ in walkable versus un-walkable areas. In other words, perceptions of the environment are related to the actual environment, and both then relate to walking.

However, this kind of comparison seems like it would overstate the link between objective reality and perceptual assessment, and would not differentiate between different aspects of the objective environment. For instance, although these types of studies show that there is a link between perceptions of safety and the overall objective environment, they do not relate perceptions of safety to objective assessments of safety. It is therefore possible that perceptions of safety are actually related to actual land use, for example, rather than actual safety. This could potentially lead to an overstatement of the links between environment and perceptions of environmental features: perceptions might well be more strongly related to the environment as a whole than single equivalent features. This is supported by studies of perceptions overall: they are more amorphous and nebulous than the environment actually is.

The three main sources of literature discussed here have provided a wealth of information regarding perceptions of the environment, objective assessment of the environment, and walking behavior. They have tended to show that perceptions of the environment and objective assessment of the environment are – at least tenuously – related to walking behavior. Over the last ten years, the measures of walking, perceptions and the environment have all drastically improved, leading to more disaggregate, targeted data and robust analysis. However, there is still no consensus regarding the importance of the environment on walking, which features of the environment are important, or how perceptions really fit into this equation. How do perceptions relate to the environment? How is the environment related to walking? How do perceptions fit in these relationships? There are still no convincing answers to these questions. This presents a challenge but also an opportunity to further explore how perceptions, environment and behavior relate to each other.

This study will fill gaps in the literature by quantitatively analyzing perceptual and objective environmental data and relating them to walking behavior. Thanks to the availability of micro-level data, which have largely been out of reach in previous research, a more detailed analysis of the relative importance of objective and perceptual assessment of the environment in terms of walking behavior can be reached. Considering the continued efforts from urban planning and public health fields in unraveling the relationship between environment and walking, and the recent interdisciplinary studies, it is particularly interesting to find whether either of their more common approaches (objective assessment of the environment from the urban planning perspective and perceptions of the same from the public health perspective) is more appropriate, or whether a combination would yield better results.

The literature linking walking to better health and quality of life is quite clear: walking regularly – and for long periods – is a good thing. Therefore, increasing walking is a very desirable outcome. By more fully understanding the impact of perceptions on the relationship between the built environment and walking behavior, it will be possible to more precisely pinpoint policy decisions to insure the most effective interventions.

Chapter 3: Methodology

The goal of this study is to determine how *perceptual* and *objective* assessments of the environment interact with each other and with walking behavior. As discussed in the previous chapters, this question is made relevant by the differing measures used in the two main branches of walkability research: objective assessment of the environment from travel behavior research and perceptual assessment of the same from public health research. Since there has been little overlap between those two branches up to the recent past, it is still very unclear which measures of the environment - objective or perceptual assessment of the environment (or perhaps even a combination of both) – best help in understanding walking. In order to achieve a better understanding of the relationship between the environment and walking, it would be useful to find which of these two points of view is more effective. To achieve this goal, three aims are to be met:

1. Find whether perceptions of the environment and objective assessment of the same environment are similar and, if not, how they differ.
2. Explore the variation of perceptions and objective assessment of the environment, paying particular attention to the relationship between socio-demographics and perceptions.
3. Determine how perceptions and/or objective assessment of the environment are related to walking behavior.

By answering these three questions, a deeper understanding of the relationship between the environment and walking can be reached. This can aid future researchers in measuring the environment more effectively and in turn elaborating interventions which more directly and efficiently alter the environment for increased walkability.

Research Design

This study consists of a cross-sectional research design that examines: (1) the relationship of perceptions of various aspects of the environment with each other, (2) their relationship to the equivalent objectively measured environmental features, and (3) how both perceptions and environment relate to walking behavior while controlling for socio-economic and other variables.

The study design involves three major categories of data: (1) objective environment data, collected through an audit and secondary archival GIS sources, (2) perceptual data, collected through a survey questionnaire, and (3) walking behavior data, collected through a travel diary and survey questionnaire.

Four constructs of major features of the environment (transportation, safety, aesthetics and land use) are elaborated in both the objective and perceptual assessments of the environment. The constructs are elaborated to take full advantage of the available data, which are described in depth below, while taking into consideration the unique way people interact with the environment, as discussed above. For instance, the respondents are not asked about details of the environment they probably do not notice by themselves (like the presence of curb cuts or number of crosswalks, for example) but rather are asked about their overall feelings about the walking environment (are sidewalks and crosswalks present and accessible?).

Similarly, where respondents might notice features but not what they entail (e.g.: buffers are easily noticeable but laypeople might not realize that these increase their safety from traffic, and they might not recognize the word "buffer") they are asked about those features in simple terms. Measurement of the environment are at the micro-scale to allow for the elaboration of effective constructs that accurately capture the pedestrian environment at low levels of aggregation.

The quantitative analyses for this study consist of the elaboration and testing of statistical tests of inter and intra array relationships to assess the relationship of perceptual measures of the environment with objective measures of the same; and through models of walking behavior as a function of environment, perceptions, and socio-demographic measures, to understand how perceptions and objective assessment of the environment relate back to walking behavior.

Environments & Participants to be Studied

This study is concerned with the perceptions of adults of their residential environment. Children were not included in this study both for practical reasons and because their developmental level (as well as physical size) entail a different relationship with the environment. The study also required choosing a suitable study area. This area would ideally possess a wide range of built environments and have geospatial data available both for preliminary classification and environmental analysis. Below, the method for choosing the study areas and the characteristics of the chosen study areas are described. This is followed by a description of the study participants and how they relate to the general population in the same geographic areas, as measured by the Census.

Study Areas

Montgomery County, Maryland was chosen as study area partly because it contains a variety of built environments. From exurban areas to highly urbanized, transit-oriented areas, Montgomery County provides opportunities to test the relevant associations described herein. Montgomery County borders the northern side of Washington, DC. It is the most populous jurisdiction in the state of Maryland and is ranked fourth in median household income in the country, ahead of all other Maryland counties (US Census, 2004 Community Survey). The Beltway (I-495) crosses the county East to West, and I-270 crosses it North to South. The County is also served by the Red line of the Washington Metro, with stops along Wisconsin Avenue (Route 355) and along Georgia Avenue (Route 97). Across Montgomery County, there are differences in factors such as urban density, the age and racial mix of the population, employment level, income, and automobile ownership. The age of the built environment itself (measured by the age of residential structures) is different in the urban, suburban, and exurban areas of the County. In addition, the GIS data needed for this study, including land use, transportation, safety and crime, are available for the entire County.

A Built Environment Index (BEI) developed by Rodriguez (et al., 2006) was used to choose the specific study areas in Montgomery County. The County's 318 Transportation Analysis Zones (TAZ) were classified based upon the index. Application of principal components analysis methods yielded the classification of 75 urban, 120 suburban, and 123 exurban TAZs, shown in Figure 2.

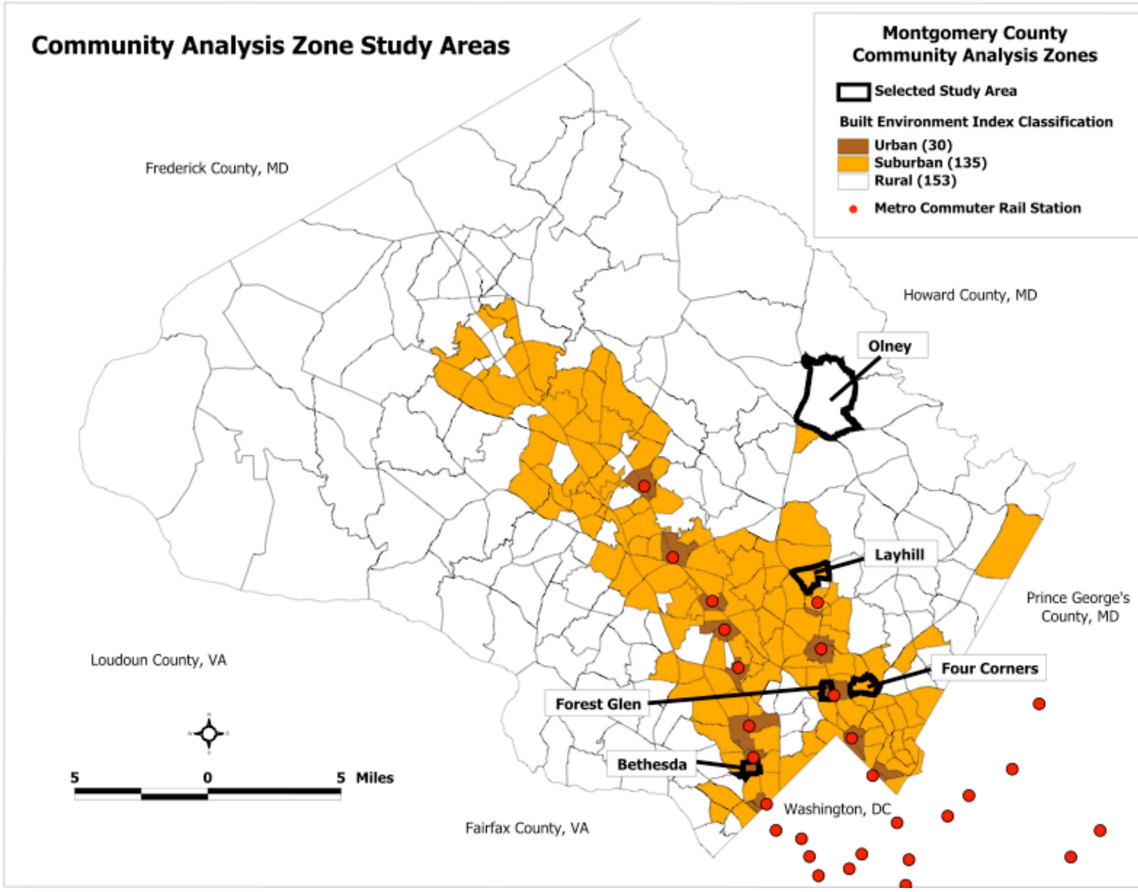


Figure 2: Study Areas

Table 1 below provides summary statistics for the urban, suburban, and exurban TAZs in the County as defined using the principal components method. Five TAZs within Montgomery County were randomly selected within the classifications (ALR Round 5 grant, Rodriguez, PI) that represent the variety found in the county. These are in Bethesda/Chevy Chase (urban), Forest Glen, Four Corners, Layhill (suburban) and Olney (exurban). The five study areas are shown in Figure 2. More detailed maps of all five study areas (at the same scale) and of each study area individually (for more detail) can be found in Appendix A.

Table 1: Socio-economic Characteristics by TAZ

	Urban	Suburban	Exurban
Total population	3,192	3,239	1,917
Population density (residents/sq. mile)	7,847	4,144	1,116
% under age 18	22.2	24.7	28.0
% over age 64	13.2	12.6	9.8
% male	47.7	47.7	49.0
% White	65.6	64.3	75.1
% unemployed	3.8	3.3	2.1
% of workers commuting <10 min.	6.2	5.8	5.1
% of Households with no vehicles	9.6	6.0	2.0
Median Income ($)	68,078	79,174	108,326
Median year houses were built	1959	1968	1977
Median year current resident moved in	1993	1992	1990

* Population and population density characteristics are from 2000 Montgomery County Traffic Analysis Zone Data and other socioeconomic characteristics are from Census 2000 Data.

Study Participants

Two hundred ninety-three adults were recruited to participate in the study. Participants were recruited and interviewed from April 2005 to September 2006. No more than one person per household was recruited. Criteria for participation were as follows: (1) aged 18 years or older, (2) lived at their residence for 6 months or more, (3) capable of walking 20 minutes at a time, unassisted and (4) not wearing a pacemaker. Level of engagement in physical activity and walking were not used as recruitment criteria.

Recruitment strategies were varied, utilizing mailouts, phone recruitment, and referrals. These different methods were used both to attract a variety of people, who might not respond to mail-outs, and for practical purposes: this allowed for more rapid recruitment. Response rates and respondents by recruitment strategy are shown in Table 2. Targeted mail-outs were implemented every two weeks for every known home address in the study areas. Mail out materials can be found in Appendix B.

Table 2: Response Rates & Recruitment

	Response Rate for Phone Recruitment	Number of Participants from Phone	% Participants from Phone	% Participants from Letter	% Participants from Other	Total Participants
Bethesda	13%	16	34%	51%	15%	47
Forest Glen	15%	20	45%	43%	11%	44
Four Corners	11%	27	40%	48%	12%	67
Layhill	10%	17	27%	48%	24%	62
Olney	8%	21	29%	51%	21%	73
TOTAL	11%	101	34%	48%	17%	293

Publicity for the study was conducted through television coverage on local news, posters and announcements at local community groups, listservs and other methods. Mail-outs were supplemented by phone calls after October 2005. Phone calls were made at various times during the day and evening on both weekdays and weekends. As many as 10 attempts were made to reach every household. Door-to-door recruiting was also attempted during summer months. A small number of participants were also referred to the study by their neighbors.

Overall, women were significantly over-represented in the study respondents (67%). To try to prevent or alleviate this problem, phone recruiters asked the respondent if a male was available to participate in the study. This was done from the beginning of the recruitment effort. As shown in Table 3, respondents in more urban areas (Bethesda and Four Corners) had a higher incidence of cars in the household but were less likely to have children in the household than respondents in more suburban (Forest Glen, Layhill) and rural (Olney) TAZs. This reflected the census data for the same areas. Overall, respondents were also more likely to have a high income and be Caucasian than the general population of the County.

Table 3: Participants by TAZ

		Bethesda	Forest Glen	Four Corners	Layhill	Olney
Participant Data	Number of Participants	47	44	67	61	73
	Average Age	51.4	48.8	49.3	52.8	49.1
	Percent Employed	60%	68%	58%	69%	78%
	Average Number of Cars in HH	1.3	1.5	1.9	2.3	2.3
	Percent Nonwhite	6%	34%	16%	18%	15%
	Percent with less than $100,000 HH Income	57%	74%	60%	40%	39%
	Percent Female	70%	75%	67%	61%	67%
	Percent With Children in HH	13%	31%	46%	54%	58%
Census Data*	Percent of Households with Two or More Vehicles	20%	45%	57%	65%	73%
	Percent Nonwhite	21%	41%	34%	40%	24%
	Percent with less than $100,000 HH Income	78%	82%	74%	65%	58%
	Percent Female	56%	54%	51%	50%	53%
	Percent Employed	78%	66%	66%	70%	74%
	Percent with Children in HH	45%	54%	50%	47%	63%

* 2000 Census, SF-1, SF-3, SF-4. Census tracts used as unit of analysis are slightly larger than the TAZs used for the study.

Measurement Methods

Measurement of the Physical Environment

In this study, micro-scale built environment data were collected using an environmental audit methodology, PEDS (Pedestrian Environment Data Scan) (Clifton et al., 2007). The methodology includes an audit instrument, training package and administration design.

The audit instrument was based on other tested environmental audits with an emphasis on the pedestrian environment (Emery et al., 2003, Vernez-Moudon and Lee, 2003, and Pikora et al., 2002.) The audit drew heavily on the audit from SPACES (Pikora et al., 2002). Reviews of the literature, as well as variations in the environment from Australia (for which SPACES was developed) to the United States, informed alterations made to the audit and development for the training materials. Audit items include sections on the environment (macro-scale), pedestrian facilities, road attributes, and the walking/cycling environment (micro-scale). Each audit item has been designed to objectively assess individual elements of the built and natural environment with respect to pedestrian accommodation.

The audit was designed to be administered on street or pedestrian network segments of approximately 400 feet each (typically block length) with non-pedestrian accessible segments removed and long segments divided to ensure that micro-scale details are not missed. The instrument is supported by extensive training materials including training and survey protocol. The audit was developed as a pencil and paper instrument but was adapted for a Personal Digital Assistant (PalmOS) platform and administered in that manner in this audit. This eliminated the need for data entry, thereby reducing error incurred through transposing data from written to electronic format. The PDA instrument also reduced surveyor error through the use of radio buttons, drop down menus and checks (such as "all fields required" before moving to another tab). The audit and associated training were tested and results indicated that the survey instrument is quite reliable, especially for residential areas (Clifton et al., 2007). For more information about the audit and how it compares to others, please refer to Clifton et al., 2007. The audit instrument can be found in Appendix C.

Forty-one measures of the environment resulted from the audit. Those measures are generally binary in nature, with a few exceptions, and comprise land use, street and sidewalk network, traffic control devices, crossing aids, aesthetic features, and maintenance. Of those measures, sixteen were used in this study. The measures, coding and descriptive statistics by study areas are shown in Appendix F. As shown in that table, environmental measures varied a great deal among the study areas. For instance, Bethesda and by far had the most commercial uses, while Forest Glen and Layhill had none at all. Three-and four way intersections were also much more common in Bethesda than in Layhill, for example. Bethesda and Olney both had lots of sidewalk while the other study areas – which were much more single-use residential – did not. Overall, there was strong variation in most environmental measures between the study areas.

The audit was administered in the five study areas in Montgomery County during the summer of 2005. In addition to the segments in the study areas themselves, buffers of ½ mile around each study area were also audited, permitting buffers of various sizes to be constructed around each participant's home.

Seven auditors, working in teams of two, surveyed the segments using the Palm Pilot interface after undergoing the training regimen. The segments had been previously prepared to include all walkable segments (discounting interstate highways, for instance) resulting in a total of 3800 segments. Of those, 3635 segments, or 96% of the total were audited. Reliability tests were conducted throughout the development and implementation of the audit, showing strong Kappa statistics (Clifton et al., 2007).

In addition to the audit, transport and other related archival spatial secondary data were gathered and used to supplement primary data. Data were collected from various sources, including the US Census, Land Cover Data, Orthophotos, etc. Three main macro-level GIS archival measures were used in this study to supplement audit data: density, land use, population mix and street network. Those density particular measures were chosen, as discussed in the following chapter, because they are the traditional measures of the environment used in travel behavior studies. They are also known as the "3Ds" (Cervero and Kockleman, 1997; Cervero, 2002.) The particular macro-level GIS measures used in this study are:

- POPULATION DENSITY: Gross population density (persons per acre)
- LAND USE: Mix measure (entropy) for all major uses for each geography.
- STREET NETWORK: Density of 3-and 4-way intersections for each geography.

Measurement of Walking Behavior

Walking behavior was measured with the use of a paper-and-pencil travel diary and through self-reported data in the survey. The survey data included non-walking physical activity, while the diary also included travel by other modes. This allowed for analysis of walking both in terms of overall physical activity and overall transportation.

a) Travel diary

Travel diaries were used to collect detailed information about study subjects' daily trips. These self-report, paper-and-pencil diaries allowed participants to record a log of the time trips took place (departure and arrival time), their destination (home, work, home neighborhood, work neighborhood and other) and the travel mode used (walk, bike, car, ail, bus or other). The diaries consisted of small booklets (5 by 3 inches) to encourage respondents to carry them all day and complete them as they were engaging in activities, to reduce issues of missing data, incomplete and estimated answers). An example page of the diary is shown in Figure 3. The diaries used in this project were piloted in Chapel Hill, NC in winter 2004-2005. The pilot and respondent feedback informed the development of the diary format and of the protocols. Data from these diaries were then computed to provide number of trips and travel times in minutes per day by mode and destination.

Day 1 Date: M T W Th F S Su

#	**WHEN** did you leave?	**WHERE** did you go? *Mark only one*	**HOW** did you travel? *Mark only one*	**WHEN** did you arrive?
1	: am/pm	☐ Home ☐ Home Neighborhood ☐ Work/School ☐ Work/School Neighborhood ☐ Other	☐ Auto ☐ Rail ☐ Bus ☐ Walk/Run ☐ Cycle ☐ Other	: am/pm
2	: am/pm	☐ Home ☐ Home Neighborhood ☐ Work/School ☐ Work/School Neighborhood ☐ Other	☐ Auto ☐ Rail ☐ Bus ☐ Walk/Run ☐ Cycle ☐ Other	: am/pm
3	: am/pm	☐ Home ☐ Home Neighborhood ☐ Work/School ☐ Work/School Neighborhood ☐ Other	☐ Auto ☐ Rail ☐ Bus ☐ Walk/Run ☐ Cycle ☐ Other	: am/pm
4	: am/pm	☐ Home ☐ Home Neighborhood ☐ Work/School ☐ Work/School Neighborhood ☐ Other	☐ Auto ☐ Rail ☐ Bus ☐ Walk/Run ☐ Cycle ☐ Other	: am/pm
5	: am/pm	☐ Home ☐ Home Neighborhood ☐ Work/School ☐ Work/School Neighborhood ☐ Other	☐ Auto ☐ Rail ☐ Bus ☐ Walk/Run ☐ Cycle ☐ Other	: am/pm
6	: am/pm	☐ Home ☐ Home Neighborhood ☐ Work/School ☐ Work/School Neighborhood ☐ Other	☐ Auto ☐ Rail ☐ Bus ☐ Walk/Run ☐ Cycle ☐ Other	: am/pm

Figure 3: Sample Travel Diary Page

b) Survey

The survey, administered to all participants, provides complementary information to the other collected behavior data. The survey collected information about number of walk trips to various destinations – such as stores, public transportation and park – from the previous month (30 days) from home. Although not typically considered to be as accurate as objective measures, these self –report recall survey data provide some context for the objective data collected during the study.

The survey also included questions from the International Physical Activity Questionnaire (IPAQ). This questionnaire, developed by Michael Booth and a large international team of public health researchers in 1996, has been used in numerous studies focused on physical activity and public health, and has been shown to have high reliability (Ainsworth et al., 2000; Craig et al., 2003). Relevant IPAQ questions for this study ask respondents the number of days of the last seven where they engaged walk trips (for transport, exercise/leisure, and work), and the duration of walk trips on those days. Descriptive statistics of the survey data can be found in Appendix F. The full survey questionnaire including the IPAQ and other walking questions can be found in Appendix D.

The diary and survey data together produce a thorough picture of walking undertaken by the respondents. Interestingly, the measures of walking from the diary and survey were significantly but not strongly related to each other (with $P < 0.3$). This lack of agreement is probably due to a number of factors. For instance, the IPAQ questionnaire and the diary did not cover the same period of time, as the questionnaire was asked at the beginning and the diary was completed over the following week. Furthermore, the act of walking was measured differently in each: only walking outdoors for more than three minutes was counted in the diary, while only walking for more than ten minutes, both indoors or outdoors, was counted in the

IPAQ questionnaire. Finally, it likely that walk trips were over-reported in the IPAQ and under-reported in the diary (Stopher et al., 2007). While they are both self-report, and as such have the intrinsic limitations of self-report questionnaires, they had complementing strengths: the IPAQ questionnaire provided a comprehensive detailing of physical activity, but is by its nature more aggregate in measurement, and worked best with routine activities (hence the risk of over-reporting). In contrast, the diary provided a complete recounting of travel undertaken, including walking, and because of its portability would be more insulated from problems associated with recall questionnaires (but walk trips in this would be more likely to be under-reported). By approaching walking from those two angles, a more complete assessment of walking could be used.

Measurement of Perceptions of the Environment

Individual level information was collected about each participant through a computerized questionnaire, where respondents were also asked about their physical activity, as described above. These data concern the individuals' attitudes and perceptions about the built environment, socio-demographics; physical activity, and transportation; health and physical condition; and types of physical activity. The entire survey questionnaire was administered in person.

Perceptual data in the questionnaire focus on the home neighborhood (defined as 1 mile or 20 minute walk from residence) and include: types of housing present, distance to destinations, sidewalk infrastructure, street network, access to transit, aesthetics (both built and natural), safety from crime and traffic, and sense of community. The full survey questionnaire can be found in Appendix D. Questions in the survey mainly consist of questions developed for the Neighborhood Environment Walkability Survey (NEWS). The reliability of these questions has been tested elsewhere (Saelens et al., 2003; Brownson et al., 2004).

Socio-demographic data include basic information about the individual and his/her household such as sex, race/ethnicity, educational attainment, marital status, presence of children and their ages, civil status, employment status (including number of jobs and commute information), and household income. Data about the individuals' residence include the location and type of dwelling and length of time at that location. Respondents were also asked whether they own a dog and, if so, if and how often they walk it.

Environmental Data Aggregation

The environmental data are aggregated to each participant's home residence in the study. Aggregation of both the audit and supporting archival GIS data were conducted at multiple buffers: 1/8, 1/4 and 1/2 mile around their home. These three buffer sizes were calculated to allow for more in-depth analysis, to find which buffer was most useful in determining walking behavior. The 1/4 mile buffer (approximately 400 meters) was chosen as it is a generally accepted "walkable" distance in existing research (Pushkarev and Zupan, 1975; Atash, 1994). The 1/8 and 1/2 mile buffers were also calculated to find whether these increments could also be useful and yield a better relationship to perceptions and behavior. Because of the limited size of the study areas, many respondents lived relatively close to each other, causing a high degree of overlap in buffers if larger ones were chosen. With the 1/8 mile buffer, the variance between participants is maximized and the overlap in areas minimized. This has potential statistical benefits as it reduces the likelihood of geographic correlation. On the other hand, the 1/2 mile buffer provides a more complete assessment of participants' home neighborhoods, which might yield better results when relating the environment to behavior. In order to test all these tradeoffs, and select the most beneficial buffer for the analysis, all three buffer sizes were calculated.

Aggregation of the GIS data for the 1/8, 1/4 and 1/2 mile buffers was accomplished individually for every different measure of the environment. This was done because of the different scale of data available for various measures. As a result, aggregated data for GIS measures range from binary (for instance, presence of Metro stop within the buffer) to continuous. The audit data were also aggregated at the 1/8, 1/4 and 1/2 mile buffers, for the reasons elaborated above. Two alternatives of the aggregation of PEDS variables within the buffer of each participant were calculated:

A. Average value of variable (by total number segments within buffer)

A. $$I_j = \frac{\sum_{i=1}^{n} V_{ij}}{n}$$

B. Weighted average of variable based on the length of street segments within buffer of each participant's home (by segment-miles within buffer.)

B. $$I_j = \frac{\sum_{i=1}^{n} V_{ij} \times l_{ij}}{\sum_{i=1}^{n} l_{ij}}$$

Method A was used for features that are not dependent on length of segment (such as land use, number of intersections, presence of path obstructions, etc.) while method B was used for features which are length-dependent, such as slope, sidewalk connection, or articulation. The full distribution of measure by aggregation method is listed in Table 4.

Table 4: PEDS Audit Aggregation Method by Measure

Method A (not weighted by length of segments)	Method B (weighted by length of segments)
Restaurant/Café/Commercial Uses	Building Height
Office/Institutional Uses	Presence of Pedestrian Facility
Presence of Parking Lots	Sidewalk Maintenance
3 and 4 way Intersections	Overall Cleanliness & Building Maintenance
Minimum Number of Lanes	
Bus Stop	
Crosswalks	
Crossing Aids	
Traffic Control Devices	
Industrial/Vacant Uses	
Degree of Enclosure	
Tree Cover	

Analysis Plan

To examine the research questions described in this chapter, the analyses were four-fold. First, the data collected in the study were aggregated to indices of the environment both for the objective and perceptual data. Development of the indices was completed through the use of both supporting theory and precedent in the literature and through statistical means. The description of the development of the indices and the methods used to accomplish this aggregation as well as descriptive statistics of the resulting indices are discussed in the next chapter. This process resulted in six indices for both objective and perceptual data in the categories of land use, transport (pedestrian and motorized), safety and aesthetics (cleanliness and tree cover).

After the indices were complete, the appropriateness of the objective and perceptual indices was tested against traditional methods of measuring the environment (aggregate objective measures of density, diversity, and design, also called the "3Ds"). Using Pearson correlation coefficients, the degree to which the micro-level measures, both objective and perceptual, are comparable to macro-level measures of density, diversity and design, was measured.

Third, the relationship between objective and perceptual measures of the environment were further explored, to respond to the first hypothesis: that objective and perceptual measures of the environment are not the same. The correlations between perceptions of the environment and the objectively measured environment were computed using Pearson correlation coefficients. Correlations within each array (objective and perceptual) were also computed to find whether the environments – perceived or real – have the same relationships between different aspects of the environment or whether people perceive the environment as more or less fragmented. This responds to the second major hypothesis: that variation within objective assessment is different than variation within perceptual assessment. To further understand how perceptions of various aspects of the environment relate to the objectively measured environment when controlling for personal characteristics, six linear models of perceptions were estimated as follows:

$$P = f(SD, OE, SA)$$

where:

P: measure of perception of the environment (one model each for each dependent variable as follows: land use, motorized transportation network, pedestrian transportation network, safety, tree cover, and maintenance of the environment)

SD: Socio demographic characteristics of the individual consisting of age, gender, presence of children in the home, employment status, and automobile ownership.
OE: Objective assessment of the environment as measured in indices of land use, motorized transportation network, pedestrian transportation network, safety, tree cover, and maintenance of the environment.
SA: Study area indicator consisting of binary measures denoting the study area.

Finally, the explanatory power of socio-demographics, the built environment and perceptions of the environment on walking behavior was examined. This relates to the third hypothesis: that both perceptions and objective assessment of the built environment are related to walking behavior. Linear regression models were estimated as a function of socio-demographics, perceptions of the environment and built environment measures. The following models were estimated:

(1) $W = f(SD, OE)$
(2) $W = f(SD, PE)$
(3) $W = f(SD, ME)$
(4) $W = f(SD, OE, SA)$
(5) $W = f(SD, PE, SA)$
(6) $W = f(SD, ME, SA)$
(7) $W = f(SD, PE, OE, SA)$

where:

W: Number of walk trips to destinations made in the last seven days
SD: Socio demographic characteristics of the individual consisting of age, gender, presence of children in the home, employment status, and automobile ownership.
PE: Perceptions of the environment as measured in indices of land use, motorized transportation network, pedestrian transportation network, safety, tree cover, and maintenance of the environment.
ME: Macro-level measures of the environment consisting of density, land use mix and street network.
OE: Objective assessment of the environment as measured in indices of land use, motorized transportation network, pedestrian transportation network, safety, tree cover, and maintenance of the environment.

SA: Study area indicator consisting of binary measures denoting the study area.

Control models, with driving trips and rail trips as the dependent variables, were also estimated to find whether results were consistent with expectations. Results from these analyses are discussed in Chapter 5. Results show that perceptions of the environment and objective assessment of the environment (as measured through the audit) are different than the 3Ds, indicating that they measure different aspects of the environment. Furthermore, the analyses related to the three hypotheses in this paper support all three: (1) correlations between the objective and perceptual measures of the environment and models of perceptions indicate that they are not strongly related (2) correlations among objective and perceptual measures of the environment indicate that features of the environment are more or less related to other features depending on the measurement point of view and (3) models of walking behavior show that both perceptual and objective measurement of the environment are related to walking in different ways. These results are all discussed in depth in Chapter 5.

Chapter 4: Built Environment Indices

As presented in the last chapter, a great deal of data was collected for this study, with dozens of perceptual questions about the built environment in the questionnaire, as shown in Appendix D, and over forty objective questions in the audit, as shown in Appendix C. However, a meaningful comparison of these data is extremely difficult and limited. Because of the nature of these different data sources, they often do not line up. In addition, because they were designed to operationalize the environment, they are intrinsically limited in scope. As a result, aggregating these data into meaningful indices was deemed necessary. The theoretical underpinnings of the indices, as well as the measures taken to form and justify the indices, are discussed in this chapter.

Two goals, sometimes at odds with each other, were sought for the indices. First, that they be as comprehensive as possible in their measure of the environment. However, the second goal made this sometimes undesirable. To produce meaningful comparisons of the objective and perceptual indices, these must first and foremost be as theoretically equivalent in construct as possible. This entails that measures, even if they are very good at capturing an aspect of the environment, cannot be included in the index if there are no equivalent measures in the other category (perceptual or objective.) Because the value of this comparative analysis between objective and perceptual indices was considered central to this thesis, the issue of equivalence was chosen as the most important factor.

The four categories of indices chosen for this study were: land use (density and mix), transport (street network and pedestrian network), safety from traffic and aesthetics (built and natural environment). The transport and aesthetics measures were further divided in two measures each following analysis described below. These four indices were designed to describe the walking environment while remaining distinct. Existing literature both from the public health and travel behavior fields were consulted.

Indexing Methodology

For this study, it was decided to construct indices rather than use disaggregate data. This was done to aid in meaningful comparisons between objective and perceptual assessment of the environment: a higher level of aggregation aids in developing equivalent indices of the environment from both perspectives. A four-step process was used to form the indices: first, the relevant literature and theory were consulted to choose the measures that were most likely to be important for the analysis at hand. Second, chosen measures were reduced by keeping only those that had equivalent measures from each perspective (objective and perceptual). Third, the groupings were tested with PCA analysis to confirm through statistical means that the groupings worked well. Finally, the chosen measures were normalized and aggregated to form the indices. The steps taken in forming the indices are shown in Figure 4.

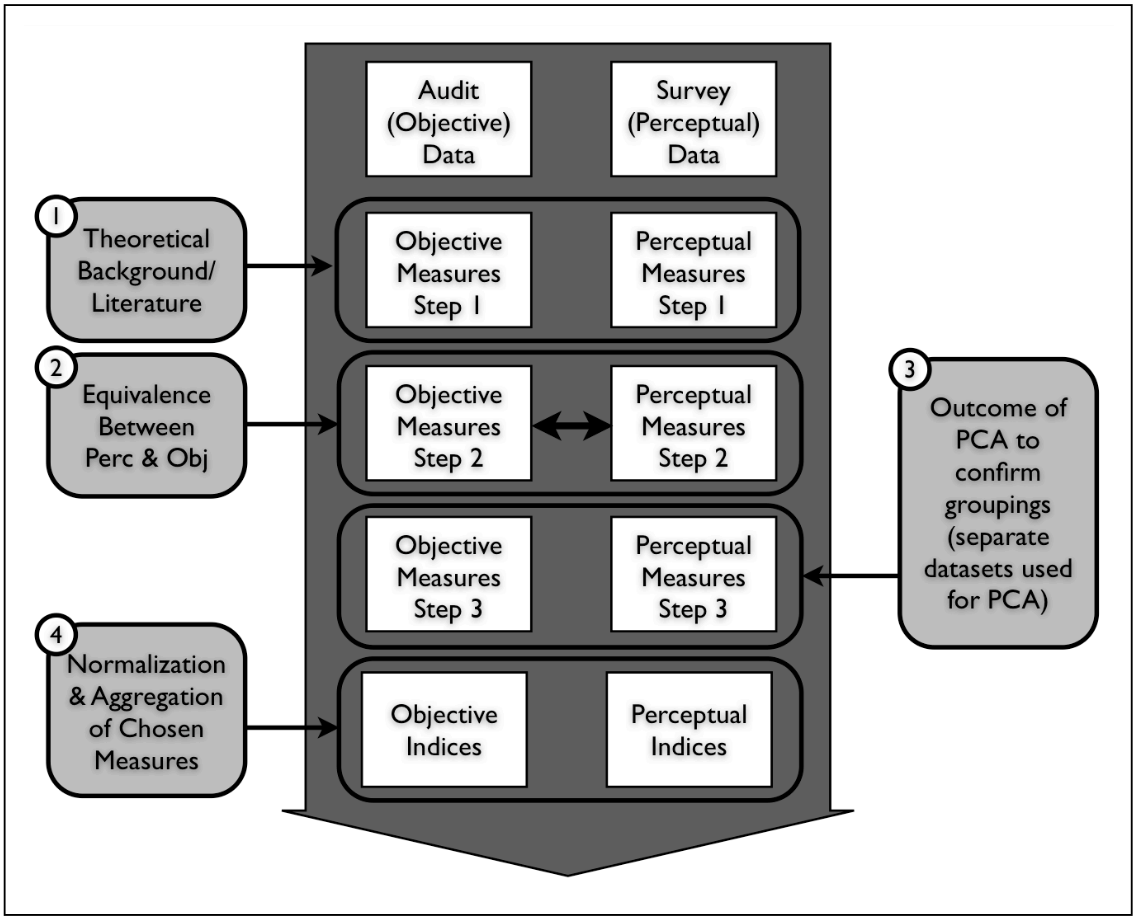


Figure 4: Steps in Construction of Indices

As stated above, the first step in constructing the indices was to consult the literature to find how previous researchers had aggregated their environmental data. Many researchers agree that several aspects of the environment are probably important for walking activity. For instance, Handy (2002) discusses the following dimensions of the built environment as affecting physical activity: density and intensity, land use mix, street connectivity, street scale (enclosure), aesthetic qualities and regional structure. Because this study relied upon NEWS questionnaire responses, the full complement of environmental factors as discussed by Handy (2002) was not possible. For instance, “regional structure” was not at all discussed in the questionnaire. Furthermore, her structuring of the boundaries between each factor is perhaps debatable: for instance, must enclosure (degree to which streets are defined by buildings, trees, etc.) be considered separately or can it be considered a part of aesthetics? Because environmental features are intrinsically related (for instance, street network and pedestrian infrastructure are strongly entwined), it is difficult to separate them.

There are multiple ways that measures could have been identified. For instance, they could have been identified in value-laden instead of value-neutral terms: instead of speaking of transportation network, one could think of the environment as a series of "attractions", "barriers", and "walking aids". However, this seems counterintuitive, especially since the NEWS questionnaire has been used in other studies.

In this study, the indices developed were simpler than those used by Saelens et al. (2003) but more comprehensive than in Humpel et al. (2004)'s analysis as discussed in Chapter 2: instead of separating land use and density as in Humpel's study, those were taken together. Safety from crime was removed, for multiple reasons. First, comparison with objective measures of safety was problematic: the audit only contained two questions which might serve as proxy for safety (presence of industrial/vacant land and street lighting). Furthermore, the lighting measure was imperfect, as audits were conducted during the day. These data overall were considered insufficient. Crime data could have been used, but these would have introduced other issues: how could/should they be aggregated? Which types of crime should be included? Moreover, crime was very strongly and significantly related to other measures used in this study, which would have led to issues of multicollinearity. For those reasons and to preserve the robustness of the analysis, the crime measure was left out of the study. However, the pedestrian and motorized environment were included, in contrast to Humpel et al.'s study (2004).

Once the literature was consulted to choose the measures most likely to be related to walking behavior, the chosen measures from the objective (audit) and perceptual (survey) standpoints were compared to see whether there was a direct relationship (step 2 in Figure 4.) Measures without a direct corollary were removed. For instance, although the presence of curb cuts might be related to walking, there was no equivalent measure from the perceptual dataset. Similary, attractiveness or beauty of the environment were not measured in the objective (audit) dataset and were therefore removed.

Those measures chosen through theoretical means and with equivalence from the objective and perceptual datasets were then analyzed with principal component analysis (PCA) (using SPSS 11) with a Varimax rotation (step 3 in Figure 4.) PCA analysis was conducted to assess whether each chosen index is a good summary of all of the information that was in the input variables and thereby refine the theory-derived index measures. The components produced by the PCA preserve a maximum of the original variance of the included data.

However, the PCA was not used to justify which measures to be included, as this method does not indicate which input variables are the best at measuring the construct. In other words, PCA analysis aids in finding how measures fit together by keeping the highest variance, but does not say anything about which measures are most related to walking behavior, which is of utmost concern in this research. For this reason, PCA analysis was only used in a supporting role, while theory directly influenced the measures taken into consideration. Furthermore, not all measures produced good factors, and in those cases the theoretical grouping of the measures into an index overrode the poor PCA fit. The factors resulting from the PCA analysis were not used. Instead, the measures were normalized and then their mean was calculated. This was done so that the qualities of the indices would not be defined by the inherent limitations in PCA factors (Wainer, 1976). Summary results of the PCA analyses are shown in Appendix E. To increase the robustness of the analysis, data collected from another location were used to develop and test the index factors. The data utilized for this are from College Park, MD. These data were collected in the summer of 2004, using the same PEDS audit and the same auditing methodology. Nine hundred fifty two segments were surveyed and 75 buffers of 1/8 mile were calculated (the same way as the Montgomery County audit data, as described in Chapter 4). Measures loading at 0.5 or more in the factors were retained.

After the PCA analysis refined the choice of measures made through theoretical means, the measures then had to be aggregated into indices (step 4 in Figure 4). Chosen measures were first normalized: because of different scales, this was deemed necessary to make sure the data were comparable. The mean of the chosen measures for each index was calculated. The components for each index are discussed below, organized by type (land use, transport, safety, aesthetics) and by assessment method (objective, followed by perceptual). Tables showing the descriptive statistics of the measures chosen for the indices as well as their types

(Likert, binary, etc.) are in Appendix F. The descriptive statistics of all the resulting indices are presented and discussed at the end of the chapter.

Perceptual and Objective Indices

Land Use: This index measure consists of measures involving uses and density. As discussed above, this grouping was chosen because it is relatively common, usually discussed in terms of accessibility (Lee and Vernez Moudon, 2006; Handy et al., 2005; Owen et al., 2004.) Audit questions involving use (restaurant, office, industrial, residential) and density (building height) were considered. In addition, the parking lot measure (one must walk through a parking lot to get to buildings) was also included after reversing its scoring: having to walk through a parking lot to access buildings is associated with lower densities. The industrial use measure was removed because there is no equivalent measure originating from the survey. The residential use measure was removed after the PCA analysis as it did not load very highly. The resulting objective land use index measure is as follows:

Land Use Index, Objective. Mean of:

Building Heights

Restaurant/Café/Commercial Uses

Office/Institutional Uses

Parking Lot (must walk through to get to uses) (scoring reversed)

In terms of perceptions, land use was assessed through access to destinations. In particular, respondents were asked the length of walk needed to access twenty-three destinations (such as stores, post office, library, park, etc.) Respondents were also asked about access to destinations in more general terms. PCA analysis here indicated a single factor, underscoring the unity of this construct. The perceptual land use measure is as follows:

Land Use Index, Perceptual. Mean of:

Facilities (distance to 23 amenities)

Shopping "can do most of my shopping at local stores"

Stores "stores are within easy walking distance of my home"

Destinations " there are many places to go within easy walking distance of my home"

Transport: This index measure is divided into two categories: pedestrian infrastructure and motorized infrastructure. PCA analyses confirmed that this category should be divided into two indices, both for the perceptual and the objective measures. For the pedestrian index, the audit (objective) contained much more information than the survey (perceptual). Only two measures had direct equivalence in the survey (presence/type of pedestrian facility and sidewalk maintenance in the audit, presence of sidewalk and maintenance in the survey questionnaire). As a result, the additional measures that do not have equivalent measures in the questionnaire were removed (sidewalk materials, connectivity, completeness).

On the other hand, for the motorized transport index, the audit has much less information than the survey questionnaire. Because there was more information available from the survey questionnaire side for the motorized transportation index, some relevant measures were not included in order to preserve parity. The cul-de-sac measure (is there a cul-de-sac in the street segment?) was kept as it was highly correlated with the intersections measures and therefore did not seem to significantly measure something that was not available from the audit side. In fact, this question was very similar, if worded differently than the presence of intersections question in the audit. The resulting objective and perceptual transportation indices are:

Transportation Indices, Objective

Transport - Pedestrian: Mean of:

Presence/Type of Pedestrian Facility

Sidewalk Maintenance

Transport – Motorized: Mean of:

3 and 4 way Intersections

Minimum Number of Lanes

Bus Stop

Transportation Indices, Perceptual

Transport - Pedestrian: Mean of:

Sidewalks “There are sidewalks on most of the streets in my neighborhood.”

Sidewalk Maintenance “The sidewalks in my neighborhood are well maintained.

Transport - Motorized: Mean of:

Intersections “There are many four-way intersections in my neighborhood.”

Cul-de-sac “The streets in my neighborhood do not have many cul-de-sacs.”

Bus Stops

Safety: This measure is concerned with safety from traffic. Respondents were asked directly about their feeling of safety. From the objective audit information, only the existence of safety features was available. This difference in measurement between the perceptual and objective was not avoidable since only presence and not risk could be assessed from the audit: the audit measures features present and measurable in the environment, not potential events (such as pedestrian collisions) which could take place. As a result, the index constructs built for the safety measure were elaborated to minimize the differences, as discussed below. The resulting index was constructed as follows:

Safety Index, Objective. Mean of:

Crosswalks

Crossing Aids

Traffic Control Devices

The traffic control devices measure covers the presence of traffic lights, stop signs, speed bumps, traffic circles and chicanes/chokers. The crossing aid measure covers yield to pedestrian paddles, pedestrian signals, medians, overpass/underpass, pedestrian crossing signs and flashing warnings.

Unlike the audit index safety measure, the perceptual index only includes questions about sense of safety, since there are no direct questions in the survey about specific environmental safety features. In addition to this difference, while the audit measures positive features – presence of traffic control measures, pedestrian signals, etc. – the perceptual survey asks negative questions. As a result, it is hypothesized that the audit and the perceptions index will have a negative relationship with each other. However, it could also be that traffic control devices and streets perceived as dangerous for pedestrians are one and the same, since there is no need for traffic control where there is little traffic to begin with. This could cause the relationship to be positive. This relationship between objective and perceptual measures of safety from traffic is further explored in the following chapter. The PCA analysis of the survey questions yielded a single factor, underscoring the fact that the safety questions work together is a coherent manner. The measures used in the perceptual safety index are:

Safety Index, Perceptual: Mean of:

Traffic/Own Street "There is so much traffic on the street I live on that it makes it difficult or unpleasant to walk in my neighborhood"

Traffic/Nearby Streets "There is so much traffic on nearby streets that it makes it difficult or unpleasant to walk in my neighborhood"

Traffic Speed "Most drivers exceed the posted speed limit while driving in my neighborhood"

Aesthetics: PCA analyses determined that this category should be divided into two indices. The division of these indices also follows theoretical assessment of the environment as one measures overall cleanliness and maintenance of the environment (aesthetics - cleanliness) while the other looks at sense of enclosure and natural features (aesthetics – tree cover). PCA analysis found the same division from both the objective and the perceptual side, ensuring that these measures would again be similarly constructed. In this category, again, there was much more information on the perceptual side than the objective side, so almost all relevant measures were considered. The aesthetics indices are:

Aesthetics Indices, Objective

Aesthetics - Cleanliness: Mean of:

Overall Cleanliness & Building Maintenance

Industrial/Vacant Uses (negative)

Aesthetics – Tree Cover: Mean of:

Tree Cover

Enclosure

Aesthetics Indices, Perceptual

Aesthetics - Cleanliness: Mean of:

Interesting Things "There are many interesting things to look at while walking in my neighborhood"

Litter "My neighborhood is generally free from litter"

Attractive Buildings "There are attractive buildings/homes in my neighborhood"

Aesthetics – Tree Cover: Mean of:

Trees "There are trees along most of the streets in my neighborhood"

Shade "Trees give shade for the sidewalks in my neighborhood"

Distribution of Indices

The descriptive statistics for the perceptual (survey) and objective (audit) measures in all five study areas are shown in

Table 5. The distribution of the objective measures is shown at all three buffer sizes. The mean and range of the measures varies widely for both perceptual and objective assessments within the five study areas, indicating different environments. For the land use index, Bethesda had the highest mean and the smallest standard deviation, which means that Bethesda is both the most dense study area and the one which varies least in density. This is unsurprising, as Bethesda is the most urban study area and the small size of the area entails relatively little variation in the density and land use to be found. In contrast, the other study areas have much lower means and larger standard deviations. In particular, Olney has a wide array of land use mix and density, which again is to be expected considering it is the largest study area and consists of a centralized town and rural areas. This pattern of distribution among the study areas for the land use measure is similar in both the perceptual and objective indices.

The pedestrian transportation perceptual measure was positive for Bethesda and Olney but negative in the three other study areas, which are all more singularly residential. This means that residents viewed their pedestrian network – quality and quantity of sidewalks – as better in Bethesda and Olney than in the other study areas. Because those other areas are solely residential, it is not surprising that the rating of the pedestrian network was more negative there: there are fewer sidewalks, and fewer connections, in areas without commercial uses. The objective assessment showed the same pattern except for the Forest Glen study area. The difference in perceptions from objective assessment in a single study area is interesting. Perhaps people tend to minimize arterials in their characterization of the pedestrian environment: in Forest

Glen, residences are not directly on arterials, and those are the most likely to have sidewalks.

Table 5: Descriptive Statistics of Perceptual and Objective Measures

			Bethesda				Forest Glen				Four Corners				Layhill				Olney			
			Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
Perceptual Measures		Land Use	0.42	3.31	2.39	0.63	-3.02	1.73	-1.08	1.26	-3.07	2.49	0.20	1.36	-3.61	1.79	-1.22	1.36	-3.51	3.10	-0.02	1.74
		Transit - Pedestrian	-4.15	1.61	0.62	1.49	-5.10	1.61	-0.44	1.91	-5.10	1.61	-0.91	1.76	-3.81	1.61	-0.21	1.70	-1.24	1.61	1.05	0.85
		Transit - Motorized	-0.91	2.88	1.57	1.10	-3.42	2.88	1.05	1.76	-3.36	2.88	0.85	1.43	-6.24	1.96	-1.28	1.67	-6.24	2.88	-1.28	1.80
		Safety	-2.94	6.04	1.20	2.31	-4.04	4.76	0.72	2.48	-4.04	4.76	-0.54	2.01	-4.04	6.04	-0.41	2.04	-4.04	6.04	-0.36	1.81
		Aesthetics - Trees	0.42	1.04	-0.30	2.21	-5.83	1.04	-0.31	1.89	-2.88	1.04	0.60	0.90	-3.39	1.04	0.08	1.44	-5.83	1.04	-0.28	1.79
		Aesthetics - Cleanliness	-7.88	2.83	0.35	2.49	-6.45	2.83	-1.41	2.48	-6.18	2.83	-0.43	2.27	-4.75	2.83	0.41	1.93	-4.75	2.83	0.68	2.04
Objective Measures	1/8 Mile	Land Use	-0.22	8.10	4.03	2.15	-2.05	1.01	-0.71	0.81	-2.15	2.47	-1.63	0.97	-2.15	1.36	-1.20	0.97	-2.15	6.14	0.36	1.59
		Transit - Pedestrian	-1.07	2.32	1.04	0.64	-1.10	2.75	1.00	0.94	-3.49	1.64	-1.74	1.01	-3.59	2.98	-1.19	1.99	-4.10	2.98	1.32	1.25
		Transit - Motorized	-5.08	1.11	-0.93	1.70	1.11	6.92	2.17	1.67	-2.77	2.08	0.88	0.67	-5.82	3.80	-1.86	2.64	-8.13	3.27	0.07	2.43
		Safety	-0.74	6.85	3.48	2.09	-1.43	4.44	0.42	1.87	-2.41	3.17	-0.14	1.23	-3.76	3.17	-2.03	1.52	-3.76	2.74	-0.65	1.59
		Aesthetics - Trees	-1.35	3.69	1.02	1.32	-1.37	2.55	1.33	0.89	-1.87	3.54	-0.03	1.10	-5.09	2.46	-0.92	2.15	-5.53	2.09	-0.70	2.07
		Aesthetics - Cleanliness	-2.00	1.31	-0.14	1.07	-2.80	1.31	0.26	1.14	-4.41	1.31	0.04	1.24	-1.40	1.31	0.41	0.84	-5.88	1.31	-0.46	2.23
	1/4 Mile	Land Use	-0.24	8.98	4.12	2.49	-1.94	-0.61	-1.07	0.29	-2.61	2.44	-1.58	1.31	-2.61	0.18	-1.36	0.72	-2.50	6.99	0.61	1.81
		Transit - Pedestrian	-0.96	2.61	1.09	0.77	-0.21	2.10	1.09	0.52	-3.61	0.96	-1.73	1.18	-4.41	2.64	-1.41	1.59	-5.20	3.17	1.44	1.26
		Transit - Motorized	-1.91	1.39	0.06	0.89	1.09	3.59	2.61	0.75	-0.75	1.36	0.65	0.48	-5.47	4.16	-2.47	2.57	-7.89	3.11	-0.09	2.61
		Safety	1.91	7.97	4.53	1.72	-1.89	1.22	-0.22	0.86	-1.71	3.03	-0.22	1.12	-4.15	2.02	-2.33	1.71	-4.30	3.63	-0.60	1.79
		Aesthetics - Trees	0.73	4.30	1.84	0.77	0.33	3.41	1.80	0.73	-1.34	1.42	-0.18	0.73	-4.02	1.28	-1.36	1.37	-7.13	3.57	-0.98	2.17
		Aesthetics - Cleanliness	-0.81	1.83	0.23	0.70	-1.31	1.60	0.63	0.76	-3.73	1.94	-0.07	1.33	-2.02	1.94	0.61	0.79	-5.16	1.94	-1.00	2.17
	1/2 Mile	Land Use	0.47	7.64	4.44	1.83	-1.59	0.01	-1.10	0.35	-3.09	-0.16	-1.54	1.03	-2.49	-1.54	-2.06	0.26	-2.63	5.47	0.96	2.11
		Transit - Pedestrian	-2.82	3.24	0.89	1.68	0.22	1.99	1.36	0.45	-3.62	0.51	-1.26	1.03	-3.89	1.29	-1.57	1.55	-7.20	2.79	1.10	1.61
		Transit - Motorized	0.07	1.99	1.02	0.47	2.30	3.25	2.80	0.18	-0.56	0.81	0.24	0.21	-5.37	0.43	-2.59	1.55	-11.11	3.40	-0.35	2.91
		Safety	1.96	7.78	5.10	1.52	-1.22	0.27	-0.55	0.36	-1.65	1.66	0.02	0.82	-4.27	0.02	-2.62	1.21	-5.76	3.20	-0.74	2.18
		Aesthetics - Trees	2.22	3.70	2.63	0.42	1.24	2.39	1.87	0.27	-0.86	1.40	-0.02	0.64	-2.85	0.45	-1.46	0.91	-5.03	3.95	-1.56	1.62
		Aesthetics - Cleanliness	0.99	1.56	1.26	0.13	-0.25	1.53	0.76	0.41	-1.19	1.12	-0.26	0.55	-0.35	1.82	0.62	0.50	-4.07	2.96	-1.54	1.90
		N	47				44				67				61				73			

Perceptions of motorized transit, which mainly assesses street network and access to public transportation, was as expected: Bethesda had the most positive scores and scores declined in order of the Built Environment Index. Objectively measured, however, the picture was not nearly as clear, with Bethesda garnering negative scores, for instance. The safety measure, however had similar patterns of distribution both objectively and perceptually: Bethesda and Forest Glen had positive scores while the other study areas did not. For all study areas, there was a great deal of variation.

The aesthetic measures, like the motorized transport measure, had very different distributions when measured objectively versus perceptually. The tree cover measure, assessed perceptually, had positive scores for Four Corners and Layhill but not the others. In contrast, the objective assessment had Bethesda and Forest Glen with positive scores with the rest negative. For the cleanliness measure, there was also a great deal of variation between objective and perceptual measurement although the results for Layhill were identical for both. Interestingly, Olney and Bethesda were positive perceptually whereas Forest Glen and Four Corners were positive when measured objectively. This discrepancy could maybe be caused by the fact that Olney and Bethesda are both areas with more newly-constructed buildings: perhaps people thought of cleanliness and maintenance also in terms of newness. However, this cannot be answered from the data available.

Overall, the distribution of the objective and perceptual measures make it clear that the study areas did in fact have very different environmental qualities in terms of all the aspects of the environment captured in this study. Further, these distributions start to demonstrate that there are significant differences between perceptions and objective assessment of the environment, although these differences are not on the same order of magnitude for each environmental feature: people internalize aspects in different ways; some tend to coincide with objective measures while others are influenced by socio-psychological aspects of the individual. These differences might indicate that capturing both will be important for research.

This chapter discussed how the indices for this study were developed, and the distribution of the resulting indices in the five study areas. Rooted in theory, these indices are likely to be related to walking behavior: previous studies have used similar measures of the built environment and related them to walking. Furthermore, these indices, because they measure the same environmental features from perceptual and objective viewpoints, can explore how these viewpoints differ and whether one or the other is more strongly related to walking behavior. The relationship among and between objective and perceptual measures of the environment, as well as the relationship of both with walking behavior, is explored below.

Chapter 5: Objective and Perceptual Assessment of the Environment and their Relationship with Walking Behavior

This chapter discusses the results of analyses laid out in Chapter 3. First, the micro-level objective and perceptual indices of the environment will be assessed. The indices are compared to the 3Ds in their effectiveness in measuring the pedestrian environment: do micro-level objective and perceptual indices significantly improve our understanding of the pedestrian environment as it relates to walking? These analyses set the stage for comparing the micro-level perceptual indices and the perceptual indices and relating them to walking. Results show that indeed, the micro-level measures measure different aspects of the built environment, as shown by their lack of significant correlation with the 3Ds. This indicates that micro-level assessment of the environment might yield otherwise unattainable data regarding the walking environment.

This chapter then further explores the relationship between perceptual and micro-level measures and also relates both to walking behavior, in response to the three hypotheses laid-out in Chapter 1. In response to the first hypothesis *perceptions differ by personal characteristics as well as by environmental features*, Pearson correlations between objective and perceptual indices of the built environment are run, with results showing that they are indeed different: relationships were weak and few are significant.

Then, the second hypothesis, *the importance of personal attributes in shaping perceptions entails that variations in perceptions are different than variations in the built environment*, is explored. Analyses include linear models of perceptions as well as Pearson correlations among objective and perceptual measures of the environment. Results of these analyses show that relationships between various features of the environment are different from an objective and perceptual standpoint: where objective measures are significantly correlated, showing an environment where features change in tandem, perceptions of the same are not significantly correlated. Models of perceptions emphasize this by showing that objective measures of the environment and socio-demographics are both only weakly related to perceptions. This indicates that other factors, such as experience and temperament, are probably involved in shaping perceptions.

Finally, the third hypothesis, *that perceptions as well as the environment both have an association with walking behavior*, is explored with multiple models of walking behavior. First, models of driving and rail trips are estimated to confirm that relationships are as expected. Second, models of both time spent walking and number of trips are estimated, with perceptions, objective assessment, socio-demographics and the 3Ds as independent variables. Results show that indices of perceptions of the environment and objective assessment of the environment are both related to walking behavior, that different indices are significant from the two perspectives, and that they are more strongly related to walking than the 3Ds. This shows the value of capturing and including these micro-level measures, and that they are not interchangeable.

Micro-level Environmental Measures & the 3Ds

One of the ways to assess the usefulness of the audit is to compare it to the traditional macro-level data used in pedestrian environment analysis: density (usually measured through number of persons per geography), land use mix (measured through varied measures such as gravity index, entropy index or Hierfendahl index) and street network (usually measured through density of intersections or block length). These three measures of the environment, commonly known as the "3Ds", are used in numerous studies focused on transportation and the built environment, as discussed in Chapter 2 (Cervero & Kockleman, 2997; Cervero, 2002; Boarnet and Sarmiento, 1998, for instance). These 3Ds are associated with transportation choices (including walking) in recent studies. Therefore, the degree to which the micro-level objective measures are related to the 3Ds is of interest: are they strongly related? If so, it is probably unnecessary to measure the micro-level features: they would only be measuring the same thing over again without any added information. If, however, the micro-level measures and the 3Ds are not strongly related, then the micro-level measures might be able to capture aspects of the pedestrian environment not assessed by the 3Ds. In that case, the micro-level features might be worth the effort of data collection as they would complement the 3Ds.

Micro-level Objective (Audit) Data and the 3Ds

The three sizes of micro-level objective measures (audit buffer) were tested against macro-level data which had also been aggregated to the same buffer size (1/8 to 1/8, 1/4 to 1/4 and 1/2 to 1/2) with Pearson Correlations. The results are shown in Table 6.

Table 6: Pearson Correlations between Macro and Micro-Level Objective Measures at Three Buffer Sizes

		Macro Data		
Objective (Audit)		Density	Land Use	Street Network
1/8 Mile	Land Use	0.549**	**0.637****	-0.015
	Transport Pedestrian	0.111	0.578**	0.061
	Transport Motorized	-0.001	0.221**	0.489**
	Safety	0.450**	0.459**	0.171**
	Aesthetics Trees	0.157**	0.062	0.318**
	Aesthetics Clean	-0.202**	-0.327**	0.051
1/4 Mile	Land Use	0.561**	**0.781****	-0.003
	Transport Pedestrian	0.237**	0.597**	0.069
	Transport Motorized	0.374**	0.145*	0.579**
	Safety	**0.642****	**0.633****	0.230**
	Aesthetics Trees	0.365**	0.237**	0.425**
	Aesthetics Clean	-0.073	-0.354**	0.118*
1/2 Mile	Land Use	0.525**	**0.806****	0.224**
	Transport Pedestrian	0.351**	0.044**	0.226**
	Transport Motorized	0.571**	0.336**	**0.662****
	Safety	**0.693****	**0.678****	0.548**
	Aesthetics Trees	0.519**	0.258**	**0.618****
	Aesthetics Clean	0.298*	-0.302**	0.257**

* significant at the 0.05 level
** significant at the 0.01 level

The correlations between the audit and the macro-level data show a few strong relationships. Strong relationships were expected between the land use audit measure and the macro land use and density measures and between the motorized transport audit measure and the street network measure since they measure similar aspects of the environment, even if they are not measured the same way. Although there are no specific equivalents on the macro side, the safety audit measure was also expected to be correlated with all the macro measures as the presence of traffic calming and pedestrian safety features would seem to be related to denser, busier areas with dense street networks and therefore more vehicles on the roads. The street network macro measure was also hypothesized to be correlated with the pedestrian audit measure for the same reason: denser streets would indicate more a likely presence of sidewalks. However, the relationship between the two aesthetic audit measures and the macro-level was very uncertain. It was hypothesized that these would have a weaker relationship – if any – with the macro measures and that they would be generally negatively related to all macro measures. Finally, it was hypothesized that relationships would become stronger at the larger buffer sizes as outliers would fall out.

Almost all hypotheses were supported by the correlation results. At the largest buffer size (1/2 mile), some relationships were strong (with $\rho > 0.6$), all of them being statistically significant. The safety micro-level measure was significantly related to all the macro-level measures, while for other micro-level measures the relationships with the macro measures were more limited. Interestingly, the aesthetics tree cover measure, although not as strongly related to the macro measures as the other micro-level objective indices, was significantly related to the macro measures of street network. The coefficient was also particularly high at the 1/2 mile buffer: $\rho = 0.618$. This indicates that having shade from street trees is associated with a street network with more intersections. The smaller buffer sizes yielded weaker relationships although the relationship between the two land use measures (micro and macro) remained strong.

Overall, these relationships between the macro-level environmental measures and the micro-level indices indicate that they are both clearly measuring related items of the environment. In particular, the land use measures seem to be highly and significantly related to each other. However, the majority of micro-level indices with lower correlations with the macro-measures – in particular pedestrian network and aesthetics - are clearly not being captured by researchers in most current analyses, and this might have adverse consequences in their analysis if these measures are related to walking.

These results are unsurprising: the land use micro-level measure and the motorized transport measure are mostly measuring the same environmental aspects as the 3Ds, albeit with different measurements. The micro-level land use measure consists of both density and land use, while the motorized transport measure consists mainly of street network. As such, it is expected that they would have very strong relationships with their macro-level counterparts. However, even these did not have very strong relationships at the 1/8 mile buffer, which seems to indicate that collecting the micro-level measures might yield additional information about the environment. Furthermore, the micro-level measures with no direct macro-level equivalent (safety, aesthetics, pedestrian network), with their low correlations with the macro-level measures, clearly seem to capture environmental aspects not available with the 3Ds alone. This indicates that collecting micro-level data, although time consuming and expensive, might be worthwhile to capture the environment in richer and more complete ways.

Micro-level Perceptual (Survey) Data and the 3Ds

The perceptual indices were also correlated to macro-level measures of the environment. This was done to assess how different perceptions are from the commonly used environmental measures found in most research focused on pedestrians from the transportation field. As with the correlations with audit measures, the 3Ds, three macro-level measures, were assessed: land use, density and street network. Since three buffer sizes of these were available (1/2, 1/4 and 1/8), all three were analyzed, as shown in Table 7. However, only one buffer size was available for the perceptual data, since respondents only answered for a single distance from home.

Results show some positive correlations, particularly for the perceptual land use measure (with density and land use) and the perceptual motorized transport measure with the macro street network measure. However, the perceptual aesthetics index measures were not significantly related to the macro measures. Again, this is as expected, as are the weaker relationships with safety: those measures are not directly assessed by the macro measures and tend to vary according to personal characteristics as well as the environment.

Overall, the relationship between macro-level objective data and perceptions is much weaker than the relationship between the macro and micro-level objective measures, as discussed above: although most relationships are significant, the coefficients are quite low. This emphasizes that the perceptual data are very different from the macro-level objective data, and that they therefore add to the understanding of the environment. Further, this would seem to indicate that the perceptual measures are very different from the micro-level objective measures, since their relationship with the macro-level measures is stronger. This is further explored in the last section of this chapter.

Table 7: Pearson Correlations between the Micro-Level Perceptual (Survey) and Macro-level Data at Three Buffer Sizes

		Macro Data: 1/2		
		Density	Land Use	Street Network
Perceptions (survey)	Land Use	0.448**	0.539**	0.311**
	Transport Pedestrian	-0.059	0.260**	-0.215**
	Transport Motorized	0.513**	0.228**	0.582**
	Safety	0.216**	0.116*	0.169*
	Aesthetics Trees	-0.001	-0.036	0.062
	Aesthetics Clean	-0.093	0.055	-0.239**
		Macro Data: 1/4		
	Land Use	0.496**	0.444**	0.121*
	Transport Pedestrian	-0.027	0.335**	-0.244**
	Transport Motorized	0.512**	0.098	0.431**
	Safety	0.231**	0.125*	0.109
	Aesthetics Trees	0.019	-0.102	0.068
	Aesthetics Clean	-0.079	0.094	-0.266**
		Macro Data: 1/8		
	Land Use	0.489**	0.224**	0.040
	Transport Pedestrian	0.024	0.273**	-0.143*
	Transport Motorized	0.434**	0.089	0.329**
	Safety	0.124*	0.166**	0.020
	Aesthetics Trees	0.008	-0.114*	0.019
	Aesthetics Clean	-0.027	-0.040	-0.213**

* Significant at the 0.05 level
** Significant at the 0.01 level

Objective & Perceptual Micro-level Measures of the Built Environment

To respond to the first major hypothesis of this paper, that perceptions and objective assessment of the environment differ, Pearson correlations between the objective (audit-based) and perceptual (survey-based) indices were conducted. These were examined to test whether each feature is related to its corollary and find how each feature is related to the other features of the environment. Pearson correlations were used as all index measures were normalized. All three buffer sizes (1/8, 1/4 and 1/2 mile) of the audit were included, as shown in Table 8.

Table 8: Pearson Correlations between Objective (Audit) and Perceptual (Survey) at Three Buffer Sizes

		Survey					
		Land Use	Transport Pedestrian	Transport Motorized	Safety	Aesthetics Trees	Aesthetics Clean
Audit 1/8 Mile	Land Use	0.516**	0.271**	0.190**	0.180**	-0.099	0.078
	Transport Pedestrian	0.155**	0.372**	-0.045	0.091	-0.131**	0.031
	Transport Motorized	0.120*	-0.046	0.310**	0.049	0.006	-0.164**
	Safety	0.496**	0.140*	0.448**	0.203**	-0.017	-0.067
	Aesthetics Trees	0.138*	-0.019	0.296**	0.187**	0.093	-0.100**
	Aesthetics Clean	-0.189**	-0.148*	-0.037	-0.046	-0.021	0.067
Audit 1/4 Mile	Land Use	0.575**	0.284**	0.200**	0.144*	-0.071	0.051
	Transport Pedestrian	0.209**	0.343**	-0.002	0.079	-0.112	-0.003
	Transport Motorized	0.222**	-0.047	0.394**	0.106	-0.004	-0.174**
	Safety	**0.615****	0.145*	0.456**	0.184**	-0.046	-0.080
	Aesthetics Trees	0.212**	-0.025	0.372**	0.258**	0.012	-0.112
	Aesthetics Clean	-0.258**	-0.210**	-0.046	0.061	-0.036	-0.006
Audit 1/2 Mile	Land Use	**0.655****	0.285**	0.255**	0.167**	-0.077	0.063
	Transport Pedestrian	0.212**	0.225**	0.114	0.112	-0.076	-0.022
	Transport Motorized	0.342**	-0.030	0.488**	0.144*	-0.003	-0.175**
	Safety	**0.688****	0.107	0.489**	0.209**	0.001	-0.025
	Aesthetics Trees	0.272**	-0.079	0.502**	0.300**	-0.003	-0.157**
	Aesthetics Clean	-0.146*	-0.130*	0.087	0.135*	-0.073	-0.056

* significant at the 0.05 level
** significant at the 0.01 level

At larger buffer sizes, the micro-level objective measures were more highly correlated to the perceptual measures than at the smallest buffer size. This is probably an artifact due to the averaging effects of the larger buffers. It is probably also rooted in peoples' ability to perceive at larger scales: perceptions are more "nebulous" than objective assessment, where the aggregation can be tightly controlled and small in scale. Indeed, as shown in the previous chapter, people tend to see their environment in more unformed and not as coherent ways than is actually the case. This does not entail a value judgment of one versus the other but simply of a control or lack thereof in the exact operationalization of the environment.

When comparing the perceptual measures to their objectively measured counterparts, one finds that some measures have a statistically significant relationship and a relatively high coefficient while others do not. In particular, the perceptual land use measure is significantly and strongly correlated with the micro-level objective land use measure, especially at the 1/2 mile buffer. The two transport measures, and the safety measure are also significantly correlated, although not as strongly. However, the perceptual measures of aesthetics are not significantly related to their objectively measured counterparts. All of these relationships make intuitive sense. The land use and transport measures do not have a strong emotional or personal component: measuring those can be done relatively dispassionately. In contrast, perceptions of aesthetics are much more personal, and include an intrinsic value judgment absent from the measures of land use and transport. As a result, it was correctly expected that the perceptual aesthetic measures would not be strongly related to the micro-level objective aesthetic measures.

The perceptual safety measure was significantly related to the audit safety measure, but this relationship was relatively weak. Again, this was as expected, although it is interesting to note that the audit/perceptual safety relationship was stronger than that of the aesthetic measures. This could indicate that perceptions of aesthetics are particularly unique to individuals (this is supported in psychological literature, for instance Nasar, 1988). When expanding the correlations to the other measures of the environment, the same pattern emerged: land use was significantly correlated with everything else, in some cases strongly. For instance, the objectively measured safety features had a strong correlation with perceptions of land use. At the other end of the spectrum the aesthetics measures were not significantly correlated with most measures of the environment.

Overall, perceptions of the environment were not very strongly correlated with objective measures of the environment. This supports the first hypothesis of this paper: that individuals experience and perceive the environment differently instead of all seeing a homogenous space. This merits further attention: are perceptions of different aspects of the environment related to each other as objective assessment of the same? Do models of perception bear out that perceptions are associated with the objectively measured environment, or are other measures at play? This is discussed below.

Relating Perceptions to the Environment

Intra-Index Relationships: Objective Measures

The micro-level objective indices derived from the audit were tested for correlation among themselves with Pearson Correlations to explore the relationship between the various features of the environment. These tests were administered for all three buffer sizes (1/8, 1/4 and 1/2 mile), as shown in Table 9, Table 10, and Table 11, both to enrich the analysis and to ensure that measures subsequently added to regression models would not result in problems of multicollinearity and geographical overlap. The correlations with a coefficient above 0.6 are shown in the tables in **bold**.

Table 9: Pearson Correlations of Objective Measures at 1/2 Mile Buffer

		1/2 Mile					
		Land Use	Transport Pedestrian	Transport Motorized	Safety	Aesthetics Trees	Aesthetics Clean
1/2 Mile	Land Use	1	0.541**	0.389**	**0.842****	0.246**	-0.148**
	Transport Pedestrian		1	**0.620****	0.510**	0.219**	-0.181*
	Transport Motorized			1	**0.618****	0.555**	-0.276**
	Safety				1	0.583**	-0.001
	Aesthetics Trees					1	0.380**
	Aesthetics Clean						1

* significant at the 0.05 level
**significant at the 0.01 level

As expected, some objective (audit) indices were correlated with one another. High land use scores, indicating a dense, mixed area, were strongly positively correlated with the presence of traffic control (safety) and to a lesser extent the presence of sidewalks, and street network (motorized transport). On the other hand, land use scores were not significantly correlated with cleanliness and maintenance of the environment or tree cover. This is unsurprising, as highly used and dense areas tend to result in more disorder (Ewing et al., 2006). Cleanliness and maintenance of the environment was negatively correlated with almost every other environmental measure, although very weakly. It was, however, weakly positively associated with the tree measure. This is in line with expectations as trees are considered a positive aesthetic environmental feature (Hoehner et al., 2005; Saelens et al., 2003). The relatively weak relationship might be due to the negative association of cleanliness with leaves and other debris on the ground: although trees are usually seen as positive, their consequences are not.

Table 10: Pearson Correlations of Objective Measures at 1/4 Mile Buffer

		1/4 Mile					
		Land Use	Transport Pedestrian	Transport Motorized	Safety	Aesthetics Trees	Aesthetics Clean
1/4 Mile	Land Use	1	0.545**	0.072	**0.786****	0.101	-0.311**
	Transport Pedestrian		1	0.440**	0.464**	0.219**	-0.225**
	Transport Motorized			1	0.448**	0.469**	-0.261**
	Safety				1	0.377**	-0.277**
	Aesthetics Trees					1	0.205**
	Aesthetics Clean						1

* significant at the 0.05 level
**significant at the 0.01 level

Although the objective (audit) correlations were similar at all three buffer sizes, there were some differences. Relationships maintained the same directionality but the strength of those relationships changed according to the buffer size. Overall, the relationships among the environmental indices were stronger as the buffer widened. This is as expected: as the environment measured is larger, outliers are less statistically disruptive and the unified aspect of the environment becomes more pronounced. However, this high degree of correlation for a few measures at the larger buffer indicates that it would be preferable to use the smaller buffer indices for use in regression models to avoid problems of multicollinearity (between the safety and land use measures, for instance). This is further emphasized by the need to minimize overlap in the buffer areas to avoid geographic correlation. Indeed, if the buffers overlap a great deal then the difference between different environments is reduced. Therefore, using the smaller buffer for regression analysis is preferable to allow maximum distinction between the environments of the participants.

Table 11: Pearson Correlations of Objective Measures at 1/8 Mile Buffer

		1/8 Mile					
		Land Use	Transport Pedestrian	Transport Motorized	Safety	Aesthetics Trees	Aesthetics Clean
1/8 Mile	Land Use	1	0.453**	-0.063	**0.641****	0.035	-0.240*
	Transport Pedestrian		1	0.310**	0.328**	0.271**	-0.127**
	Transport Motorized			1	0.334**	0.288**	-0.253**
	Safety				1	0.227**	-0.223**
	Aesthetics Trees					1	0.072
	Aesthetics Clean						1

* significant at the 0.05 level
** significant at the 0.01 level

Intra-Index Relationships: Perceptual Measures

The survey indices were correlated to each other to find whether these are strongly related to each other or whether people perceive the environment differently than the environmental measures relate when measured objectively. The Pearson Correlations are shown in Table 12. This table shows that although there are some significant correlations between some environmental features, none of these relationships is strong (with $\rho > 0.6$).

Table 12: Pearson Correlations among Perceptual (Survey) Measures

	Land Use	Transport Pedestrian	Transport Motorized	Safety	Aesthetics Trees	Aesthetics Clean
Land Use	1	0.137*	0.404**	0.107	0.000	0.066
Transport Pedestrian		1	-0.106	-0.293**	0.136**	0.250**
Transport Motorized			1	0.143*	0.006	-0.120*
Safety				1	-0.246**	-0.213**
Aesthetics Trees					1	0.255**
Aesthetics Clean						1

* significant at the 0.05 level
** significant at the 0.01 level

As expected, land use was positively (but weakly) correlated with the transport indices, although it was not significantly related to the safety or aesthetics measures. This is surprising and shows a difference between perceptions and objective assessment of the environment: land use is significantly correlated with most index measures when measured objectively.

The directionality of the correlations also differed from the objective assessment of the environment. For instance, cleanliness was positively correlated with pedestrian transport from a perceptual standpoint, but not objectively. This might be that people have generally more positive perceptions of areas that are walkable, or that they think of side streets instead of arterials with sidewalks (but also likely more litter and less maintenance).

Overall, the results of these correlations seem to indicate that people perceive the facets of their environment in ways that are less strongly related than they are when measured objectively. The perceptual correlations overall show weak relationships among the environmental measures whereas the correlations of the objectively measured features, as discussed above, show stronger and more significant relationships. This is in line with the hypotheses elaborated in this paper as well as common sense: where the environment might change in a rational and related way, one might not sense that various features of the environment are in fact related and mistakenly think them largely independent. Furthermore, because people internalize aspects of the environment in different ways, some might coincide with objective measures while others might not. As a result, the relationships between the various aspects of the environment are different from each perspective.

This has deep implications for policy: if people do not perceive aspects of the environment as being related, they might expect outsize effects from interventions that will prove relatively minor in their consequences. On the other hand, since interventions are generally based on objective data, they might not influence people in the desired way. This might indicate a need to consider people's perceptions (even if "irrational") and intervene in ways that would have the most behavioral impact, rather than built environment impact (through education, for instance).

Models of Perception

The section above has shown that what people think is present in their environment can be very different from what is actually there. Further, this can be more or less true depending on the aspect of the environment in question. These results are in line with existing literature, as discussed in Chapter 2, as well as with common sense: people see their environment in myriad ways. It is not possible in a paper of this scope to look at how these different perceptions arise. In fact, there is still only limited understanding on how perceptions are internalized, and what characteristics, both of the environment and of individuals, are relevant (Ittelson, 1973, for example).

However, finding whether perceptions – as narrowly defined as they are here – are related to the environment and socio-demographic measures, does have some value. Although this will not show what causes perceptions to be as they are, it does provide some understanding of the relationship between the environment and perceptions, and how those are in turn influenced by socio-demographics. One would expect that some perceptions, particularly those of aspects of the environment that are more easily measured and less emotionally laden, would be strongly associated with the environment and have weaker relationships with socio-demographics. For instance, street network, unlike safety, is not associated with strong emotions: feeling that the environment has few or many intersections is much less emotionally laden than feeling that the environment is safe. Therefore, it is expected that this measure would be strongly related to the environment, whereas safety might not be. Similarly, measuring density (for instance types of housing, as asked in the survey in this paper) is easier to do than thinking about cleanliness or tree cover (the baseline and unit of measurement is much more unclear.)

To assess the contribution of the environment or socio demographics in shaping perceptions, regression models of perceptions were estimated, with perceptions as a function of objective measures of the environment and socio-demographic measures. The micro-level objective measures included here were at the 1/8 mile buffer to avoid problems of multicollinearity as discussed in the previous chapter. All environmental measures were included in the models because all the objective measures are at least partially related: as shown in the previous chapter, the objectively measured environment does form a coherent, if not very highly correlated whole. Further, it is unclear how precise perceptions are. It seems likely that perceptions of one aspect of the environment may draw from others. For instance, sense of safety has been shown to be associated with enclosure (Stamps, 2005). This would indicate that perceptions of safety might be associated with land use or tree cover in this study.

Socio-demographic data were chosen for their previously-assessed relationship with walking behavior as discussed in relevant literature, with the idea that qualities that related to walking would probably also relate to the perceptions that would encourage or discourage walking. These measures are as follows:

- Age (continuous): younger people, at the aggregate level, walk more than older people (Giuliano, 2003; Badland & Schofield, 2005).
- Gender: women, at the aggregate level, walk more than men (NHTS, 2001) but that is not always reflected at the personal level (Handy, 2006)
- Presence of children in the household: adults with children in their household tend to walk less than people without children in their home (Handy, 2006).

- Number of automobiles available: people with fewer cars available for use by their household walk more than people with more cars. (as reviewed in TRB-IOM, 2005)
- Income: people of lower incomes, at the aggregate level, walk more than people with higher incomes. (as reviewed in TRB-IOM, 2005)

The analysis here is at the individual level, but one would expect that these socio-demographic measures, which have a strong impact on walking overall, are important in relation to perceptions of the walking environment. It is expected that groups which walk less will also have more negative perceptions of the environment, and vice-versa. Although these socio-demographic measures are important, it should be noted that other qualities that might impact perceptions were not included in these models. In particular, it was not possible to capture peoples' experience with possible incidents while walking, personalities, brain patterns, and self-selection, among others. As psychologists have always wrestled with, the contributions to perceptions are multifold and endlessly complex. It is not realistic to attempt to capture all personal characteristics associated with perceptions; it is only possible to find how much the actual environment can play a role. The models of perceptions are shown in Table 13.

Table 13: Models of Perceptions (N=293)

	Perceptions											
	Land Use		Transport Pedestrian		Transport Motorized		Safety		Aesthetics Trees		Aesthetics Cleanliness	
Independent Variables	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**
Constant	0.190	0.729	-0.583	0.322	1.104	0.073	1.303	0.102	-0.266	0.674	0.178	0.837
Audit												
Land Use	**0.374**	**0.000**	0.001	0.823	**0.126**	**0.070**	0.124	0.168	-0.005	0.411	0.154	0.116
Transport - Pedestrian	**-0.197**	**0.001**	**0.378**	**0.000**	**-0.381**	**0.000**	-0.006	0.520	**-0.141**	**0.045**	0.008	0.419
Transport - Motorized	0.008	0.115	**-0.138**	**0.011**	**0.193**	**0.001**	-0.001	0.872	-0.001	0.793	-0.007	0.366
Safety	**0.128**	**0.029**	0.006	0.295	**0.267**	**0.000**	0.007	0.409	0.003	0.635	-0.113	0.220
Aesthetics - Trees	**0.116**	**0.028**	-0.005	0.372	**0.252**	**0.000**	**0.208**	**0.007**	**0.131**	**0.032**	-7.100	0.196
Aesthetics - Cleanliness	-0.003	0.660	**-0.149**	**0.033**	0.109	0.127	0.000	0.995	-0.006	0.399	0.131	0.195
Socio-Demographics												
Sex	-0.001	0.783	0.003	0.682	-0.004	0.532	0.000	0.449	0.001	0.201	0.001	0.206
Age	-0.319	0.111	0.222	0.301	-0.005	0.981	**-0.718**	**0.014**	0.002	0.919	**-0.690**	**0.029**
Children at Home	-0.340	0.109	0.006	0.783	0.167	0.477	0.004	0.904	-0.307	0.208	0.001	0.964
Automobile Ownership	0.006	0.574	**0.263**	**0.029**	-0.139	0.249	-0.005	0.749	**0.239**	**0.064**	0.223	0.191
Income	0.134	0.239	-0.110	0.366	**-0.211**	**0.097**	0.002	0.889	-0.162	0.216	-0.106	0.554
R square		**0.355**		**0.217**		**0.357**		**0.097**		**0.070**		**0.072**

The models of perceptions follow much the same pattern of previous correlations: that land use, in particular, followed by transport measures, is strongly related to the environment, while the more "subjective" perceptions of safety and particularly aesthetics are not. Interestingly, most objective measures were significant in predicting the motorized transport perceptual measure, even more than for the land use perceptual measure. The R square for the motorized transport measure was also slightly higher than for the land use measure. The R squares for both of these models seem to indicate that perceptions of land use and motorized transport are significantly associated with environmental features. Perceptions of pedestrian transport were not as strongly related to objective assessment of the environment, as shown by its weaker R square (0.217). None of the environmental measures were significant in predicting the perception of cleanliness, only one (presence of trees) was significant in predicting perceptions of safety, and only two (presence of trees and pedestrian network) were significant in predicting the perception of tree cover. The R squares for these models were also all particularly low (less than 0.1), which indicates that the fit of these models is poor and that the included measures do not explain much of the dependent variable. These results are unsurprising: those three measures of perceptions, because they are more difficult to measure and operationalize, were not expected to be strongly related to the environment.

One interesting result of these models of perceptions is the low significance of socio-demographic measures almost across the board. Sex and presence of children in the home were not significant in any of the models. The other socio-demographic measures were only significant in one or two models each. For instance, age was a negative both in predicting sense of safety and perception of cleanliness. This is in line with anticipated results: the elderly tend to feel less safe within the environment than younger people (Badland and Schofield, 2005) and have higher standards for environment cleanliness and maintenance. For instance, it is likely that a person in their twenties will be more comfortable in a more complex and busy environment like a downtown in the evening than a person in their sixties or seventies might be. Again, it is evident that other personal characteristics, not measured in this study, are probably important in determining perceptions of the environment. However, from these models, it is clear that the actual environment is important in predicting perceptions of land use and transport (both motorized and, to a lesser extent, pedestrian), but that the objectively measured environment is not as important – if at all – in relation to perceptions of safety and aesthetics.

These results punctuate the literature discussed in Chapter 2: perceptions are much more complicated than mere reflection of the environment or of socio-demographics. In addition to being related to these factors, a myriad others, such as personality and experience, significantly complicate the interaction. As such, it is unlikely for urban planners to fully understand how perceptions come about, only to measure them as they exist. This would indicate that better measuring perceptions would allow the most in-depth understanding of how they interact with the environment: trying to get to underlying personal reasons for those perceptions is not feasible.

Models of Walking Behavior

The main goal of this study is to assess how perceptions add to our understanding of the built environment/walking behavior relationship. The analysis up to this point has focused on the relationship between objective and perceptual measures of the environment, and has shown that those two ways of assessing the environment are in fact quite different. However, this does not mean that both types of measures are significant when related back to walking behavior. The following analyses focus on the import of both perceptual and objective assessment of the environment relate to walking to find whether perceptions are relevant within this relationship. This responds to the third and final hypothesis of the study: that both perceptions and objective assessment of the environment are related to walking behavior.

For the models of walking behavior, walking behavior as reported as number of trips in the travel diary was used. This account of walking behavior was used rather than the survey-based physical activity responses because the answers were more accurate and detailed than the questions in the survey, as has also been found in other studies (Stopher et al., 2007). The survey questions, based on IPAQ, asked about number of walking trips for various reasons and average length (in minutes) of the trips, but did not have information regarding the location of the trip or the actual length of the trip. Further, recall questions such as those in the IPAQ questionnaire tend to have lower reliability than self-report diaries completed right after trips occur.

The diary questions are specific regarding length of trips (minutes traveled) and also include origin and destination of the trip. Two walking behavior dependent variables were developed from the diary. Both were aggregated for all seven days of participation. Both were also reduced to the number of walking trips taken with origin or destination being either “Home” or “Home Neighborhood”. The rationale behind this decision was that the home neighborhood environment is likely not related to work-based or other-locations-based walking but is very relevant for home-based and home-neighborhood-based walking. The first measure of walking developed from this aggregation is of total time spent walking to/from home for seven days. The second measure developed is of total number of walking trips to/from home for seven days. Descriptive statistics of the walking measures for the five study areas are shown in Table 14. Walk trips to/from home were significantly more numerous and longer in the urban study area (Bethesda). Number and duration of home-neighborhood based trips declined in more suburban neighborhoods. However, there was an increase in both number of trips and duration in the Olney study area. This could be due to more mixed environment in Olney, which varies from rural to town center, or could also be due to more leisure-based rather than transportation-based walking trips.

Two other dependent variables were aggregated from the diary: total driving trips and total rail trips (both for seven days). These models were developed mainly as controls: one would expect that the environment would be relatively unimportant for automobile trips, with personal characteristics being more important, while the environment would be much more important for rail trips. This was tested to make sure that the measures of the environment were accurate and were measuring the environment as expected.

Table 14: Descriptive Statistics of Walking Measures

		Number of Walk Trips (per week)		Total Time Spent Walking (minutes per week)	
Study Area	N	Mean	Std. Dev.	Mean	Std. Dev.
Bethesda	47	10.6	9.2	210.49	224.4
Forest Glen	42	5.0	5.2	89.60	140.9
Four Corners	65	3.9	5.2	84.71	136.8
Layhill	61	2.8	3.4	79.16	102.1
Olney	71	3.7	4.9	101.06	127.7

The independent variables for the models include socio-demographic measures, the survey and audit indices, macro measures and study area dummies. The socio-demographic measures are: age, sex, presence of children in the home, employment status, and number of vehicles. Income was not included because of the relative lack of variation in incomes in the study areas. These socio-demographic measures were included because of their demonstrated importance in models of travel behavior (Law, 1999; TRB-IOM, 2005; Handy, 2006). Descriptive statistics of the walking measures by status of the measures mentioned above are shown in Table 15.

The distribution of walking for the various socio-demographic groups were as expected compared to more macro-level studies of travel behavior. For instance, residents with fewer cars walked more than residents with cars in the household. Similarly, women walked slightly less than men, and the presence and children in the home was associated with fewer walking trips. Younger respondents walked more trips than those aged 30-64 but spent less time walking. Respondents 65 or older walked both the most number of trips and spent the most time walking.

Table 15: Descriptive Statistics of Walking Trips and Duration for Different Socio-Demographic Groups

		N	Number of Walk Trips (per week)		Total Time Spent Walking (minutes per week)	
			Mean	Std. Dev.	Mean	Std. Dev.
Age	18-29	25	5.00	5.82	73.88	80.63
	30-45	78	4.38	4.83	83.38	109.32
	46-64	138	4.95	7.04	116.95	165.47
	>64	45	5.51	6.26	148.36	196.88
Gender	Women	193	4.69	5.29	110.92	104.94
	Men	93	6.56	5.58	166.66	121.51
Presence of Children in HH	No	161	5.37	6.70	119.13	174.47
	Yes	124	4.30	5.61	96.48	120.27
Employment Status	No	93	5.23	5.91	138.09	173.64
	Yes	193	4.73	6.42	94.94	140.73
Number of Cars in HH	0	8	13.00	13.18	248.50	250.17
	1	91	5.93	7.36	126.58	192.76
	2	133	4.15	5.08	96.16	124.27
	>2	54	3.74	4.09	90.19	110.56

The environmental measures developed and discussed above were supplemented by binary indicator variables representing each study area. Olney is considered the baseline study area. Although Olney is exurban and has lower densities than some of the other study areas, it is better as a baseline than Layhill or Four Corners because it has a higher variety of environments. This means that its residents can engage in walking for transportation, leisure or both depending on where they live in the study area. In contrast, the Layhill study area consists only of single-family homes with no destinations. Olney, like Four Corners and Layhill, does not have walking-distance access to the Metro. The study-area dummies are included in some models to parse the specific impact of environmental measures as opposed to the general characteristics of each study area.

The macro-level measures were not included in models that also had the perceptual and/or objective micro-level measures because of the high correlations between a few of the measures (particularly the perceptual and objective land use measures), as discussed in the previous chapter. However, the objective and perceptual measures were included in one model together since the Pearson correlations between these measures – although significant for a few measures – was deemed low enough to be acceptable, especially for the smaller buffer aggregation (1/8 mile) for the objective measures.

Models of Time Spent Walking

Models of total time spent walking in the home neighborhood for seven days were estimated. The models are shown in Table 16. All of these models show that very few measures of the environment are statistically significant in predicting amount of walking (in minutes). The only socio-demographic measures significant in predicting walking behavior in any of the models are number of vehicles and employment status. Both, as expected, are strongly negatively associated with walking behavior: in other studies, higher number of cars and being employed were also associated with less walking (Livi Smith et al., 2007). Only one survey measure – land use – was significant in predicting walking behavior, and when including study area dummies it was no longer significant. This would seem to indicate that the land use measure is better captured at the neighborhood level and that the degree of disaggregation allowed by the audit data is unnecessary in looking at walking behavior.

Table 16: Linear Regression: Walk (Total Time) to/from Home and Home Neighborhood (N=293)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Independent Variables	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**
Constant	**114.072**	**0.036**	**117.448**	**0.022**	130.442	0.043	98.791	0.107	**136.359**	**0.018**	**142.070**	**0.033**
Age	0.729	0.317	0.603	0.378	0.465	0.508	0.753	0.301	0.570	0.405	0.501	0.466
Gender	9.388	0.659	-0.493	0.981	6.174	0.761	2.591	0.902	-0.484	0.981	3.263	0.869
Chidren in the home?	5.064	0.804	10.399	0.601	0.247	0.990	15.619	0.445	11.692	0.558	10.169	0.607
Employment status	-27.813	0.194	**-34.871**	**0.093**	**-39.464**	**0.058**	-24.015	0.261	-33.109	0.108	-30.667	0.133
Number of vehicles	**-19.900**	**0.077**	-9.855	0.378	**-19.488**	**0.082**	-12.484	0.272	-9.587	0.392	-14.926	0.178
Perceptions: Land Use	**19.011**	**0.001**					8.387	0.237				
Perceptions: Transit - Pedetrian	0.103	0.986					-6.662	0.314				
Perceptions: Transit - Motorized	-6.421	0.234					-8.883	0.149				
Perceptions: Safety	4.286	0.367					-1.109	0.822				
Perceptions: Aesthetics - Trees	3.521	0.555					6.547	0.280				
Perceptions: Aesthetics - Cleanliness	-1.878	0.672					-3.529	0.431				
Objective: Land Use			**14.572**	**0.022**					0.758	0.919		
Objective: Transit - Pedestrian			-5.961	0.332					**-14.431**	**0.079**		
Objective: Transit - Motorized			3.574	0.486					**12.765**	**0.031**		
Objective: Safety			3.962	0.503					-0.749	0.910		
Objective: Aesthetics - Trees			5.746	0.287					2.350	0.695		
Objective: Aesthetics - Cleanliness			9.606	0.146					9.449	0.154		
Macro: Density					1.464	0.337					**-3.338**	**0.074**
Macro: Land Use					75.351	0.137					-24.335	0.698
Macro: Street Network					-108.808	0.256					73.752	0.567
Study Area: Bethesda							**103.665**	**0.006**	**101.463**	**0.040**	**136.667**	**0.000**
Study Area: Forest Glen							2.327	0.951	-55.122	0.121	-13.019	0.729
Study Area: Four Corners							-25.321	0.452	**-81.860**	**0.037**	-26.319	0.410
Study Area: Layhill							-34.089	0.243	-42.742	0.205	-28.739	0.318
R Square		**0.084**		**0.094**		**0.056**		**0.131**		**0.135**		**0.121**

In contrast, two audit measures were significantly associated with time spent walking but only when including the study area binary measures. Those measures are: pedestrian and motorized transportation. Interestingly, the presence and quality of a pedestrian network was negatively associated with walking while the motorized network was positively associated with walking. This might mean that the pedestrian network in the study areas is poorly adapted to the walking habits of pedestrians (perhaps they walk mainly for pleasure) or that they fail to make the environment feel safe for pedestrians. On the other hand, this does support that dense street networks are associated with increased walking behavior.

The macro-level measures were not any more significant than the micro-level ones. Like the micro-level objective audit measures, only one macro-level measure was significantly associated with walking, and it only came out with the inclusion of the study area dummy variables. The macro-level density was negatively associated with walking, although the coefficient was very low. Interestingly, the Bethesda study area, which is very dense, was very strongly positively associated with walking. These mixed results might indicate that land use mix more than density has an impact on walking behavior, or that density alone is not enough without land use mix to be associated with walking behavior.

Overall, these models were of poor fit, especially when not including the study area dummy variables (R square of 0.084 for perceptual, 0.094 for micro-level objective and 0.056 for macro-level measures.) The micro-level objective (audit) measures showed slightly better fit than the perceptual (survey) measures, but in both cases very few measures were significant. These models show a very limited impact of the environment on total time spent walking. Along with previous studies looking at the relationship between the built environment and walking behavior (as reviewed in Badoe and Miller, 2000, for example), these results would seem to indicate that the relationship between walking and environment is very marginal. Furthermore, the models with the perceptual measures of the environment were even less significant than those with the objective assessment of the environment. This is a little surprising: researchers have emphasized that personal characteristics, especially socio-psychological ones like perceptions, are probably more strongly associated with behavior than the environment (De Bourdeaudhuij et al., 2005). Therefore, one would expect that perceptions, among other socio-psychological factors, would have a noticeable relationship with behavior, especially if the environment, objectively measured, does not. However, the results of these models do not bear this out. These two findings coupled together emphasize the difficulty in assessing the relationship between the built environment and walking behavior. However, they do not rule out that transportation, including walking, and the environment are in fact related. Although the relationship between the environment and total time spent walking was minor, this does not mean that there is not a significant relationship between the environment and walking behavior. Time spent walking might be more strongly related to personal characteristics, whereas the number of trips taken may be more strongly related to the environment.

Models of Trips: Auto and Rail Trips

Total driving and rail trips over seven days were modeled. These models were developed as controls: one would expect that the environment would be relatively unimportant for automobile trips, with personal characteristics being more important, while the environment would be much more important for rail trips. This was tested to make sure that the measures of the environment were accurate and were measuring the environment as expected. The results of those models are shown in Table 17.

Most socio-demographic measures were almost all significant in these models, all in the directions expected. Older people were less likely to make both driving and rail trips, while people with children in the home and access to more vehicles were more likely to drive but less likely to take rail trips. In contrast, employed residents were less likely to drive but more likely to take rail trips. This is as expected in the Washington, DC metro area, where taking the metro to work is less expensive (and aggravating) than driving.

The environmental measures were significant in different ways between rail and driving trips. For driving trips, very few perceived measures were significant but almost all objectively measured environmental features were. Interestingly, land use was not significant while aesthetics were. This might be because areas with better aesthetic features are also more pleasant to drive in and less likely to be very congested. Only the density measure among the macro-level measures was significant in Model 3, and it was negatively associated with driving drips. This follows common sense: very dense areas tend to have more congestion and therefore be less attractive for drivers.

Table 17: Poisson Regressions: Driving and Rail Trips (N=293)

	Model 1 (driving)		Model 2 (driving)		Model 3 (driving)		Model 4 (rail)		Model 5 (rail)		Model 6 (rail)	
Independent Variables	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**	**Coef.**	**Sig.**
Constant	**3.691**	**0.000**	**3.685**	**0.000**	**3.858**	**0.000**	-0.189	0.573	-0.460	0.149	**-0.956**	**0.019**
Age	**-0.007**	**0.000**	**-0.006**	**0.000**	**-0.007**	**0.000**	**-0.017**	**0.000**	**-0.018**	**0.000**	**-0.016**	**0.000**
Gender	**-0.195**	**0.000**	**-0.203**	**0.000**	**-0.181**	**0.000**	**0.409**	**0.000**	**0.592**	**0.000**	**0.532**	**0.000**
Chidren in the home?	**0.185**	**0.000**	**0.183**	**0.000**	**0.168**	**0.000**	**-0.533**	**0.000**	**-0.519**	**0.000**	**-0.399**	**0.000**
Employment status	-0.041	0.130	**-0.061**	**0.024**	**-0.053**	**0.047**	**1.390**	**0.000**	**1.499**	**0.000**	**1.464**	**0.000**
Number of vehicles	**0.053**	**0.000**	**0.037**	**0.010**	**0.031**	**0.026**	**-0.116**	**0.091**	-0.088	0.198	**-0.128**	**0.059**
Perceptions: Land Use	0.004	0.584					**-0.073**	**0.017**				
Perceptions: Transit - Pedetrian	-0.004	0.619					**-0.139**	**0.000**				
Perceptions: Transit - Motorized	**-0.012**	**0.080**					**0.081**	**0.007**				
Perceptions: Safety	0.004	0.549					**-0.088**	**0.002**				
Perceptions: Aesthetics - Trees	0.011	0.145					**-0.058**	**0.028**				
Perceptions: Aesthetics - Cleanliness	0.001	0.814					**-0.100**	**0.000**				
Objective: Land Use			-0.009	0.291					**-0.148**	**0.000**		
Objective: Transit - Pedestrian			**0.030**	**0.000**					0.004	0.917		
Objective: Transit - Motorized			**0.019**	**0.007**					0.015	0.622		
Objective: Safety			**-0.024**	**0.002**					**0.176**	**0.000**		
Objective: Aesthetics - Trees			**0.007**	**0.003**					0.027	0.389		
Objective: Aesthetics - Cleanliness			**0.008**	**0.000**					**-0.099**	**0.001**		
Macro: Density					**-0.011**	**0.000**					**0.018**	**0.013**
Macro: Land Use					0.000	0.663					**0.000**	**0.017**
Macro: Street Network					-0.076	0.547					**1.122**	**0.019**
Pseudo R Square		**0.086**		**0.097**		**0.085**		**0.184**		**0.181**		**0.147**

Overall, the driving models had very low pseudo R squares, which is expected since this activity is not as closely associated with the environment as using rail transit.

In contrast, the rail models (Models 4, 5, and 6) had a much better fit. This was the result that was expected: the microscale environment is much more important for transit users than for drivers. This is because using transit involves extensive time walking to/from transit and waiting for transit, entailing significant contact with the environment (Iseki & Taylor, 2007; Litman, 2008). Interestingly, perceptions were much more significant than the objectively measured environment in predicting transit use, while the opposite was true for predicting driving trips. This might indicate that what people think is there for the environment has much more of an impact on rail use while the realities of driving trump perceptions of the driving environment. Perhaps it is harder to shape perceptions according to one's attitudes and behaviors when the realities of driving are applied (for instance, it is probably easier to forget or wrongly estimate how long a trip takes on a train, without the time constantly displayed as it is in a car. This is supported by findings in the transit research (Li, 2003)). It is interesting to note, however, that in both cases micro-level measures of the environment do have a substantial relationship with behavior, even though one would expect that macro-level measures would be more significant here, especially for driving trips. Overall, these models do serve to show that the environmental measures behaved as predicted, which seems to indicate that they measure what one would expect them to. This leads to the final analysis discussed in this paper: models of walking trips.

Models of Walking Trips

Models of total walking trips to and from home and home neighborhood (over seven days) were estimated using zero-inflated negative binomial regressions. Zero-inflated negative binomial models were found to be the appropriate type as the dependant variable was a count variable, and as tests indicated that this type of model would be more appropriate than Poisson or non-zero-inflated models: the Vuong test consistently showed high coefficients and significance, and the dispersion parameter α was also significant. The results of these models are shown in Table 18. A model was run for: (1) perceptual (survey) measures, (2) micro-level objective (audit) measures, and (3) macro measures and another set was run including the study area dummy variables (Models 4, 5 and 6, respectively). Finally, a model with both the survey and audit measures as well as study area dummies was run as well (Model 7).

Age and employment were not significant in any of the models. However, gender and number of vehicles were all significant in most models. As expected, walking was negatively associated with number of vehicles available, while women were more likely to walk. These results are different than expected: analysis of the National Household Transportation Survey (NHTP) showed that at the aggregate level, women and people with children in the home walk less than men and people without children (Livi Smith et al., 2007). This would seem to indicate that perhaps a good deal of walking was done for pleasure rather than for transportation: people with children would probably walk more for leisure than to get to particular destinations. These findings seem to coincide with the environmental features that were significant in predicting walking trips, as discussed below.

Table 18: Zero-Inflated Negative Binomial Models of Walk Trips (7 days)

	Model 1			Model 2			Model 3			Model 4			Model 5			Model 6			Model 7		
Independent Variables	**Coef.**	**Sig.**	**Mfx**	**Coef.**	**Sig.**	**Mfx**	**Coef.**	**Sig.**	**Mfx**	**Coef.**	**Sig.**	**Mfx**	**Coef.**	**Sig.**	**Mfx**	**Coef.**	**Sig.**	**Mfx**	**Coef.**	**Sig.**	**Mfx**
Constant	**1.73**	**0.00**		**1.90**	**0.00**		**2.75**	**0.00**		**1.43**	**0.00**		**1.95**	**0.00**		**2.21**	**0.00**		**1.52**	**0.00**	
Age	0.00	0.85	0.01	0.00	0.77	-0.01	0.00	0.51	-0.02	0.00	0.65	0.01	0.00	0.66	-0.01	0.00	0.65	-0.01	0.00	0.74	0.01
Gender	**0.35**	**0.01**	2.13	0.16	0.21	0.95	**0.22**	**0.10**	1.35	**0.31**	**0.02**	1.81	0.19	0.13	1.14	**0.21**	**0.10**	1.24	**0.31**	**0.02**	1.76
Chidren in the home?	0.02	0.85	0.15	0.07	0.58	0.42	-0.04	0.78	-0.23	0.13	0.31	0.79	0.08	0.53	0.49	0.03	0.81	0.19	0.16	0.23	0.92
Employment status	-0.04	0.80	-0.21	-0.08	0.55	-0.48	-0.13	0.33	-0.84	-0.01	0.94	-0.06	-0.08	0.55	-0.47	-0.07	0.58	-0.44	-0.05	0.71	-0.29
Number of vehicles	**-0.23**	**0.00**	-1.40	-0.12	0.12	-0.74	**-0.22**	**0.00**	-1.40	**-0.17**	**0.03**	-1.01	-0.13	0.11	-0.75	**-0.14**	**0.07**	-0.86	**-0.16**	**0.05**	-0.91
Perceptions: Land Use	**0.14**	**0.00**	0.87							**0.10**	**0.04**	0.59							**0.02**	**0.07**	0.10
Perceptions: Transit - Pedestrian	-0.02	0.62	-0.11							-0.04	0.32	-0.24							-0.09	0.12	-0.49
Perceptions: Transit - Motorized	**-0.03**	**0.04**	-0.19							**-0.08**	**0.06**	-0.46							**-0.09**	**0.03**	0.50
Perceptions: Safety	0.05	0.10	0.32							0.02	0.47	0.14							0.02	0.61	0.12
Perceptions: Aesthetics - Trees	**0.00**	**0.09**	0.03							**0.01**	**0.08**	0.06							**0.02**	**0.06**	0.12
Perceptions: Aesthetics - Cleanliness	0.01	0.78	0.05							0.01	0.72	0.06							0.08	0.77	0.43
Objective: Land Use				**0.09**	**0.02**	0.57							0.03	0.55	0.16				0.07	0.14	0.42
Objective: Transit - Pedestrian				**-0.05**	**0.02**	-0.31							**-0.09**	**0.08**	-0.55				**-0.04**	**0.04**	-0.22
Objective: Transit - Motorized				**0.04**	**0.03**	0.22							**0.08**	**0.05**	0.44				**-0.10**	**0.02**	-0.56
Objective: Safety				0.04	0.28	0.24							0.01	0.75	0.08				0.02	0.56	0.11
Objective: Aesthetics - Trees				0.05	0.13	0.33							0.02	0.65	0.11				0.00	0.92	0.02
Objective: Aesthetics - Cleanliness				**0.11**	**0.01**	0.65							**0.10**	**0.02**	0.57				**0.01**	**0.07**	0.06
Macro: Density							0.01	0.37	0.05							**0.02**	**0.10**	0.11			
Macro: Land Use							**0.00**	**0.00**	0.00							0.00	0.32	0.00			
Macro: Street Network							-0.58	0.33	-3.64							-0.05	0.96	-0.27			
Study Area: Bethesda										**0.57**	**0.02**	4.02	**0.51**	**0.08**	3.63	**0.79**	**0.00**	6.33	**0.59**	**0.06**	4.20
Study Area: Forest Glen										0.33	0.21	2.19	-0.14	0.55	-0.78	0.17	0.48	1.05	0.11	0.70	0.64
Study Area: Four Corners										-0.02	0.92	-0.12	-0.36	0.15	-1.95	0.06	0.80	0.34	-0.26	0.35	-1.37
Study Area: Layhill										-0.24	0.24	-1.31	-0.26	0.26	-1.43	-0.16	0.44	-0.92	-0.24	0.31	-1.30
Dispersion Parameter α	0.73	0.00		0.75	0.00		0.66	0.00		0.80	0.00		0.79	0.00		0.76	0.00		0.85	0.00	
Number of Observations	271			282			283			271			282			283			271		
LR c2 (var)	38.77			42.89			28.84			49.26			49.62			44.50			57.63		
Prob > c2	0.00			0.00			0.00			0.00			0.00			0.00			0.00		
Log likelihood	-575.03			-588.53			-595.56			-579.79			-585.17			-587.73			-555.60		
Vuong test	12.79	0.00		13.15	0.00		13.51	0.00		12.52	0.00		12.95	0.00		13.42	0.00		12.53	0.00	

Without the inclusion of the study area dummy variables, most environmental measures were significant in predicting walk trips. Three micro-level objective measures were positively associated with walking: land use, motorized street network and cleanliness. Land use was also positively associated with walking in the perceptual model (Model 1), as was the presence of tree cover. Motorized street network was negatively associated with walking in the perceptual model, and pedestrian network was negatively associated with walking in the objective model.

Interestingly, although land use was associated with walking from both perspectives, the two aesthetic measures were significant only from a single perspective. The significance of land use is not surprising, as this type of measure is included and significant in almost all measures of walking behavior in existing research (Lee and Vernez Moudon, 2006; Ewing et al., 2003) and the macro-level measure of land use was also significant and positively associated with walking in model 3. Land use was also significant for models of walk duration, as discussed earlier in this chapter. However, the significance of cleanliness from the objective angle and tree cover from the perceptual angle, as opposed to other measures, is somewhat surprising. Nonetheless, Hoehner et al. (2005) also found that aesthetic measures were significant for walking both for transportation and recreation.

The objective motorized network measure as well as the objective pedestrian network measure were both associated with walking behavior, but with opposing signs, which seems to indicate that a dense street network is positive for walking but presence of pedestrian infrastructure is not. This could mean that most walking done by the study participants was leisure rather than transportation oriented. This hypothesis is supported by the significant socio-demographic measures: women walked more than men, and people with children in the household were more likely to walk as well. The significance of other environmental measures also supports this: aesthetics, both cleanliness and tree cover, were positively associated with walking behavior. Aesthetics are a concern for walking much more for leisure walking than transportation based walking: when one has a choice where to spend leisure time, the attractiveness of the environment is much more important than for utilitarian uses.

Furthermore, the responses to the IPAQ questionnaire – for which reliability is admittedly probably lower than for the diary (Stopher et al., 2007) – also support this. In all study areas, participants reported walking more for leisure than for transportation: on average, respondents walked both more days and longer times for leisure than for transportation, as shown in Table 19.

Table 19: IPAQ Walking Averages

IPAQ Measures	Mean
Days Walked for Transport	2.36 days
Time for Transport (on those days)	27.67 min
Total Time Walked for Transport	71.75 min
Days Walked for Leisure	2.41 days
Time for Leisure (on those days)	39.18 min
Total Time Walked for Leisure	98.43 min

Finally, the negative association between walk trips and pedestrian infrastructure also remains consistent with the models of time spent walking discussed above. The results of these models of walk trips and time spent walking might indicate – in addition to the mostly leisure/health nature of walking behavior for residents – that there is a problem with the pedestrian infrastructure in

Montgomery County. Sidewalks in the County are mostly found along arterials. Most large arterials in the County do have good pedestrian infrastructure (complete and well-maintained sidewalks) but these are not sufficiently buffered from traffic. It is common to see sidewalks at the edge of the curb along six or more lane highways with freeway-driving speeds. Cars also commonly make right-hand turns on red lights, making crossing streets treacherous. This might explain, in part, why walking behavior is negatively associated with sidewalks: sidewalks may be located in such a way to feel very unsafe and unpleasant for pedestrians. As a consequence, the presence of sidewalks could be ironically associated with lack of safety and unpleasant walking conditions.

The following three models (Model 3, 4, and 5) also integrated the study area dummy variables. Unsurprisingly, Bethesda was very significantly and positively associated with walking compared to the base study area (Olney). Considering the very dense, mixed, and generally pedestrian friendly characteristics of Bethesda, this was expected. The other three study areas, Forest Glen, Four Corners, and Layhill, which are both less extreme and varied than Olney, were not significant in the models. The Bethesda study area was not just significant but also had the largest marginal effects, showing that the characteristics of that study area were very strongly and positively associated with walking trips. The objective and perceptual micro-level measures in these models (5 and 6) generally retained their significance and all retained their directionality, although the land use measure lost significance in model 5.

In the final model, Model 7, which includes both the audit and the survey, all the environmental measures remained significant and retained the same directionality. The presence and quality of sidewalks were again negatively associated with walking from the objective perspective in Model 7, as they were in models 5 and 2. However, the motorized transportation measure, which includes street network, was positively associated with walking when measured objectively but negatively associated with walking when measured perceptually, as it was in Models 4 and 1. This might mean that in this measure in particular, what people believe is present in the environment is quite different than what is actually there and that both are potentially related to behavioral choices. Measurement mismatch might also be at play here: although the indices were developed to be equivalent, they are not mirror-images of each other. Nonetheless, the significant positive correlation between the two measures, as discussed early in this chapter, would seem to indicate this is not the only factor at play.

Interestingly, the safety measure was not significantly associated with walking trips from either the perceptual or objective perspective. This might indicate that the presence or absence of sidewalks and the type of street network are more characteristic of the walking environment than actual presence and/or absence of safety features.

Another surprising result is that the land use measure, in the models controlling for the study areas (models 4 onward), was only significant from the perceptual angle: for the respondents of this study, what they thought was there in terms of land use was much more important than the reality. This might indicate the presence of a feedback loop in the relationship between perceptions and walking. Perhaps walking in the environment in the first place causes changes in the perceptions of the same.

Each aesthetics-related measure was also only significantly associated with walking from a single perspective: tree cover was significant as a perceptual (survey) measure and cleanliness as an objective (audit) measure. It was unexpected for these two measures to be significant from different angles: one would expect that if either are significant at all, they would both be significant from the same perspective. This would seem to indicate that although internalization of aesthetics features is very personal and varied, not all aesthetics measures are related to walking, and perhaps other behavior, in the same way.

Model 7, was compared to the others with the log likelihood test, which showed that model 7 had a significantly better fit than the previous models (Model 1, 2, 4 and 5). Although this test does not allow for direct comparison with the models with the macro level objective measures (Models 3 and 6), the significance of many of the micro-level measures in this final model indicate that it is better than those as well. This is as expected, and indicates that the micro-level measures – both objective and perceptual – do increase our understanding of the relationship between walking behavior and the built environment.

Overall, the regression model results showed a stronger relationship between the micro-level measures and walking behavior than between macro-level measures and the same, as shown through the coefficients as well as the marginal effects of each significant measure. This emphasizes the importance of the micro-level environment on pedestrians, as they experience the built environment in scale with their relatively slow walking speed. As other studies in this field have often underlined (Handy et al., 2002; Hansen, 2006), the dearth of micro-scale data is an ongoing issue which limits the extent to which environment can be linked to behavior. These results show that micro-level data are in fact a goal worth reaching for, even with the difficulties involved in collecting them.

Furthermore, both perceptually and objectively measured micro-level environment were significant in predicting walking behavior, but different environmental factors were significant from each perspective. This indicates that while both are important to include, they are in fact distinct measures that assess separate factors, because the way people perceive the environment can be at odds with what is actually present in the environment. This clearly follows from the results discussed in earlier in the chapter: while the environment is built of parts which tend to appear in tandem, which means that measures in reality tend to be highly related to each other, people see the environment as much more holistic but also perhaps less organized. This being the case, it has serious consequences in terms of policy: to intervene in ways that will impact *behavior*, it might not be enough to measure the environment, or to change said environment. Instead, perceptions should also be taken into consideration both in measuring the environment and in elaborating interventions in order to more effectively influence behavior. These questions are discussed in the following chapter.

Chapter 6: Policy Implications & Conclusions

Perceptions are becoming more of a focus of research both from the public health and transportation fields (Kitamura et a;, 1997; Giles-Corti & Donovan, 2002), and as researchers question the relationship between the environment and walking behavior (Vernez Moudon et al., 2006; Handy et al., 2002), perceptions are showing their importance (Humpel et al., 2004; Troped et al., 2001; Leslie et al., 2005; McGinn et al., 2007). The research presented here was undertaken to deepen the understanding of the contribution of perceptions on the relationship between the environment and walking behavior, in the hopes of aiding future researchers and practitioners in elaborating better targeted studies and interventions. The analysis completed for this dissertation has responded to all three hypotheses set out in the introduction, as discussed below.

Hypothesis I: Perceptions and objective environment are not the same.

This hypothesis was the least debatable of the three. Established psychological research has for more than a century discussed the complex ways in which people internalize their environments, resulting in changed, warped and otherwise transformed perceptions (Ittelson, 1973; Kaplan, 1978; Nasar, 1999, for example). It is beyond the scope of this paper to further illuminate the processes in which people encounter their environments. Rather, the analysis presented here confirmed that indeed, when measuring specific aspects of the built environment, people's perceptions are significantly different than what is actually there when measured by objective means.

Further, the degree to which the perceptions are different than reality differs depending on the aspect of the environment being measured. In particular, the analysis shows that perceptions of more "neutral" aspects of the environment, such as land use and to a lesser extent transportation infrastructure (both for pedestrians and motorized travel) are relatively similar to objective assessments of the environment, as is evidenced by high and significant degrees of correlation. On the other hand, other aspects of the environment for which perceptions are less separate from emotion and experience, such as safety and aesthetics, are very different when measured through perceptions than measured objectively. For those features, correlations between objective assessment and perceptions are very low and generally not significant.

These results are further confirmed in the models of perceptions. These models show that the environment together with socio-demographic measures of the participants are for some aspects of the environment a good fit to predict perceptions (especially for land use) while for others the environment is not significant nor is the fit very good (safety and aesthetics, for example). Although these results are not surprising or a new discovery, it is important to establish the difference between perceptions and objective assessment of the environment before discussing the other two hypotheses.

Hypothesis II: The relationship between perceptions and the environment will vary depending on the feature and scale.

This hypothesis is important as it further explores the consequences of differences between perceptions and objective assessment of the environment. Indeed, if they are different – which the results of this study strongly suggest – then this has consequences in more than just the separate aspects of the environment. When the various parts of the environment are measured perceptually, do these keep the same relationships with each other as when they are measured objectively? It was hypothesized that there would be differences between these relationships.

Results from this study suggest that in fact the relationships among the features of the environment are different for perceptions than for objective measures of the environment. Disparate aspects of the environment, when measured objectively, tend to be highly correlated with each other. Even at a very small buffer size (1/8 mile), which reduces homogeneity of the environment, almost all aspects of the environment are significantly correlated with each other. In contrast, when measured perceptually, the same measures of the environment are generally not significantly correlated.

These results have interesting implications. They seem to indicate that people see the environment as much more diffuse than it actually is: where features are very likely to appear together in reality, people do not see them as interrelated. Although the environment, objectively, forms a coherent whole, this is not the case when the environment is perceived. If walking behavior is more closely linked to perceptions than the realities of the environment, this might indicate that targeted interventions that only tackle one aspect of the environment could be successful even though the overall environment would mostly remain unchanged. On the other hand, this also indicates that people might sometimes be more influenced by education about the environment than direct changes of the environment itself: teaching them to better "see" the environment as a whole might, by itself, improve their outlook.

Hypothesis III: Perceptions as well as objective assessment of the environment both are important in determining walking behavior.

This final hypothesis is the one with most far-reaching consequences for planners and public-health professionals. Borne out, this hypothesis would indicate that to more fully and effectively assess the walking environment, both objective and perceptual assessment are necessary. The analyses in this paper suggest that indeed perceptions as well as objective assessment of the environment are significant *in different ways* in predicting walking behavior. While features of the environment – both objectively and perceptually measured – are generally not significant in predicting amount of time spent walking, they are significant in predicting number of walking trips taken.

Further, some environmental features are only significant as measured through perceptions, while others are only significant when measured objectively. For instance, presence of tree cover is only significant perceptually and cleanliness only significant objectively. As a result, it seems that to fully understand the relationship between the environment and walking, it is necessary to assess each environmental feature separately: some objectively, and others through perceptions. This is complicated by the fact that one measure is significant in predicting walking trips but with different signs from the objective (positive) and perceptual (negative) sides. This indicates that for some aspects of the environment, perceptions and objective assessment could be different enough that they both have a significant relationship with walking, but in opposing ways.

However, the results of the analyses make it clear that both the audit and the survey micro-level measures are better at capturing the aspects of the environment relevant for walking than the macro-level measures. Taken together, the objective and perceptual measures tell us much more about the relationship between walking behavior and the environment.

Policy & Methodological Implications

The results garnered in this study indicate that to assess the environment in a way that more fully and effectively predicts walking behavior, one has to gather both perceptions of the environment and objective measures of the same. The environment seems to be related to walking both directly, as assessed objectively, and indirectly, through perceptions. In particular, different parts of the environment are more strongly related to behavior when measured through perceptions or objectively. The lacunas in existing literature, showing a weak and mixed relationship between the environment and walking behavior (Crane and Crepeau, 1998; Cervero and Kockleman, 1997; Cervero, 2002), have in part been blamed on problems related to data collections. A number of authors have deplored these data limitations (Badoe and Miller, 2000; Handy, 1996; Crane, 2000). The results of this study support these previous findings: that many studies are not capturing the full relationship between the environment and walking behavior in part because their measures of the environment are not sufficient. Therefore, the findings of this study are relevant for both fields: instead of their focus on a single method of assessing the environment, they would both benefit from collecting and analyzing objective and perceptual data.

Although this study points to richer ways to assess the relationship between environment and walking, there are still some implementation issues to consider. This type of study entails an enormous effort in data collection, including a significant and prohibitive time, financial and administrative burden. For these reasons, it seems very unlikely that researchers and practitioners will engage in the full assessment of the environment as was done here. This is to be expected, and in fact is probably preferable as the burden incurred by researchers wanting to do what was done for this study would probably prohibit all but very few in doing so.

Instead, the usefulness of this study for researchers and practitioners alike is more in determining which features of the environment are best measured through which means, and if those means are not available, to understand the potential limitations incurred. This is important to more effectively design interventions in the environment. Indeed, as shown in this study, it is likely that actual cleanliness measures rather than perceptions of the same are more important in shaping walking behavior. In that case, an objective audit and remediation of problems found therein would be effective. However, for tree cover, it seems that perceptions are significant while actual presence of trees is not. In that case, the results of a survey or interviews should be used for proper interventions. If the changes are only based on an objective assessment of the environment, they might not change walking behavior, as the link between perceptions and reality here are particularly tenuous (as demonstrated by the low reliability of such a measure, even after training, discussed in Clifton et al., 2007). Instead, it might be that education alone, or perhaps some other intervention, would be more effective.

By using the results of this study, practitioners will be able to better target their data collection and as a result have a clearer understanding not only of the problems present in the environment but also which interventions will be more likely to improve walkability and increase walking behavior.

To take this argument further, this study underlines the disconnection between planners and laypeople as well as between measurement of the environment and walking behavior. There is an assumption that people can naturally read and understand the environment in which they live, and that they can communicate this understanding through a common language. However, the results discussed here as well as in other literature (Lynch, 1960; Ewing et al., 2006) clearly counter that assumption. Instead, laypeople think of their environment in terms of prior experience and the assumptions that result from them (Kameron, 1973). This entails that they might see the environment differently depending, for instance, on the positive or negative associations of destinations (Herman et al., 1995). This is done subconsciously, and people often do not even realize it, let alone put it into words. Planners, on the other hand, have been trained to see the environment as a series of interdependent features that change in tandem, in a generally rational way divorced from preconceptions of the user. For instance, any so-called objective assessment of the environment depends on the reliability of the measures or in other words the fact that different people will see the same thing (e.g.: Clifton et al, 2007; Pikora et al., 2002). Furthermore, they have the vocabulary to describe and discuss features with others, as developed in their education.

In other words, results discussed here emphasize that laypeople and planners are not on the same page when talking about the environment. This is problematic in many ways. It can entail difficulty in simply getting projects off the ground: how does a planner convince residents that an intervention is needed when the audience will not fully understand the words and will not be convinced that the environment exists the way the planner sees it? It can also entail disappointing results: if the residents cannot fully explain what is problematic in their environment, perhaps the interventions will fail to address their concerns. Overall, this study emphasizes at the very least the need for planners to be more aware of the level of "environment literacy" laypeople have, and to tailor their process and projects accordingly. It also suggests the usefulness of training for laypeople, both in better seeing their environment and in knowing the right words in expressing it, so as to encourage more effective planning.

In practice, this might entail including a short education session at the beginning of public meetings and charettes discussing upcoming projects. In a sense, it would be like explaining terms in any technical document: it is taken for granted in the sciences that there should be a definition of terms, a glossary, etc., yet it is (wrongly) assumed that people are familiar with planning and design terms. By making sure everyone knows what is being discussed as well as the terms used, much more clarity could be reached with the audience, while giving them the sense that their input is valued. Furthermore, it would give them knowledge not just for that project but also for everyday life and future changes to their environment. A small change like this one, entailing perhaps five minutes and a dozen slides in a public meeting, could have outsize impacts on the degree of familiarity laypeople have with their environment as it is parsed by planners.

As for the uses for researchers, this study along with many others indicates that a great deal more research is needed to understand the link between the environment and walking behavior (Handy et al., 2002; Bauman et al., 2002; Ewing et al., 2003). The relationship between walking and the built environment, and in particular perceptions of the environment, is still relatively tenuous in this study as in others (Humpel et al., 2004; Hoehner et al., 2005; McGinn et al., 2007). This study emphasizes the difficulty in quantitatively analyzing these relationships and in operationalizing environmental variables. A great deal more analysis needs to take place for the relationship between environment and behavior to be better understood, and this should include the assessment of perceptions.

This study also points to the need to be careful while striving for more operationalized, standardized data. As previous studies have shown (Handy et al., 2002; Ewing et al., 2006), a stricter definition and measure of environmental features to be analyzed can lead to new problems. More and more, the environment as measured by transportation researchers is parsed in ways that has little if any relation to perceptions. Instead, either macro-level measures or very specialized micro measures are often used (as discussed in Handy, 1996). It seems very unlikely, both from a common-sense standpoint and from the research of environmental psychologists (Nasar, 1999; Proshansky et al., 1976, Rapoport, 1990), that people can accurately describe the employment density of an area, or the presence of curb cuts, for example. Although rational, quantitative analysis of the environment is crucially important, there does seem to be a risk of ignoring other factors, like perceptions. Of course, perceptions and other socio-psychological characteristics are much harder to measure, and are sometimes even hard to clearly define. However, this study, as well as a few others (Hoehner et al., 2005; Saelens et al., 2002) indicates that perceptions are important in understanding the relationship between the environment and walking. Again, this underlines the need to keep laypeople involved in research, and perhaps to educate them about their environment.

This study supports the need to measure the environment objectively in ways that are more closely comparable to perceptions. This would aid in more completely assessing for which environmental features perceptions might be more or less important than the objectively measured environment in terms of behavior. In this study, the environmental measures with equivalents from both points of view were limited, but this need not be the case in future studies. By more effectively comparing the influence of more numerous environmental features, both perceived and objectively measured, the influence of the environment on walking would be better understood.

Limitations & Future Work

Sample & Response Rate

Responses to this study were stymied by endemic as well as site-specific issues. As mentioned in Chapter 2, responses were limited by the burden of this study (which involved a 60-90 minute in person interview, being weighed and measured, as well as keeping the diary and wearing an accelerometer for one week). A number of respondents who declined to participate mentioned the time burden as their reason not to participate. Further, the Washington, DC metropolitan area, of which Montgomery County is part of, is characterized by the high transience of its population. Residents are therefore less likely to feel a sense of community and ownership in the neighborhood, resulting in a reduced desire to participate. Montgomery County is also a wealthy county, and the small incentive was not sufficient for people who would lose much more than that sum by giving an hour of their time. Finally, employed residents tend to have very long commute times, and this also reduced the number of participants. The difficulties in attracting participants meant that every qualified participant was used. As a result, women and older respondents were over-sampled.

Survey & Audit Issues

The main issue that had to be contended within this research was the limitations of the dataset available. Although the project for which data were collected (*Pedestrian Activity and the Built Environment*, Rodriguez, PI) used tested instruments which have proven their worth elsewhere, they were not ideally suited for the kind of analysis done here. In particular, the NEWS survey questions did not line up well with information garnered from the audit or secondary archival GIS data. Many questions did not directly ask about environmental features that are measurable from an objective standpoint or did so in vague, double-barreled or otherwise flawed ways. This lack of equivalence between the objective and perceptual data available severely reduced the measures useable for the analysis: only questions which did have a direct corollary were used to allow for comparison between objective and perceptual measures.

The limitations caused by the data available for this study do, however, clearly point to numerous specific improvements in the questionnaire design that could greatly enhance future studies. These potential improvements are discussed below.

Measurement and Statistical Issues

Although every effort was made to build the environmental indices to be as comprehensive as possible and as closely equivalent as possible between objective and perceptual measurement, there are potential measurement issues that could still be at play. First, because of the limitation of the data from both the objective and perceptual angles, a great deal of available data could not be used, as discussed in Chapter 4. This, coupled with the grouping of data into indices, intrinsically limits the scope of the indices themselves. Far from being a comprehensive assessment of the environment, they reduce the environment to measurable parts that do not fully represent the whole. This is unavoidable in any research, but does have some consequences. Therefore, it is important to note that the data used here were not comprehensive but rather focused on specific features of the environment theorized to be related to walking behavior.

Furthermore, the limitations in the data also entail a potential mismatch between objective and perceptual measurement, limiting the value of comparing them. The measures in both perspectives were chosen to be equivalent, but they generally did not use the same scales or the exact same wording. For instance, measuring the presence of sidewalks objectively (binary) and using a Likert scale assessment “there are sidewalks on many streets in my neighborhood” is not exactly the same thing. Allowances for this were made in the interpretation of correlation between the indices and these issues were reduced (at least in terms of differences in measurement unit) by normalizing data. On a pragmatic level, this kind of mismatch is unavoidable because of data limitations, although perhaps this could be palliated in a future study.

Again, because of limited data, not all possible measures were included in the models. The choice of measures generally followed those used in other studies (Reviewed in Crane, 2000 and Badland and Schofield, 2005, for instance) but did omit measures that could potentially have an impact on the models, such as measures of security. Measures left out from the models were all seriously considered, before being left out for theoretical reasons (measures that have not consistently been associated with walking) and/or for practical reasons. It should be noted that although omitted variable bias could be a problem, it is by no means guaranteed that it is so. For instance, there is evidence that including more measures, in addition to being counterproductive and sometimes impossible, could have adverse or unexpected effects (Clarke, 2005).

Self Selection & Feedback Effects

The issue of self-selection is problematic in this study as in all other correlational studies. It is possible that people select their residential neighborhoods consciously in order to engage in walking behavior – or not. If that is the case, then the environment is not directly related to behavior: instead, it is the residential choice that is directly related to behavior (Handy, 1996). The issue of self-selection can be addressed in a few ways. First, through temporal studies which look at residential choice and activity through time. This is not a reachable goal in this cross-sectional study.

The second way to address self-selection is by asking respondents about attitudes towards the environment and questions regarding the choice to move to their current location. However, these palliative measures are both problematic. First, it is difficult to assess the importance of the walking environment in choosing to move to a particular location, especially since other features might be much more limiting. For instance, the walking environment might seem important, but much less so than school quality for a family with young children. Similarly, housing costs are likely to be a limiting factor for many. As a result, although the walking environment might be a factor, its importance might be obscured by other factors. This is exacerbated by the scaling used for questions regarding residential choice: for usability purposes, responses are often 5 point Likert scales. This kind of response is insufficient when questions might range from ability to take a leisure walk and safety from crime: of course, safety will rate much higher. This is even more muddied because of the link between various measures of the environment: the ability to walk for pleasure is in part dependent on safety from crime. Furthermore, it is unclear whether the self-selection issue is static, or whether over time residents adapt to their environment and ascribe their new perceptions to original choice. For instance, if someone chose their residence twenty years in the past primarily to be close to work, but has been enjoying walking in the neighborhood for the past twenty years, they might think they originally chose the neighborhood in part for ease of walking.

As a result of all these theoretical and methodological issues, self-selection remains a very problematic hurdle to be addressed. However, doing so seems beyond the capacity of many studies, including this one: it would require a great deal of time and open ended yet targeted questions to begin to understand how self-selection impacts environment and behavior research.

As one of the issues regarding self-selection illustrates, perceptions are also not static but rather evolve over time. It is very likely that a feedback loop eventually takes place within the environment. Although the environment is much slower to change than perceptions, it is over time impacted by its users. As a result, it would seem logical that if a high enough density of people with positive perceptions of the environment living in an area would be more active in that area and, over time, would encourage the improvement of it both through use (resulting in higher activity, lower crime, higher cleanliness/maintenance) and through future investment (new infrastructure, beautification, destinations etc. because of higher perceived need and/or benefits). It is unclear, however, how the feedback loop would function in areas with people with negative perceptions of the environment. It seems likely that there would be lower activity, higher crime, more "broken windows" and all they entail. However, this could also, in the long term, trigger interventions to improve the infrastructure as well. Either way, the feedback loops between behavior, perceptions and environment are probably taking place, and they further complicate the relationship between the three factors. It is difficult to conceptualize how research could tackle this directly and untangle these relationships effectively. Although the theoretical relationships can be hypothesized, studies aimed at testing them remain in the future.

Future Research

There is much left to learn regarding the relationship between the built environment and walking behavior, in particular as they both relate to perceptions. The limitations of this study point to a few avenues of future research that would start to palliate the issues and problems found in this study.

The first improvement to this field of research would be the development and use of a survey better targeted to people's perceptions of the environment. This survey questionnaire would be aimed at operationalizing and measuring specific aspects of the environment rather than asking about many measures together or measuring features that have no equivalent when measured objectively. Unlike measures such as those developed by Ewing et al. (2005), these would directly measure concrete environmental features. This would be done for specific buffers around the home instead of the "in your neighborhood" definition used in this study. For instance, instead of asking "most of the streets in your neighborhood have sidewalks", it would be "if you walk two blocks from your home, do those streets have sidewalks". Furthermore, terms would have to be defined first to make sure respondents know what they're being asked about. For instance, there could be an explanation (with visuals) of what a 3 or 4 way intersection is, in contrast to a cul-de-sac, or a picture of curb cuts, or the use of maps of the study area to give the respondent a visual marker for answering.

With a clearer idea of which locations the respondents are measuring, it is likely that better data would be collected. From the problems encountered in this study, it seems likely that the best way to develop such a survey would be to first choose aspects of the environment of importance, next to develop the questionnaire through qualitative interviews of various laypeople and finally to implement the resulting survey.

The data collected regarding walking were also imperfect, although improving this would be challenging. For instance, the IPAQ questionnaire does not ask where the walking takes place. As a result, walking that was not undertaken in the study area is included. The diary yielded more useable results, but participants mentioned how burdensome it was to complete it. The poor quality of the travel time measure (as opposed to number of trips) would indicate that the diary could perhaps be improved by simplifying it. For instance, an improvement that could be made in the future would be to use a simplified diary that would only ask about walking, instead of all modes. Perhaps a more visual means could also be used instead, such as the use of maps. Another improvement would be to replace the IPAQ with a more simplified questionnaire focusing on walking instead of detailed questions about multiple types of physical activity.

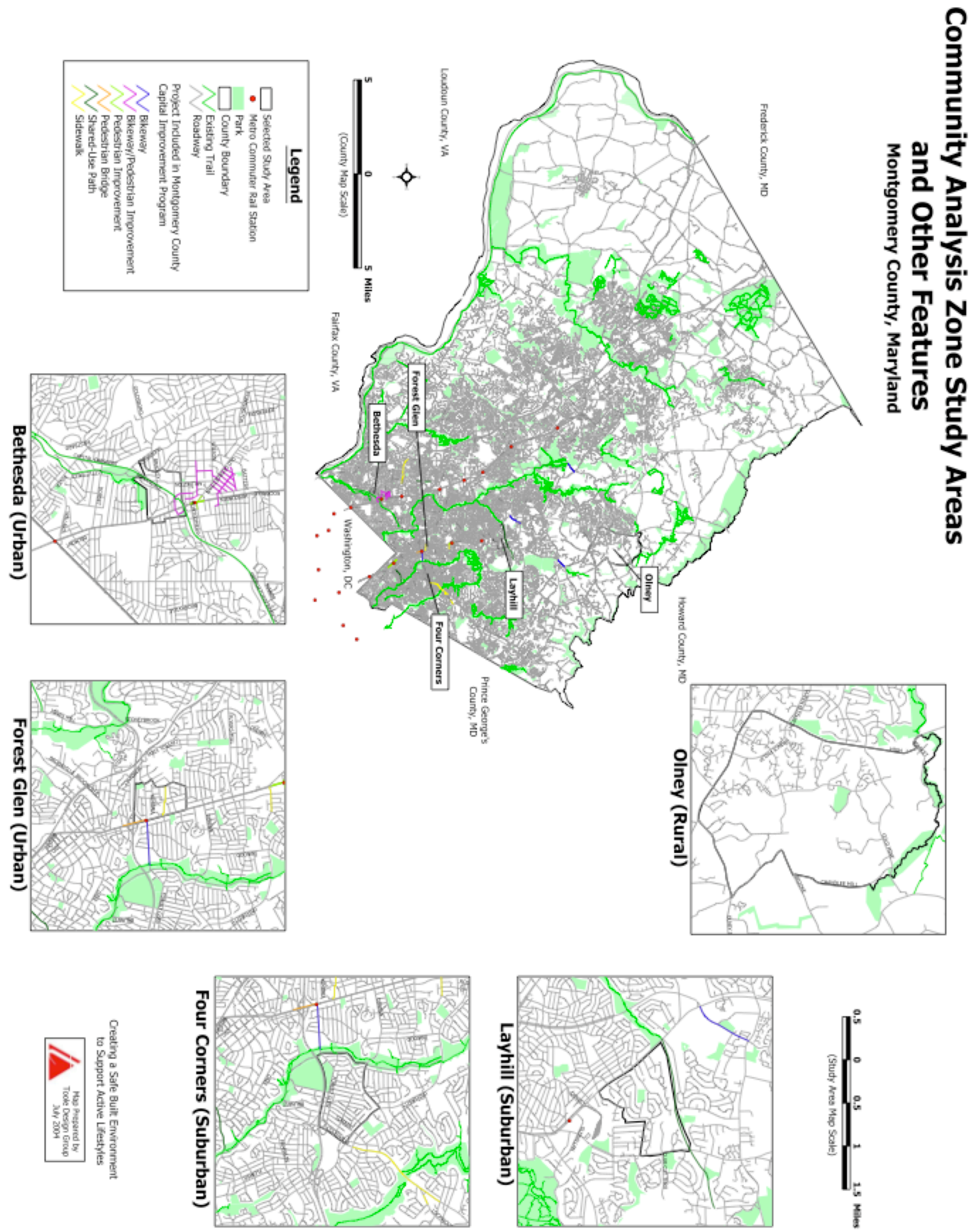
Furthermore, because this study was part of a larger research project, respondents were asked a great deal of information. It would be helpful in the future to cull the questionnaire to a more manageable length. By having a more targeted and smaller-scale goal in a future study, not only could more participants be obtained but the analysis itself would also be less daunting. The sheer amount of data that had to be managed, cleaned, and assessed here made analysis difficult: deciding what to include or not was a tedious and complex process. Furthermore, this inevitably leads to decreased data quality. At the end of an hour-long interview, respondents naturally loose interest and concentration. Likewise, remembering every detail of a trip is difficult and probably leads to some incorrect information. In the future, by simplifying the data collected and making the decisions on the front end rather than the back end, analysis could both be better targeted and easier to complete.

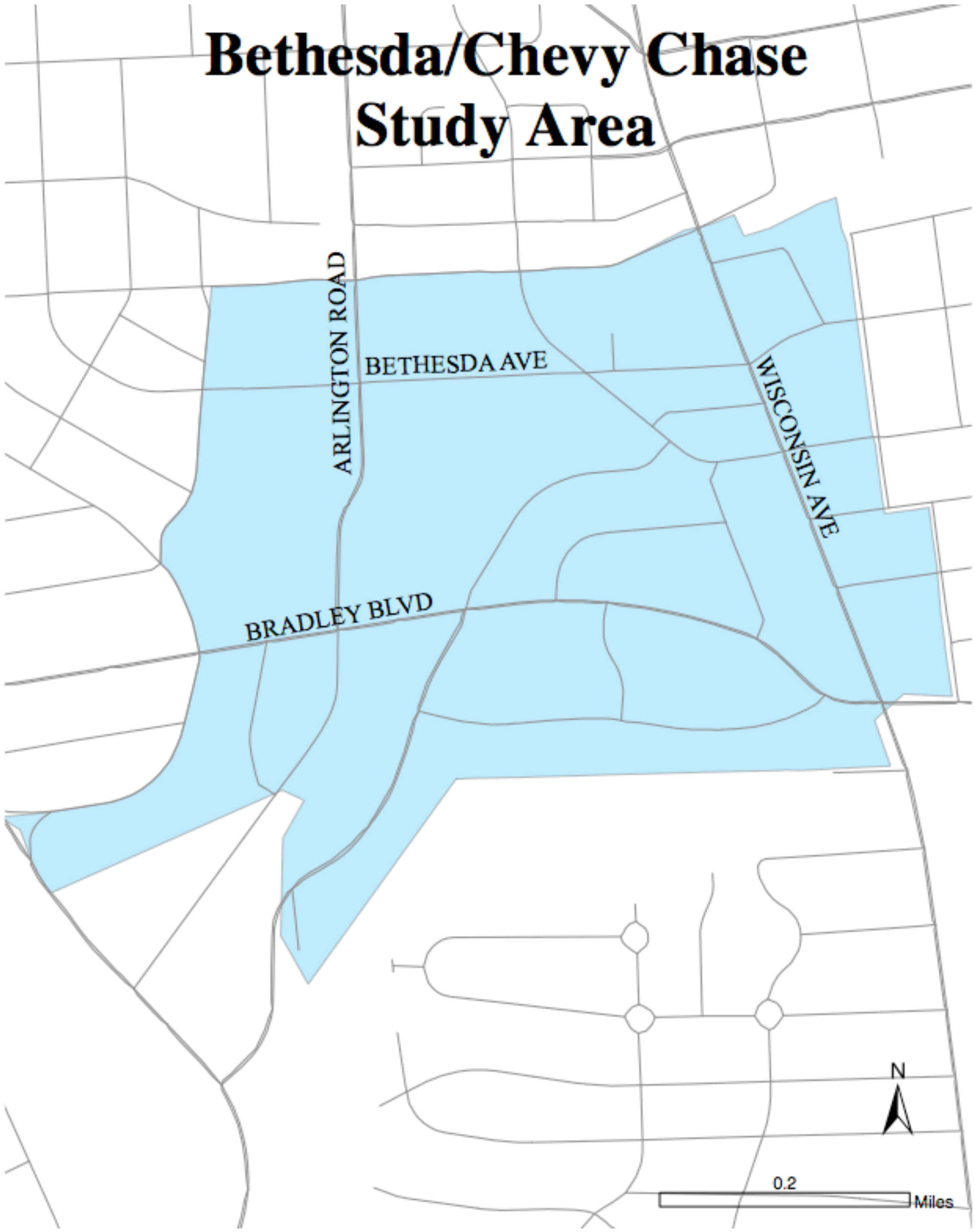
Targeting of measures could also be supported by asking specific people about items that directly relate to their lifestyle. For instance, most people don't pay close attention to curb cuts or the difference between brick sidewalks and concrete sidewalks (in terms of walking surface, not aesthetics), because they don't directly affect them. However, parents with young children, and physically disabled people as well as their family members, are much more likely to find these features important. While the environment is perceived differently by different groups of people, these are currently not differentiated in the data collecting process. Perhaps by targeting specific questions to specific groups, the process could be streamlined while providing more in-depth information for specific walkability issues.

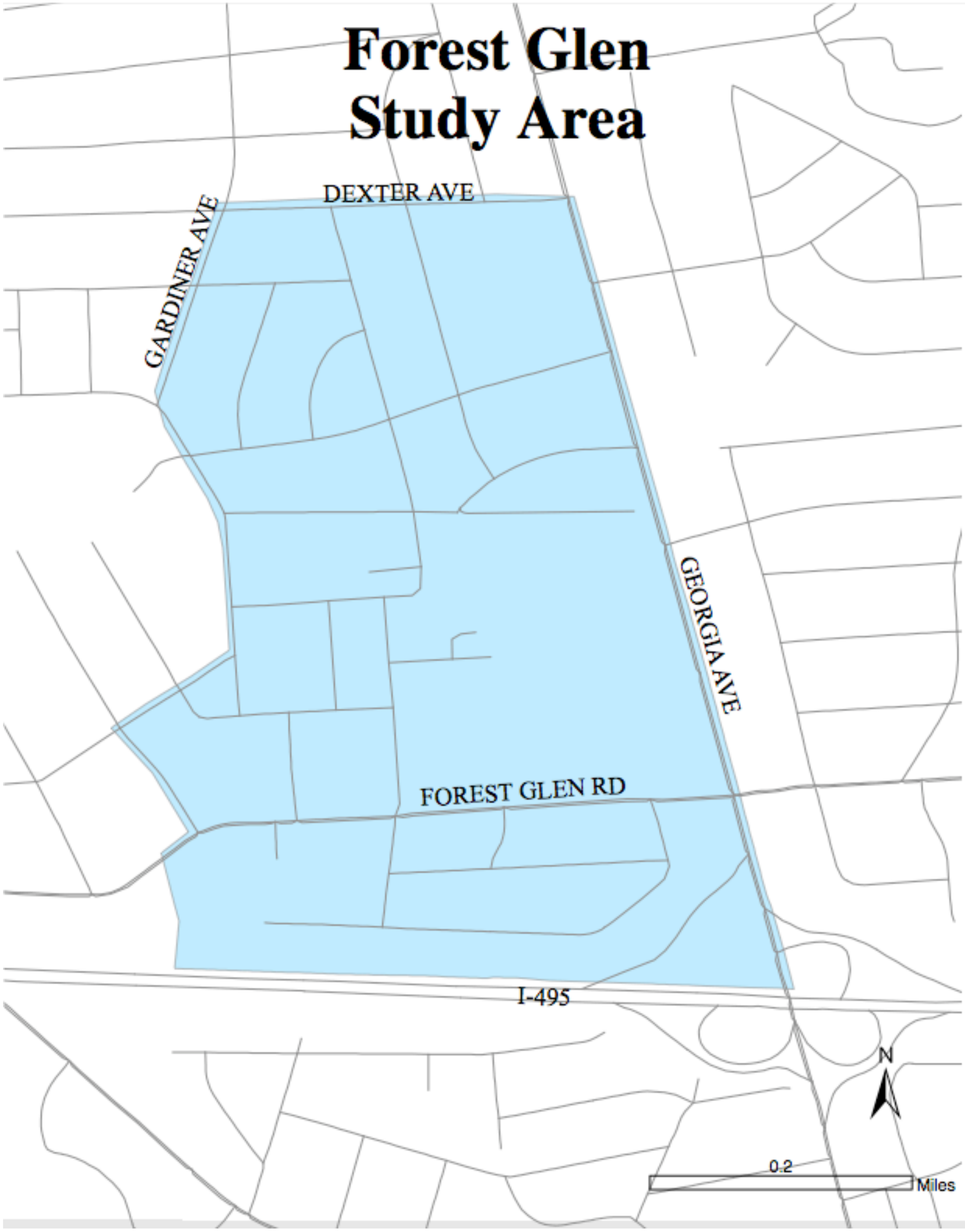
This points to a potential shift to improve future research: travel behavior and public health studies currently are still fundamentally interested in overall transportation and physical activity outcomes (TRB IOM, 2005; Handy, 2005). This means that captured data generally include all of these varied and complex behaviors. For instance, in this study, respondents were asked about use of gyms, amount of physical activity associated with their employment, etc. This "more is more" philosophy is perhaps not as effective as one would like. By asking about all these behaviors, and being redundant about many of them, there are a few fundamental downsides. These include burdening the respondent, which leads to fatigue, and also to asking questions that are better targeted for transportation or physical activity overall rather than walking in particular. Effective interdisciplinarity might better be served by targeting walking instead of trying to effectively measure all types of physical activity and/or transportation.

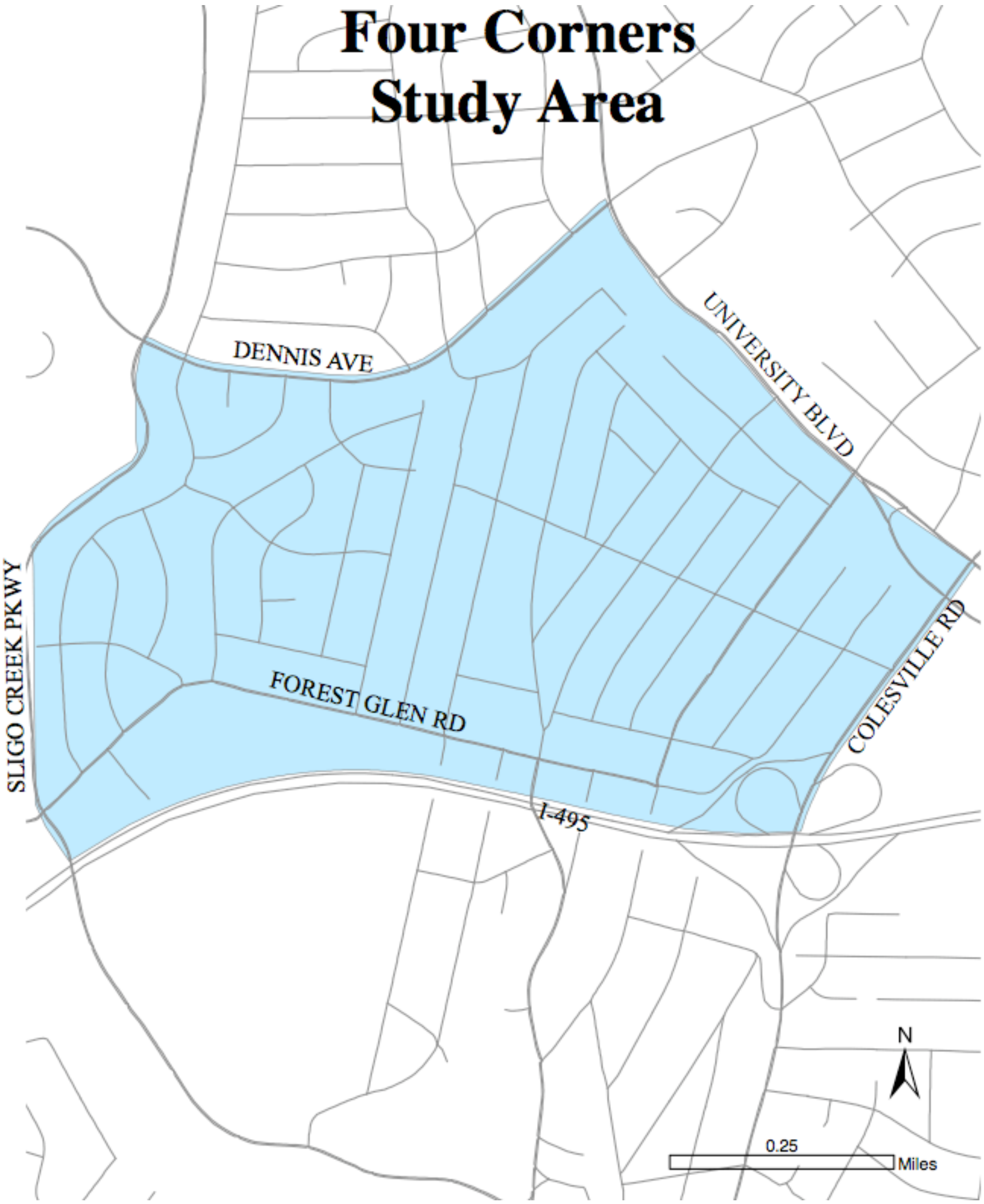
Parallel to this improvement of the survey questionnaire and diary, the audit could also be improved for future studies. In particular, the audit had many questions that were not used here. These unused measures required a great deal of time to collect. A streamlining of the audit so that only usable – and relevant - measures are collected would be helpful. For instance, the presence of trashcans and other amenities, such as street vendors, might be unnecessary to capture. Furthermore, a sampling scheme would significantly reduce the administrative burden while still capturing variation of the environment. The testing of multiple sampling schemes in order to find the most effective and efficient one is currently underway as of this writing, led by Dr. Clifton of the University of Maryland.

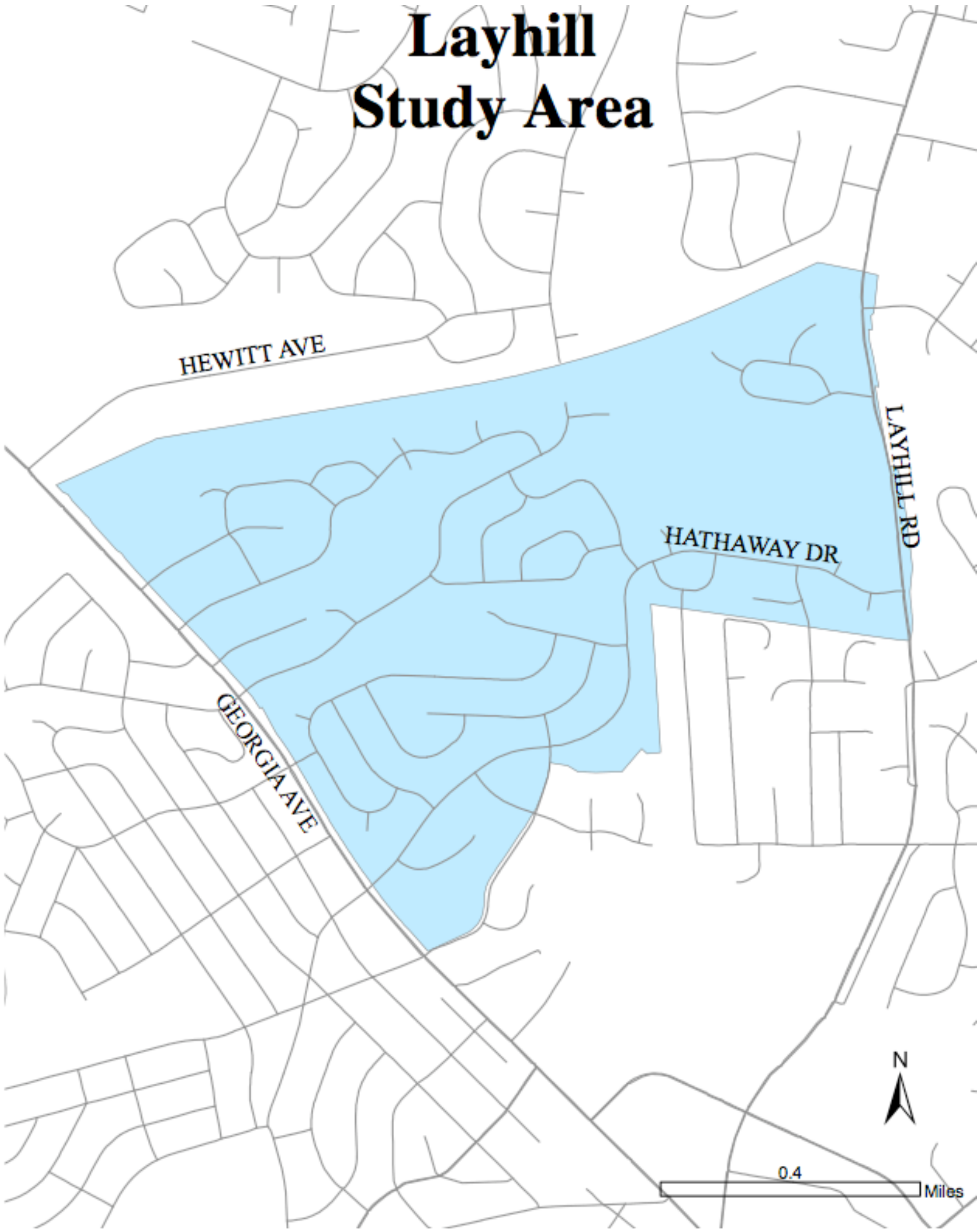
Appendix A: Study Area Maps

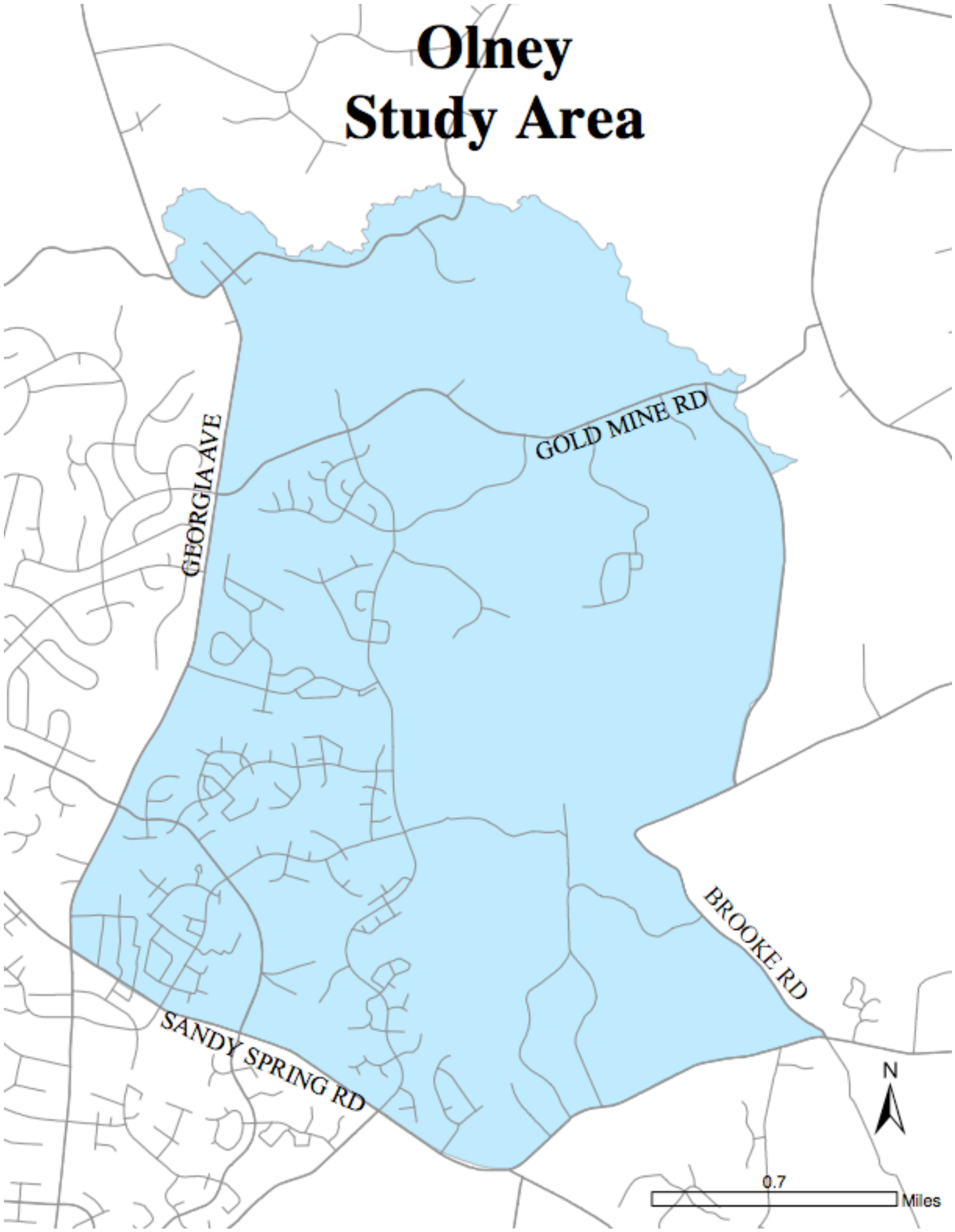



Bethesda/Chevy Chase
Study Area
ARLINGTON ROAD
BETHESDA AVE
WISCONSIN AVE
BRADLEY BLVD
N
0.2
Miles


Forest Glen
Study Area
DEXTER AVE
GARDINER AVE
GEORGIA AVE
FOREST GLEN RD
I-495
N
0.2
Miles


Four Corners
Study Area
DENNIS AVE
UNIVERSITY BLVD
SLIGO CREEK PKWY
FOREST GLEN RD
COLESVILLE RD
I-495
N
0.25
Miles


Layhill
Study Area
HEWITT AVE
LAYHILL RD
HATHAWAY DR
GEORGIA AVE
N
0.4
Miles


Olney
Study Area
GEORGIA AVE
GOLD MINE RD
BROOKE RD
SANDY SPRING RD
N
0.7
Miles

Appendix B: Recruitment Materials

UNIVERSITY OF MARYLAND

Your neighborhood

has been selected for a groundbreaking study on physical activity and design. As a resident, you are invited to participate.

Participation includes:
* Completing a questionnaire in-person
* Wearing a small physical activity monitor on your hip for 7 days
* Keeping a record of your daily travels

You will receive $40 for your participation in this study

Please call 301-405-8971 or email pabe@umd.edu today to sign up!

This study is being conducted at the University of Maryland at College Park

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UNIVERSITY OF MARYLAND

The National Center for Smart
Growth Research and Education
Suite 1112K Prinkert Fieldhouse
College Park, Maryland 20742

Want to learn more about this study? Please visit:
http://www.smartgrowth.umd.edu/pabe.htm

HOW DO YOU GET AROUND?

YOUR NEIGHBORHOOD HAS BEEN SELECTED AS PART OF A NATIONALLY-FUNDED STUDY

UNIVERSITY OF MARYLAND 1856

The National Center for Smart Growth wants to find out more about physical activity in your neighborhood.

WE NEED YOUR HELP!

WHAT'S INVOLVED?

Participants will be interviewed in person, will wear a pager-sized unit on their waist, and will fill out a week-long travel diary.

Participants will be paid $40.

HOW TO FIND OUT MORE?

www.smartgrowth.umd.edu/pabe

Or call or email us anytime!

Tel: 301 405 8971

Email: pabe @umd.edu

To: [organization name]
[organization address 1]
[organization address 2]

Dear [organization],

I am writing on behalf of the National Center for Smart Growth, Research and Education at the University of Maryland. Dr. Kelly Clifton and a team of researchers from the University of Maryland and the University of North Carolina are currently conducting a study to determine how the urban built environment influences the amount and types of physical activity people engage in. The study is located in Montgomery County, Maryland and we are currently working towards involving a total of 400 participants.

Your [organization] is located in (or close to) one of our study areas. We would like to ask you to tell your members about our study. Participation in the study involves (1) completing an in-person survey, where the respondent will be weighed and measured and (2) wearing a pager-sized activity monitor and completing a simple travel diary for seven days. Respondents will be paid $40 for participating. Information gathered during the study will be kept strictly confidential.

I have attached a map of our study area and a "Frequently Asked Questions" sheet. Additional information about our study is available on our website, http://smartgrowth.umd.edu/pabe.htm. Please also feel free to contact me at alivi@ursp.umd.edu or Dr. Clifton at kclifton@umd.edu with any questions.

I would like to thank you for considering our request, and we appreciate any help you can give us.

Respectfully,

Andréa D. Livi
PhD Candidate
Urban Studies and Planning Program
University of Maryland

Appendix C: Audit Instrument

Name: ______________________ Date: ________________ Study Area: ______________ PEDS

Segment Number: ____________ Time: ________________ Weather: ______________

0. Segment type
- Low volume road 1
- High volume road 2
- Bike or Ped path - skip section C 3

A. Environment

1. Uses in Segment *(all that apply)*
- Housing - Single Family Detached 1
- Housing - Multi-Family 2
- Housing - Mobile Homes 3
- Office/Institutional 4
- Restaurant/Café/Commercial 5
- Industrial 6
- Vacant/Undeveloped 7
- Recreation 8

2. Slope
- Flat 1
- Slight hill 2
- Steep hill 3

3. Segment Intersections
- Segment has 3 way intersection 1
- Segment has 4 way intersection 2
- Segment has other intersection 3
- Segment deadends but path continues 4
- Segment deadends 5
- Segment has no intersections 6

B. Pedestrian Facility *(skip if none present)*

4. Type(s) of pedestrian facility *(all that apply)*
- Footpath (worn dirt path) 1
- Paved Trail 2
- Sidewalk 3
- Pedestrian Street (closed to cars) 4

The rest of the questions in section B refer to the best pedestrian facility selected above.

5. Path material *(all that apply)*
- Asphalt 1
- Concrete 2
- Paving Bricks or Flat Stone 3
- Gravel 4
- Dirt or Sand 5

6. Path condition/maintenance
- Poor (many bumps/cracks/holes) 1
- Fair (some bumps/cracks/holes) 2
- Good (very few bumps/cracks/holes) 3
- Under Repair 4

7. Path obstructions *(all that apply)*
- Poles or Signs 1
- Parked Cars 2
- Greenery 3
- Garbage Cans 4
- Other 5
- None 6

8. Buffers between road and path *(all that apply)*
- Fence 1
- Trees 2
- Hedges 3
- Landscape 4
- Grass 5
- None 6

9. Path Distance from Curb
- At edge 1
- < 5 feet 2
- > 5 feet 3

10. Sidewalk Width
- < 4 feet 1
- Between 4 and 8 feet 2
- > 8 feet 3

If no sidewalk, skip now to section C.

11. Curb cuts
- None 1
- 1 to 4 2
- > 4 3

12. Sidewalk completeness/continuity
- Sidewalk is complete 1
- Sidewalk is incomplete 2

13. Sidewalk connectivity to other sidewalks/crosswalks
- number of connections ____ 1

C. Road Attributes *(skip if path only)*

14. Condition of road
- Poor (many bumps/cracks/holes) 1
- Fair (some bumps/cracks/holes) 2
- Good (very few bumps/cracks/holes) 3
- Under Repair 4

15. Number of lanes
- Minimum # of lanes to cross ____ 1
- Maximum # of lanes to cross ____ 1

16. Posted speed limit
- None posted 1
- (mph): ____ 1

17. On-Street parking *(if pavement is unmarked, check only if cars parked)*
- Parallel or Diagonal 1
- None 2

18. Off-street parking lot spaces

0-5	6-25	26+
1	2	3

19. Must you walk through a parking lot to get to most buildings?
- Yes 1
- No 2

20. Presence of med-hi volume driveways
- < 2 1
- 2 to 4 2
- > 4 3

21. Traffic control devices *(all that apply)*
- Traffic light 1
- Stop sign 2
- Traffic circle 3
- Speed bumps 4
- Chicanes or chokers 5
- None 6

22. Crosswalks
- None 1
- 1 to 2 2
- 3 to 4 3
- > 4 4

23. Crossing Aids *(all that apply)*
- Yield to Ped Paddles 1
- Pedestrian Signal 2
- Median/Traffic Island 3
- Curb Extension 4
- Overpass/Underpass 5
- Pedestrian Crossing Warning Sign 6
- Flashing Warning Light 7
- Share the Road Warnign Sign 8
- None 9

24. Bicycle facilities *(all that apply)*
- Bicycle route signs 1
- Striped bicycle lane designation 2
- Visible bicycle parking facilities 3
- Bicycle crossing warning 4
- No bicycle facilities 5

D. Walking/Cycling Environment

25. Roadway/path lighting
- Road-oriented lighting 1
- Pedestrian-scale lighting 2
- Other lighting 3
- No lighting 4

26. Amenities *(all that apply)*
- Public garbage cans 1
- Benches 2
- Water fountain 3
- Street vendors/vending machines 4
- No amenities 5

27. Are there wayfinding aids?
- No 1
- Yes 2

28. Number of trees shading walking area
- None or Very Few 1
- Some 2
- Many/Dense 3

29. Degree of enclosure
- Little or no enclosure 1
- Some enclosure 2
- Highly enclosed 3

30. Powerlines along segment?
- Low Voltage/Distribution Line 1
- High Voltage/Transmission Line 2
- None 3

31. Overall cleanliness and building maintenance
- Poor (much litter/graffiti/broken facilities) 1
- Fair (some litter/graffiti/broken facilities) 2
- Good (no litter/graffiti/broken facilities) 3

32. Articulation in building designs
- Little or no articulation 1
- Some articulation 2
- Highly articulated 3

33. Building setbacks from sidewalk
- At edge of sidewalk 1
- Within 20 feet of sidewalk 2
- More than 20 feet from sidewalk 3

34. Building height
- Short 1
- Medium 2
- Tall 3

35. Bus stops
- Bus stop with shelter 1
- Bus stop with bench 2
- Bus stop with signage only 3
- No bus stop 4

Subjective Assessment: Segment...

Enter 1,2,3, or 4 for 1=Strongly Agree 2= Agree, 3=Disagree, 4=Strongly Disagree
- ......is attractive for walking. ____ 1
- ......is attractive for cycling. ____ 1
- ......feels safe for walking. ____ 1
- ......feels safe for cycling. ____ 1

Kelly J. Clifton, PhD - National Center for Smart Growth - University of Maryland, College Park

Appendix D: Survey Questionnaire

Physical Activity and Built Environment Survey

In just a minute we will begin the survey. As a reminder, please feel free to ask any questions at any point. Also, you may notice that a few of the questions seem to repeat in different sections of the survey. Be assured that they are different and that any similarities between questions are intentional.

Throughout the survey we will be referring to your neighborhood. Please use the following definition for neighborhood: the area within a 20-minute walk or one mile radius from your home.

Hand the participant the neighborhood definition for reference.

FORM 0
Table A

These first questions are general information questions.

Participant ID				
[A1]	Do you currently have a job or do any unpaid work outside your home?	Yes =1	No=2	Refused to Answer= 999
[A2]	In general, you would say that your health is:	1= excellent 2= very good 3= good 4= fair 5= poor 998 = Doesn't know/Not sure 999 = Refused to answer		

FORM 1
Table C

For the next questions, please tell me how much you agree or disagree with the following statements:

		Strongly Disagree 1	Somewh at Disagree 1	Neutral 3	Somewh at Agree 4	Strongly Agree 5	Doesn't Know/No t Sure 998	Refused to Answer 999
[C1]	People around your neighborhood are willing to help their neighbors.							
[C2]	Your neighborhood is close-knit.							
[C3]	People in your neighborhood can be trusted.							
[C4]	People in your neighborhood generally don't get along with each other.							
[C5]	People in your neighborhood do not share the same values.							
[C6]	You and your neighbors want the same thing from your neighborhood.							
[C7]	You feel at home on your block.							
[C8]	Very few of your neighbors know you.							
[C9]	You care about what your neighbors think of your actions							
[C10]	You have no influence over what your block is like.							
[C11]	If there is a problem on your block, the people who live there get it solved.							
[C12]	It is very important to you to live on your block.							
[C13]	You expect to live on your block a long time.							

FORM 2
Table E

We would like to find out more information about the way that you perceive or think about your neighborhood. The following questions are about your neighborhood and yourself, please tell me the answer that best applies to you and your neighborhood.

		None 1	A Few 2	Some 3	Most 4	All 5	Doesn't Know/ Not Sure 998	Refused to Answer 999
[E 1] **P**	How common are detached single-family residences in your immediate neighborhood?							
[E 2] **P**	How common are townhouses or row houses of 1-3 stories in your immediate neighborhood?							
[E 3] **P**	How common are apartments or condos 1-3 stories in your immediate neighborhood?							
[E 4] **P**	How common are apartments or condos 4-6 stories in your immediate neighborhood?							
[E 5] **P**	How common are apartments or condos 7-12 stories in your immediate neighborhood?							
[E 6] **P**	How common are apartments or condos with 13 or more stories in your immediate neighborhood?							

Table F

For the next set of questions, please tell me about how long would it take to get from your home to the nearest businesses or facilities listed below if you WALKED to them at your normal walking pace?

		5 mins or less 1	6-10 mins 2	11-20 mins 3	21-30 mins 4	30 + mins 5	Doesn't Know/ Not Sure 998	Refused to Answer 999
F1	Convenience/small grocery store							
F2	Supermarket							
F3	Hardware Store							
F5	Laundry/Dry Cleaners							
F6	Clothing Store							
F7	Post Office							
F8	Library							
F9	Elementary School							
F10	Other Schools							
F11	Bookstore							
F12	Fast Food Restaurant							
F14	Bank/Credit Union							
F15	Non-Fast Food Restaurant							
F16	Video Store							
F17	Pharmacy/Drug Store							
F18	Salon/Barber Shop							
F19b	Your Main Job (not applicable is also an option here)							
F20	Bus or Train Stop							
F21	Park							
F22	Recreation Center							
F23	Gym or Fitness Center							

Table G

For the next seven questions, please tell me how much you agree or disagree with following statements.

		Strongly Disagree 1	Somewhat Disagree 2	Neutral 3	Somewhat Agree 4	Strongly Agree 5	Doesn't Know/ Not Sure 998	Refused to Answer 999

G1	You can do most of your shopping at stores within a 10-15 minute walk from your home.							
G2 **P**	Stores are within easy walking distance of your home.							
G3 **P**	Parking is difficult in local shopping areas.							
G4 **P**	There are many places to go within easy walking distance of your home.							
G5 **P**	It is easy to walk to a transit stop (bus, train) from your home.							
G6	The streets in your neighborhood are hilly, making your neighborhood difficult to walk in.							
G7	There are many canyons/hillsides in your neighborhood that limit the number of routes for getting from place to place.							

Form 3
Table H

Please tell me how much you agree or disagree with the following five statements.

		Strongly Disagree 1	Somewhat Disagree 2	Somewhat Agree 3	Strongly Agree 4	Doesn't Know/ Not Sure 998	Refused to Answer 999	Not Applicable 997
H1 **P**	The streets in your neighborhood do not have many cul-de-sacs or other dead-end streets.							
H2 **P**	There are walkways in your neighborhood that connect cul-de-sacs to streets, trails, or other cul-de-sacs.							
H3 **P**	The distance between intersections in your neighborhood is usually short (100 yards or less; the length of a football field or less).							
H4 **P**	There are many four-way intersections in your neighborhood.							
H5 **P**	There are many alternative routes for getting from place to place in your neighborhood. (I don't have to go the same way every time.)							

Table I

Please tell me how much you agree or disagree with the following seven statements.

		Strongly Disagree 1	Somewhat Disagree 2	Somewhat Agree 3	Strongly Agree 4	Doesn't Know/ Not Sure 998	Refused to Answer 999	Not Applicable 997
I1 **P**	There are sidewalks on most of the streets in your neighborhood.							
I2 **P**	The sidewalks in your neighborhood are well maintained (paved, even, and not a lot of cracks).							
I3 **P**	There are bicycle or pedestrian pathways or trails in or near your neighborhood that are easy to get to.							
I4 **P**	Sidewalks are separated from the road/traffic in your neighborhood by parked cars.							
I5 **P**	There is a grass/dirt strip that separates the streets from the sidewalks in your neighborhood.							
I6	Considering traffic and road conditions, It is safe to ride a bike in or near your neighborhood.							
I7 **P**	There are facilities to bicycle in or near your neighborhood, such as bicycle lanes, separate paths or trails, shared used paths for pedestrians and cycles.							

Table J

Please tell me how much you agree or disagree with the following eight statements.

		Strongly Disagree 1	Somewhat Disagree 2	Somewhat Agree 3	Strongly Agree 4	Doesn't Know/Not Sure 998	Refused to Answer 999	Not Applicable 997
J1 **P**	There are trees along the streets in your neighborhood.							
J2	Trees give shade for the sidewalks in your neighborhood.							
J3	There are many interesting things to look at while walking in your neighborhood.							
J4	Your neighborhood is generally free from litter.							

J5	There are many attractive natural sights in your neighborhood (such as landscaping, views).							
J6 **P**	There are attractive buildings/homes in your neighborhood.							
J7 **P**	Your neighborhood has several free or low cost recreation facilities, such as parks, walking trails, bike paths, recreation centers, playgrounds, public swimming pools, etc.							
J8	Hills, or steep slopes, are common in your neighborhood.							

Table K

For the next set of questions please tell me how much you agree or disagree with the following statements.

		Strongly Disagree 1	Somewhat Disagree 2	Somewhat Agree 3	Strongly Agree 4	Doesn't Know/ Not Sure 998	Refused to Answer 999	Not Applicable 997
K1	There is so much traffic along the street you live on that it makes it difficult or unpleasant to walk in your neighborhood.							
K2	There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in your neighborhood.							
K3 **P**	The speed of traffic on the street you live on is usually slow (30 mph or less).							
K4 **P**	The speed of traffic on most nearby streets is usually slow (30 mph or less).							
K5 **P**	Most drivers exceed the posted speed limits while driving in your neighborhood.							
K6 **P**	Your neighborhood streets are well lit at night.							
K7	Walkers and bikers on the streets in your neighborhood can be easily seen by people in their homes.							
K8 **P**	There are crosswalks and pedestrian signals to help walkers cross busy streets in your neighborhood.							

K9 **P**	The crosswalks in your neighborhood help walkers feel safe crossing busy streets.							
K10	When walking in your neighborhood there are a lot of exhaust fumes (such as from cars, buses).							
K11	You see and speak to other people when you are walking in your neighborhood.							
K12	There is a high crime rate in your neighborhood.							
K13	The crime rate in your neighborhood makes it unsafe to go on walks during the day.							
K14	The crime rate in your neighborhood makes it unsafe to go on walks at night.							
K15	Your neighborhood is safe enough so that you would let a 10-year-old child walk around your block alone in the daytime.							
K16 **P**	There are unattended or stray dogs in your neighborhood.							

Form 4
Survey Section L

Next are things about your neighborhood with which you may or may not be satisfied. Using the scale that I will read to you, tell me your satisfaction with each item.

		Strongly Dissatisfied 1	Somewhat Dissatisfied 2	Neither Satisfied or Dissatisfied 3	Somewhat Satisfied 4	Strongly Satisfied 5	Doesn't Know/ Not Sure 998	Refused to Answer 999
L1	the highway access from your home							
L2	the access to public transportation in your neighborhood.							
L3a	your commuting time to work [not applicable =997]							
L3b	your access to school [not applicable =997]							

L4	the access to shopping in your neighborhood.							
L5	the number of friends you have in your neighborhood.							
L6	the number of people you know in your neighborhood.							
L7	how easy and pleasant it is to walk in your neighborhood.							
L8	how easy and pleasant it is to bicycle in your neighborhood.							
L9	the quality of schools in your neighborhood							
L10	access to entertainment in your neighborhood (restaurants, movies, clubs, etc)							
L11	the safety from the threat of crime in your neighborhood.							
L12	the amount and speed of traffic in your neighborhood.							
L13	the noise from traffic in your neighborhood.							
L14	the number and quality of food stores in your neighborhood.							
L15	the number and quality of restaurants in your neighborhood.							
L16	your neighborhood as a good place to raise children.							
L17	your neighborhood as a good place to live.							
L18	Overall, how satisfied are you with your neighborhood?							

Table M

Please tell me if you have the following in your home, yard, or apartment complex.

		Yes 1	No 0	Doesn't Know/Not Sure 998	Refused to Answer 999

M1	stationary aerobic equipment (e.g. treadmill, cycle)				
M2	bicycle				
M4	trampoline for jogging in place				
M5	running shoes				
M6	swimming pool				
M7	weight lifting equipment (e.g. free weights, Nautilius Universal)				
M8	skis (snow or water)				
M9	toning devices (e.g. exercise balls, ankweights, Dynabands, Thighmaster)				
M10	exercise DVD, video or audiotapes				
M11	step aerobics, slide aerobics				
M12	skates (roller, in-line, or ice)				
M13	sports equipment (balls, racquets)				
M14	surf board, boogie board, windsurf board				
M15	canoe, row boat, kayak				

Form 5
Table N

Now I am going to read you a list of places where you can exercise. Please let me know if the place is on a frequently traveled route or within a 5-minute drive or 10-minute walk from your work or home.

		Yes 1	No 0	Doesn't Know/Not Sure 998	Refused to Answer 999
N1	aerobics studio				
N2	basketball court				
N3	beach, lake, river, or creek				
N4	bike lane or trails				
N5	golf course				
N6	health spa/gym				
N7	martial arts studio				
N8	playing field (soccer, football, softball, etc.)				
N9	public park				
N10	public recreation center				
N11	racquetball/squash court				
N12	running track				
N13	skating rink				
N14	sporting goods store				
N15	swimming pool				
N16	walking/hiking trails				
N17	tennis courts				
N18	dance studio				

Private recreational facilities are places to be physically active which you have to join or pay a fee to use. Examples of private facilities include YMCA's, health clubs or gyms, martial arts studios, dance studios, or yoga studios.

N20	Would you say that the availability of recreational and exercise facilities in your community was . . .	Excellent = 1	Good = 2	Fair = 3	Poor = 4	Doesn't Know/Not Sure = 998	Refused to Answer = 999	Not Applicable = 997
N22	How often do you use the recreational and exercise facilities in your local area?	Very Often = 1	Often = 2	Sometimes = 3	Never = 4	Doesn't Know/Not Sure = 998	Refused to Answer = 999	Not Applicable = 997
N23	Would you say that the quality of the recreational and exercise facilities in your local area was...	Excellent = 1	Good = 2	Fair = 3	Poor = 4	Doesn't Know/Not Sure = 998	Refused to Answer = 999	Not Applicable = 997

Table O

Next I will read to you reasons for moving to your neighborhood. Please rate how important each of the following reasons was in your decision to move to your neighborhood. For each reason, please select a number between 1 and 5, with 1 being not at all important and 5 being very important.

		Not at all important = 1	Somewhat Important = 2	Somewhat Important = 3	Somewhat Important = 4	Very Important = 5	Doesn't Know/Not Sure = 998	Refused to Answer = 999
O1	Affordability/Value							
O2	Closeness to open space (for example, parks)							
O3	Closeness to job or school							
O4	Closeness to public transportation							
O5	Desire for nearby shops and services							
O6	Ease of walking							
O7	Sense of community							
O8	Safety from crime							
O9	Quality of schools							
O10	Closeness to recreational facilities							
O11	Access to freeways							

Form 6
Table Q

Please tell me how much you agree or disagree with the following statements.

		Strongly Disagree = 1	Somewhat Disagree = 2	Neutral = 3	Somewhat Agree = 4	Strongly Agree = 5	Doesn't Know/Not Sure = 998	Refused to Answer = 999
Q4	You would like to have more time for leisure							
Q6	You think that it's important for children to have a large backyard for playing							
Q7	You think that environmental protection is an important issue							
Q8	You enjoy a house close to the sidewalk so that you can see and interact with passersby							
Q9	You think that too much land is consumed for new housing, stores, and offices							

Q10	You enjoy bicycling							
Q11	You enjoy living in close proximity to your neighbors							
Q13	You prefer a lot of space between your home and the street.							
Q16	You think that children should have a large public play space within safe walking distance of their home.							
Q17	You think that having shops and services close by is important.							

		Less than 5 min =1	Between 5 and 15 min = 2	Between 15 and 30 min = 3	More than 30 min =4	Doesn't Know/Not Sure = 998	Refused to Answer = 999	Not Applicable = 997
Q18	Now, please tell me what would be your ideal one-way commuting time to work or school:							

		Less than 5 min = 1	Between 5 and 15 min = 2	Between 15 and 30 min = 3	Between 30 and 45 min = 4	Between 45 min and 1 hr = 5	More than 1 hour = 6	Doesn't Know/Not Sure = 998	Refused to Answer = 999	Not Applicable = 997
Q19	And please tell me what would be the longest acceptable time for you to commute one-way to work or school.									

Table R
Next, I am going to ask you about walking for transportation purposes. Please let me know how many days in the past month you have walked to a:

		Home	And/or fromWork
	market/retail store from home, from work	R2:HOME	R2:WORK
	school/day care center from home, from work	R3:HOME	R3:WORK
	bank/credit union from home, from work	R4:HOME	R4:WORK
	post office from home, from work	R5:HOME	R5:WORK
	restaurant/café from home, from work	R6:HOME	R6:WORK
	gym/health club/rec facility from home, from work	R7:HOME	R7:WORK
	park from home, from work	R8:HOME	R8:WORK
	public transportation/park and ride facility from home, from work	R9:HOME	R9:WORK
	work site/office from home, from work	R10:HOME	R10:WORK

Table S
For the questions below, please do not count stationary biking.

S5	If you were to bicycle in your neighborhood you would feel safe from cars while riding.	Strongly disagree 1	Somewhat disagree 2	Neutral 3	Somewhat agree 4	Strongly agree 5	Doesn't Know/Not Sure = 998	Refused to Answer = 999
S1	How often do you bicycle, either in your neighborhood or starting from your neighborhood?	Never = 0	Less than once a week = 1	1-2 times a week = 2	3-6 times a week = 3	Everyday = 4	Doesn't Know/Not Sure = 998	Refused to Answer = 999

S2	When you bicycle, how far do you normally ride?	Miles

S3	How often would you bike if you thought it was safe from cars?	Never = 0	Less than once a week = 1	1-2 times a week = 2	3-6 times a week = 3	Everyday = 4	Doesn't Know/Not Sure = 998	Refused to Answer = 999

Form 7
Table T

Now, I am going ask a number of questions about your workplace environment.

T2	Do you usually work at: (#of sites)	One site each day = 1	Multiple sites each day =2	Refuse to Answer =999

T3	Is your primary work: (indoors/outdoors)	Indoors = 1	Outdoors =2	Mixed indoors and outdoors = 3	Refuse to Answer = 999

	How many days in the past month or so (20 work days) did you go to work by:	Days
T4a	Walking	
T4b	Biking	
T4c	Drive Alone	
T4d	Carpool Driver	
T4e	Carpool Passenger	
T4f	Vanpool	
T4g	Bus	
T4H	Taxi	
T4i	Train	

T5	How long does it take you to walk from your parking space, transit stop, or drop off location to your primary workplace? (in minutes)	Minutes

Are any of the following items available at your work or from your employer?

		Yes = 1	No = 0	Doesn't Know/ Not Sure = 998	Refused to Answer =999
T6b **P**	Exercise facilities (e.g. workout room/gym, exercise equipment, walking path /PAR course)				
T7b **P**	Regular exercise programs (e.g. aerobic classes, team sports, walking groups, etc.)				
T8b **P**	Shower facilities that you can use				
T9b **P**	Lockers for clothes				
T10b **P**	Safe bicycle storage				
T14a **P**	Does your employer offer incentives not to drive to work?				

For each of the following programs, please tell me a) is it offered to you by your employer, and b) do you use it more than twice per month.

		Yes = 1	No = 0	Do you use it?	Yes = 1	No =0
T14b 1a,1b **P**	An exercise specialist or activity coordinator available for employees.					
T14b 2a, 2b **P**	Paid time for you to exercise.					
T14b 4a, 4b **P**	The ability to work at home one or more days per week.					
T14b 5a, 5b **P**	A guaranteed ride home.					
T14b 6a, 6b **P**	Cash in lieu of using a parking space or a reduced transit pass.					
T14b 7a, 7b **P**	Incentives for carpooling, such as a ridematching program or preferential parking.					

		Yes = 1	No = 0	Not Applicable = 997	Refused to Answer = 999
	Are the stairs at your work:				
T15a	available to use most of the time?				
T15b	safe?				
T15c	pleasant?				

		Answer
T16	What is the full address of your primary workplace? (please provide a street address, not a PO Box number)	
T17	What is the nearest intersection to your primary workplace?	
T18	How many days per week do you usually go to your primary workplace?	

Form 8
Table U
Please tell me how much you agree or disagree with the following statements.

		Strongly Disagree =1	Somewhat Disagree =2	Somewhat Agree =3	Strongly Agree = 4	Doesn't Know/Not Sure =998	Refused to Answer = 999
U1	The streets in your workplace neighborhood do not have many, or any, cul-de-sacs.						
U2 **P**	There are many four-way intersections in your workplace neighborhood.						
U3 **P**	There are sidewalks on most of the streets in your workplace neighborhood.						
U4	There are bicycle or pedestrian trails in or near your workplace neighborhood that are easily accessible.						
U5	There are many interesting things to look at while walking in your workplace neighborhood.						
U6 **P**	There are trees along the streets in your workplace neighborhood.						
U7	Your workplace neighborhood is generally free from litter.						
U8	There is so much traffic along the streets that it makes it difficult or un-pleasant to walk in your workplace neighborhood.						
U9 **P**	There are crosswalks and pedestrian signals to help walkers cross streets in your workplace neighborhood.						
U10	You see a lot of other people when you are walking in your workplace neighborhood.						
U11	There is a high crime rate in your workplace neighborhood.						

Form 14
Table BB
Please think about the place that you most frequently visit during a typical week. This can be a friend or relative's house, a park, a library, a mall, etc... Now, I am going to ask you some questions about this place.

BB1	Is the place you most frequently visit:	Indoors = 1	Outdoors =2	Mixed indoors and outdoors =3	Refuse to Answer =999

	How many days in the past week did you go to this place by:	Days
BB2	Walking	
BB3	Biking	
BB4	Drive Alone	
BB5	Being a Carpool Driver	
BB10	Train	
BB6	Being a Carpool Passenger	
BB7	Riding in a Vanpool	
BB8	Bus	
BB9	Taxi	

B11	How long does it take you to walk from your parking space, transit stop, or drop off location to your most frequently visited place? (in minutes)	Minutes

Are any of the following items available at this place?

		Yes =1	No =0	Doesn't Know/Not Sure = 998
BB12	Exercise facilities.			
BB13	Exercise programs.			
BB15	Shower facilities.			
BB16	Safe bike storage.			
BB15	Locker facilities.			

		Yes = 1	No = 2	Not Applicable = 997	Refused to Answer = 999
	Are the stairs at this place:				
BB17	available?				
BB18	safe?				
BB19	pleasant?				

		Answer
BB20	What is the full address of this place? (please provides	

	a street address, not a PO Box number)	
BB21	What is the nearest intersection to this place?	
BB22	How many days per week do you usually go to this place?	

Form 13
Table EE

		Strongly Disagree =1	Somewhat Disagree =2	Somewhat Agree =3	Strongly Agree = 4	Doesn't Know/Not Sure =998	Refused to Answer = 999
EE1 **P**	Parking is always an issue in your neighborhood						
EE2 **P**	There are an adequate number of off-street parking spaces in your neighborhood.						
EE3 **P**	There are an adequate number of on-street parking spaces in your neighborhood.						
EE4 **P**	The cost for parking in your neighborhood, on- or off-street, seem reasonable to you.						
EE5 **P**	You are satisfied with the transit frequency in your neighborhood.						
EE6 **P**	Transit takes you where you want or need to go.						
EE7 **P**	It is easy to get to the bus or rail transit from your neighborhood.						
EE8 **P**	I would like to have more stores and restaurants within walking distance of where I live.						

Table DD

		Yes =1	No = 0	Doesn't Know/Not Sure =998	Refused to Answer =999
DD22 **P**	Are there any trails or pathways in your neighborhood, not including state parks or national forests?				
DD23	Do you ever use the trails or pathways?				

DD24	Why don't you use the trails or pathways?	
DD25	How did you find out about the trails or pathways in your neighborhood?	
DD26	How do you get to the trails or pathways in your neighborhood?	
DD28	How often do you use the trails or pathways in your neighborhood?	Times per month

You are doing great and we are more than half way through the survey. Let's take a short break and measure your height and weight.

Form 9
Table V

V0a	We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. During the past month, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?	Yes =1	No = 0	Doesn't Know/Not Sure =998	Refused to Answer =999

V0b	During the past month, when you participated in physical activities, did you usually do it :	Near your home =1	At your home = 2	Near your workplace = 3	At your workplace = 4	Near both home and workplace =5	Some other place = 6	Doesn't Know/ Not Sure = 998	Refused to Answer = 999

The next questions are about all the physical activity you did in the last 7 days as part of your paid or unpaid work. This does not include traveling to and from work.

V2	During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, heavy construction, or climbing up stairs as part of your work? Think about only those physical activities that you did for at least 10 minutes at a time.	Days
V3	How much time did you usually spend on ONE of those days doing vigorous physical activities as part of your work?	Hrs/Mins per day

V4	Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads as part of your work? Please do not include walking.	Days

V5	How much time did you usually spend on ONE of those days doing moderate physical activities as part of your work?	Hrs/Mins per day

V6	During the last 7 days, on how many days did you walk for at least 10 minutes at a time as part of your work? Please do not count any walking you did to travel to or from work.	Days

V7	How much time did you usually spend on ONE of those days walking as part your work?	Hrs/Mins per day

These next questions are about how you traveled from place to place, including to places such as work, stores, movies and so on.

V8	During the last 7 days, on how many days did you travel in a motor vehicle like a train, bus or car?	Days

V9	How much time did you usually spend on ONE of those days traveling in a car, bus, train or other kind of motor vehicle?	Hrs/Mins per day

V10	During the last 7 days, on how many days did you bicycle for at least 10 minutes at a time to go from place to place?	Days

V11	How much time did you usually spend on ONE of those days to bicycle from place to place?	Hrs/Mins per day

V12	During the last 7 days, on how many days did you walk for at least 10 minutes at a time to go from place to place?	Days

V13	How much time did you usually spend on ONE of those days walking from place to place?	Hrs/Mins per day

This section is about some of the physical activities you might have done in the last 7 days in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

V14	Think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, chopping wood, shoveling snow, or digging in the garden or yard?	Days

V15	How much time did you usually spend on ONE of those days doing vigorous physical activities in the garden or yard?	Hrs/Mins per day

V16	Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate activities like carrying light loads, sweeping, washing windows, and raking in the garden or yard?	Days

V17	How much time did you usually spend on ONE of those days doing moderate physical activities in the garden or yard?	Hrs/Mins per day
V18	Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate activities like carrying light loads, washing windows, scrubbing floors and sweeping inside your home?	Days

V19	How much time did you usually spend on ONE of those days doing moderate physical activities inside your home?	Hrs/Mins per day

This section is about all the physical activities that you did in the last 7 days solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

V20	Not counting any walking you have already mentioned, during the last 7 days, on how many days did you walk for at least 10 minutes at a time in your leisure time?	Days

V21	How much time did you usually spend on ONE of those days walking in your leisure time?	Hrs/Mins per day

V22	Think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do vigorous physical activities like aerobics, running, fast bicycling, or fast swimming in your leisure time?	Days

V23	How much time did you usually spend on ONE of those days doing vigorous physical activities in your leisure time?	Hrs/Mins per day

V24	Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis in your leisure time?	Days

V25	How much time did you usually spend on ONE of those days doing moderate physical activities in your leisure time?	Hrs/Mins per day

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already listed.

V26	During the last 7 days, how much time did you usually spend sitting on a weekday?	Hrs/Mins per day

V27	During the last 7 days, how much time did you usually spend sitting on a weekend day?	Hrs/Mins per day

Form 10
Table W

For the next six questions you will again need the following definition for "vigorous activity".

"Vigorous" exercise includes activities like jogging, running, fast cycling, aerobics classes, swimming laps, singles tennis, and racquetball. These types of activities usually increase your heart rate, make you sweat, and you get out of breath (do not count weight lifting).

Now, please tell me how much you agree or disagree with the following statements for vigorous activities.

		Strongly Disagree = 1	Somewhat Disagree =2	Neutral =3	Somewhat Agree =4	Strongly Agree =5	Doesn't Know/Not Sure =998	Refused to Answer = 999
W 1	You enjoy doing vigorous physical activities.							
W 2	You enjoy the feeling you get while doing vigorous activities.							
W 3	You enjoy the feeling you get after doing vigorous activities.							

Table Y

Now, please tell me, on a scale of 1 to 5, how sure you are that you could exercise vigorously in each of the following situations.

		I'm sure I cannot =1	= 2	Maybe I can =3	= 4	I sure I can = 5	Doesn't Know/ Not Sure =998	Refused to Answer =999
Y1	Vigorous physical activity even though you're feeling sad or highly stressed.							
Y2	Stick with a program of vigorous physical activity even when family or social life takes a lot of time.							
Y3	You will set aside time for vigorous physical activity.							

Tables W&Y

Now, for the next six questions you will again need the following definition for "moderate physical activity".

"Moderate" physical activity includes activities like brisk walking, gardening, slow cycling, or dancing. A moderate physical activity is any activity that takes moderate physical effort and makes you breathe somewhat harder than normal.

Please tell me how much you agree or disagree with the following statements for moderate physical activities.

		Strongly Disagree = 1	Somewhat Disagree =2	Neutral =3	Somewhat Agree =4	Strongly Agree =5	Doesn't Know/Not Sure =998	Refused to Answer = 999
W4	You enjoy doing moderate physical activities							
W5	You enjoy the feeling you get while doing moderate physical activities							
W6	You enjoy the feeling you get after doing moderate physical activities							

Now, please tell me, on a scale of 1 to 5, how sure you are that you could exercise moderately in each of the following situations.

		I'm sure I cannot =1	= 2	Maybe I can =3	= 4	I sure I can = 5	Doesn't Know/ Not Sure =998	Refused to Answer =999
Y4	Do moderate physical activity even though you're feeling sad or highly stressed.							
Y5	Stick with a program of moderate physical activity even when family or social life takes a lot of time.							
Y6	You will set aside time for moderate physical activity.							

Table Z

Read the valid responses after each question.

		Never = 0	Rarely = 1	Sometimes =2	Often =3	Vary Often = 4	Doesn't Know/Not Sure =998	Refused to Answer =999
Z1 a	During the past three months your family did physical activity with you.							
Z1 B	During the past three months your friends did physical activity with you							
Z2 a	During the past three months your family offered to do physical activity with you.							
Z2 b	During the past three months your friends offered to do physical activity with you.							
Z3 a	During the past three months your family gave you encouragement to do physical activity.							
Z3 b	During the past three months your friends gave you encouragement to do physical activity.							

Form 11
Table AA

Read the valid responses after each question.

		Detached single house 1	Duplex 2	Row house, town house 3	Apart. Or Condo. 4	Mobile home or trailer 5	Dorm room 6	Other 7	Doesn't Know/ Not Sure 998	Refused to Answer 999
AA 1	Do you live in a:									

		Owned 1	Rented 2	Provided by job or military 3	Other 4	Doesn't Know/Not Sure 998	Refused to Answer 999
AA2	Do you own or rent your home?						

		Answer
AA3	Including yourself, how many people live in your household? Please do not include anyone who usually lives somewhere else or is just visiting, such as a college student away at school.	

		Yes 1	No 0	Doesn't Know/Not Sure 998	Refused to Answer 999
AA 4	Are any of these people related to each other?				

		Age	Don't Know	Refuse to Answer
AA5	What is your age?			

		Male	Female	Refuse to Answer
AA6	What is your gender?			

		Yes 1	No 0	Doesn't Know/Not Sure 998	Refused to Answer 999
AA 9	Are you of Hispanic or Latino origin?				

		White 1	African American 2	Asian 3	American Indian Alaskan Native 4	Native Hawaiian or Pacific Islander5	Multiracial 7	Other 8	Doesn't Know/ Not Sure 998	Refused to Answer 999

AA 10	Please tell me which best describes your race									

		Less than high school diploma 1	Completed high school diploma (GED) 2	Vocational training (beyond high school) 3	Some college (less than four years) 4	College /university degree 5	Graduate or professional degree 6	Doesn't Know/ Not Sure 998	Refused to Answer 999
AA11	Please tell me the highest education degree you have completed.								

		Never married 1	Married 2	Separated 3	Divorced 4	Widowed 5	Doesn't Know/ Not Sure 998	Refused to Answer 999
AA12	Please tell me what is your marital status.							

		Yes 1	No 0	Doesn't Know/Not Sure 998	Refused to Answer 999
AA13	Are you a parent, foster parent, or legal guardian of children that live with you?				

		Answer
AA14a	Please specify the number of children for whom you are a parent, foster, parent, or legal guardian.	

		Answer
AA14b	Please specify the ages of the children for whom you are a parent, foster, parent, or legal guardian.	

	These are Yes/No	Working	Home maker	Looking for work	Going to school	Traveling	Retired	Temporarily absent from job/ business	Other	Doesn't Know/ Not Sure	Refused to Answer
	During most of last week you were... (please indicate all that apply)	AA15a	AA15b	AA15c	AA15d	AA15e	AA15f	AA15g	AA15h	AA15i	AA15j

		Yes 1	No 0	Doesn't Know/ Not Sure 998	Refused to Answer 999
AA16	Last week, did you do any work for pay?				

		Full time 1	Part time one job 2	Part time multiple jobs 3	Doesn't Know/Not Sure 998	Refused to Answer 999
AA17	During most of last week you were working...					

		Yes 1	No 0	Doesn't Know/Not Sure 998	Refused to Answer 999
AA18	Do you have more than one job?				

		Sales or service 1	Clerical or administrative 2	Manufacturing, construction, maintenance, farming 3	Professional, managerial, technical 4	Other 5	Doesn't Know/ Not Sure 998	Refused to Answer 999
AA19	I am going to read four categories of occupations. Please tell me which one your primary job falls under.							

		Miles/ blocks	Doesn't Know/ Not Sure	Refused to Answer	Not applicable
AA24	What is the one-way distance from your home to your primary workplace, in miles or blocks?				

		Minutes	Did not work in usual workplace	Did not work last week	Doesn't Know/Not Sure	Refused to Answer
AA25	How many minutes did it usually take you to get from home to work last week?					

		Vehicles	None	Doesn't Know/ Not Sure	Refused to Answer
AA29	How many vehicles are owned, leased or available for regular use by the people who currently live in your household?				

I have a few questions about these vehicles:

	Starting with the newest vehicle:	Answer

30a1	What is the make of the vehicle? (for example: Honda, Volkswagen)	
30a2	What is the model of the vehicle? (for example: Accord, Jetta)	
30a3	What is the year of the vehicle?	
30a4	What is the type of the vehicle? (for example: car, van, SUV, truck)	

	Starting with the second newest vehicle:	Answer
30b1	What is the make of the vehicle? (for example: Honda, Volkswagen)	
30b2	What is the model of the vehicle? (for example: Accord, Jetta)	
30b3	What is the year of the vehicle?	
30b4	What is the type of the vehicle? (for example: car, van, SUV, truck)	

	Starting with the third newest vehicle:	Answer
30c1	What is the make of the vehicle? (for example: Honda, Volkswagen)	
30c2	What is the model of the vehicle? (for example: Accord, Jetta)	
30c3	What is the year of the vehicle?	
30c4	What is the type of the vehicle? (for example: car, van, SUV, truck)	

	Starting with the fourth newest vehicle:	Answer
30d1	What is the make of the vehicle? (for example: Honda, Volkswagen)	
30d2	What is the model of the vehicle? (for example: Accord, Jetta)	
30d3	What is the year of the vehicle?	
30d4	What is the type of the vehicle? (for example: car, van, SUV, truck)	

		Bicycles	Don't Know	Refuse to Answer
AA32	How many adult-sized bicycles does your household have in working order? Please include all bikes that are in working order and that are large enough to be used by an adult.			

		Yes 1	No 0	Refused to Answer 999
B12	Do you have a dog at home?			

		Times per day
B13	Approximately how many times per day do you walk your dog?	
		Minutes
B14	For each time, approximately how long do you spend walking your dog?	

I am going to read several annual income categories, please tell me which category best matches your annual household income:

	Less than $10,000 1	$10,000 - $19,000 2	$20,000 - $29,000 3	$30,000 - $39,000 4	$40,000 - $49,000 5	$50,000 - $59,000 6	$60,000 - $69,000 7	$70,000 - $79,000 8	$80,000 - $89,000 9	$90,000 - $99,000 10	More than $100,000 11	Refused to Answer 998	Refused to Answer 999
AA33													

For these last few questions, I am going to ask for your contact information. Some of this is necessary in order to send you your participation check of $40.

		Answer
AA34	What is your home address?	

		Answer
AA35	What is the nearest street intersection to your home?	

		Answer
AA36	What is your email address?	

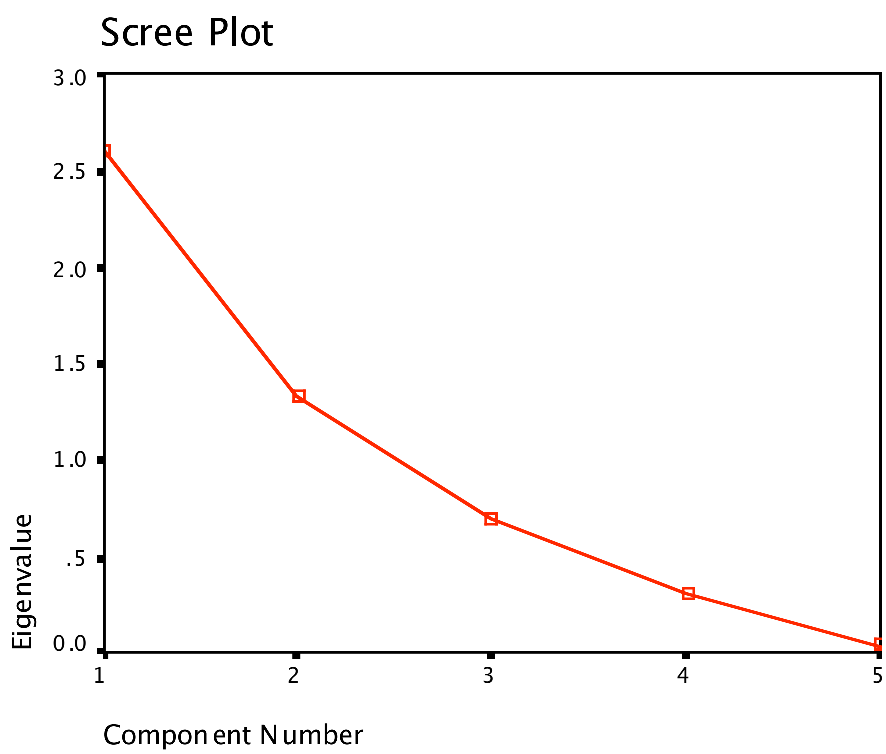
		Answer
AA37	What is your phone number?	

End of Survey

Appendix E: Principal Component Analysis

OBJECTIVE PRINCIPAL COMPONENT ANALYSIS

TRANSPORT ONLY



Component Matrix
a 2 components extracted.

Rotated Component Matrix

	Component	
	1	2
PED_FAC	.973	
CONNECT_	.924	
CON_PATH	.663	.602
BUSSTOP	.500	.432
INTER34		.914

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 3 iterations.

Total Variance Explained

Component	Rotation Sums of Squared Loadings Total	% of Variance	Cumulative %
1	2.522	50.436	50.436
2	1.424	28.487	78.923

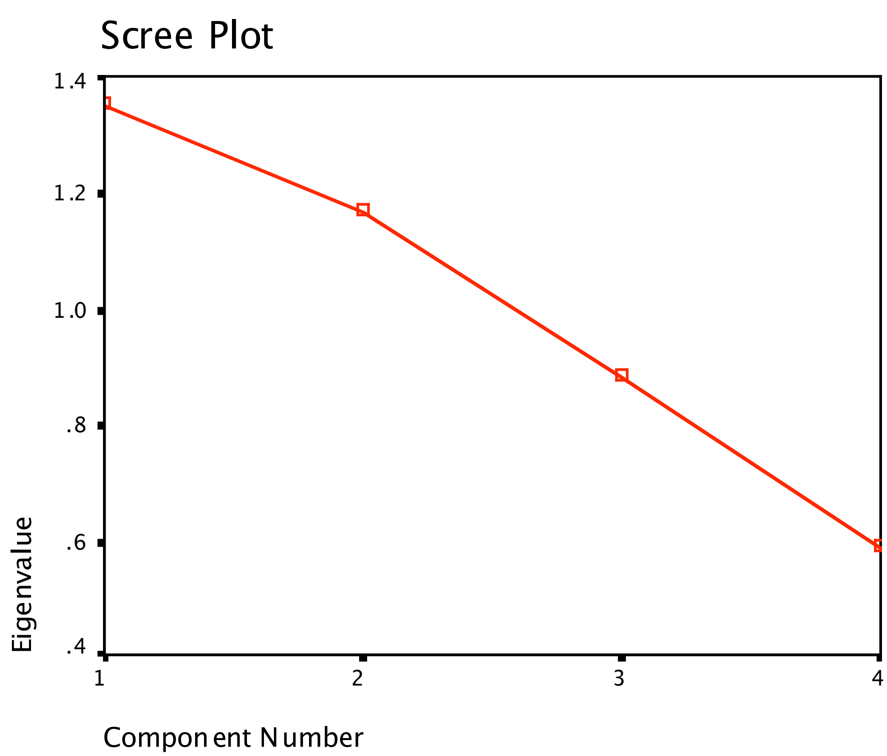
Extraction Method: Principal Component Analysis.

Component Transformation Matrix

Component	1	2
1	.965	.260
2	-.260	.965

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

AESTHETICS ONLY



Component Matrix
a 2 components extracted.

Rotated Component Matrix

	Component	
	1	2
CLEAN	.843	
INDVAC	-.728	
NO_TREES		.831
DEG_ENCL		.698

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 3 iterations.

Total Variance Explained

	Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %
1	1.326	33.141	33.141
2	1.200	30.010	63.151

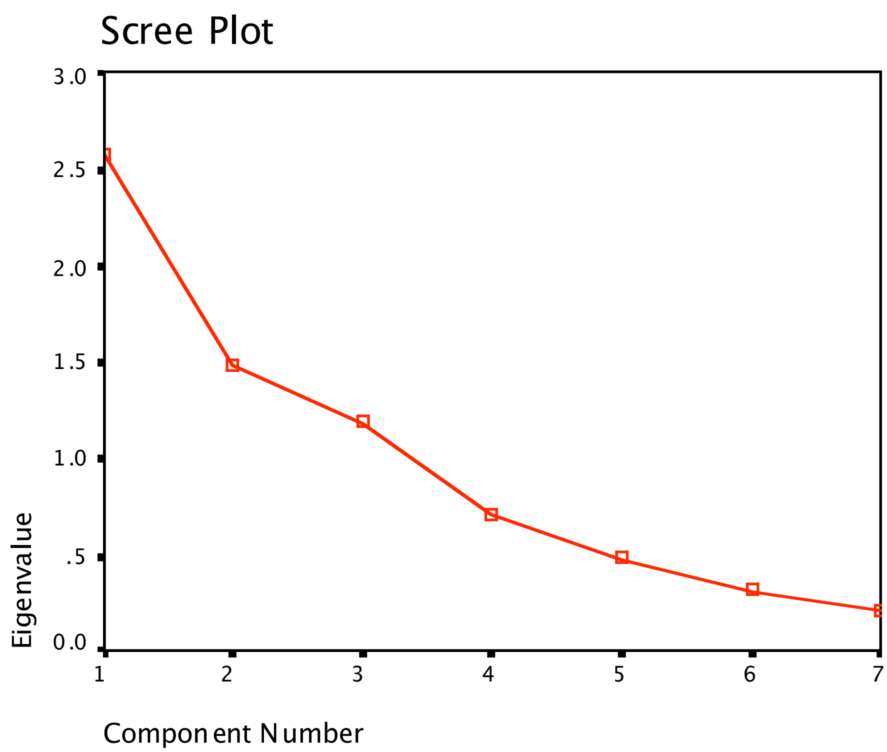
Extraction Method: Principal Component Analysis.

Component Transformation Matrix

Component	1	2
1	-.915	.404
2	.404	.915

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

SAFETY ONLY



Rotated Component Matrix

	Component	
	1	2
CROSSW	.830	
CROSSAID	.821	
TCONTROL	.685	
CURBCUTS		.814
BUFFER_A	-.482	.675
OBS_PATH		-.379

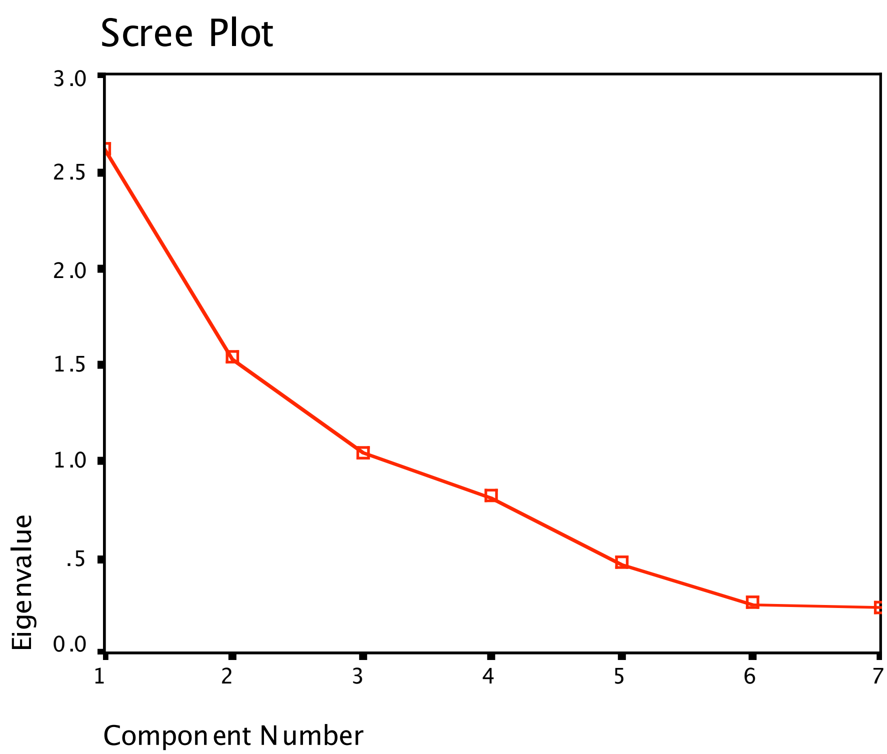
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 3 iterations.

Component Transformation Matrix

Component	1	2
1	.920	.393
2	-.393	.920

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

LAND USE ONLY



Component Matrix
a 3 components extracted.
Rotated Component Matrix

	Component 1	2	3
OFFICEINST	.857		
RESTCOMM	.887		
INDVAC		.609	
RECUSE			.963
BUILDSET		.847	
BUILDHT	.488	.604	.387
PARK_LOT	.910		

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser

Normalization.
a Rotation converged in 4 iterations.

Total Variance Explained

Component	Rotation Sums of Squared Loadings Total	% of Variance	Cumulative %
1	2.619	37.419	37.419
2	1.472	21.026	58.445
3	1.112	15.884	74.329

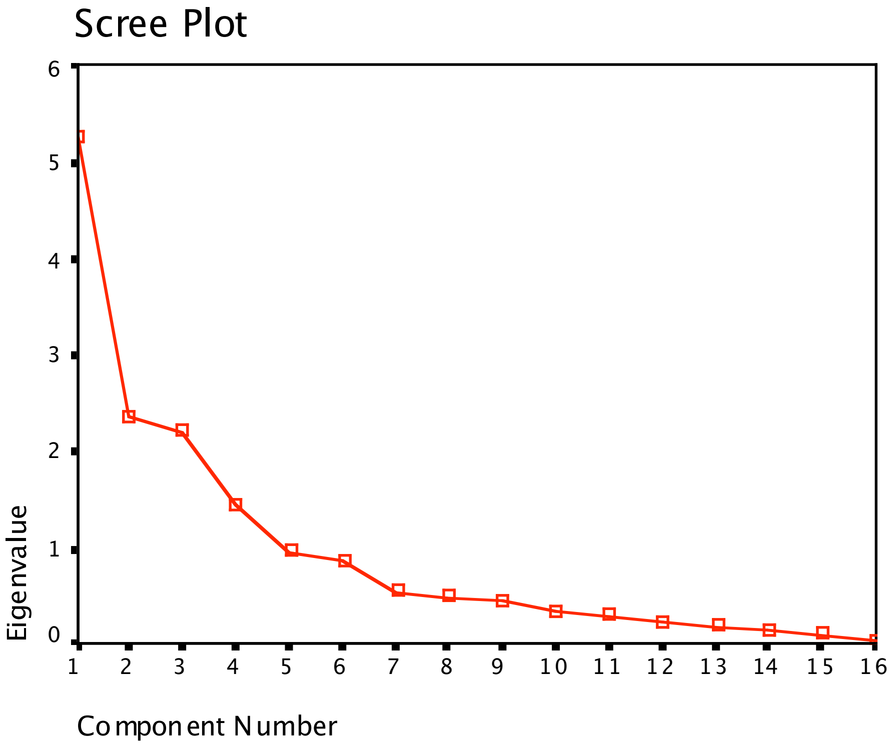
Extraction Method: Principal Component Analysis.

Component Transformation Matrix

Component	1	2	3
1	.997	.061	.037
2	-.070	.924	.376
3	-.012	-.378	.926

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

ALL MEASURES



Component Matrix
a 6 components extracted.

Rotated Component Matrix

	Component					
	1	2	3	4	5	6
CROSSAID	.909					
OFFICEINST	.894					
CROSSW	.727					
RESTCOMM	.716					-.346
PARK_LOT	.714	.314				-.336
PED_FAC		.895				
BUILDHT		.858				
CONNECT_		.858				

	1	2	3	4	5	6
CON_PATH		.551	.313		.354	.426
NO_TREES			.913			
DEG_ENCL			.893			
INDVAC				.831		
BUSSTOP	.470			.750		
INTER34					.806	
TCONTROL	.303				.796	
CLEAN	-.355					.830

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 8 iterations.

Total Variance Explained

	Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %
1	3.916	24.472	24.472
2	2.905	18.158	42.630
3	1.937	12.108	54.737
4	1.629	10.183	64.920
5	1.537	9.606	74.527
6	1.232	7.698	82.224

Extraction Method: Principal Component Analysis.

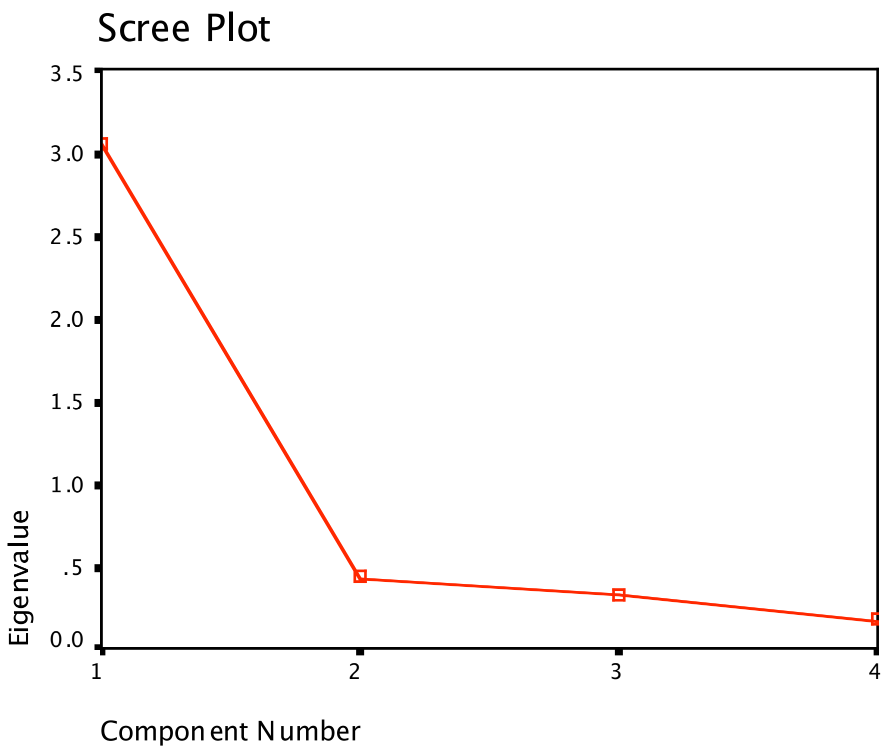
Component Transformation Matrix

Component	1	2	3	4	5	6
1	.789	.545	.172	.162	.091	-.130
2	.267	-.610	.517	-.153	.509	-.087
3	-.385	.312	.520	.476	.265	.433
4	.057	-.227	-.526	.688	.411	-.161
5	-.073	.316	-.352	-.498	.671	.268
6	.387	-.287	-.179	.055	-.207	.831

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

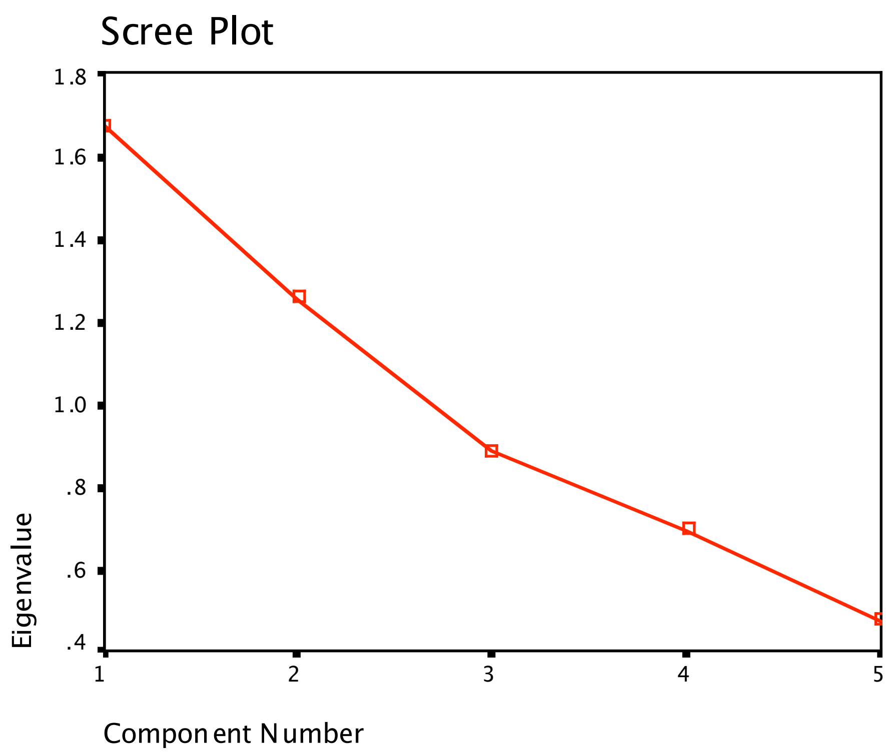
PERCEPTUAL PRINCIPAL COMPONENT ANALYSIS

LAND USE ONLY



Component Matrix
a 1 components extracted.

TRANSPORT ONLY



Component Matrix
a 2 components extracted.

Rotated Component Matrix

	Component	
	1	2
I2	.855	-3.983E-02
I1	.843	-6.067E-02
H1	-.238	.716
H4	-.104	.710
G5	.271	.577

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 3 iterations.

Total Variance Explained

	Rotation Sums of Squared Loadings		
Componen	Total	% of	Cumulativ

t		Variance	e %
1	1.583	31.664	31.664
2	1.354	27.070	58.734

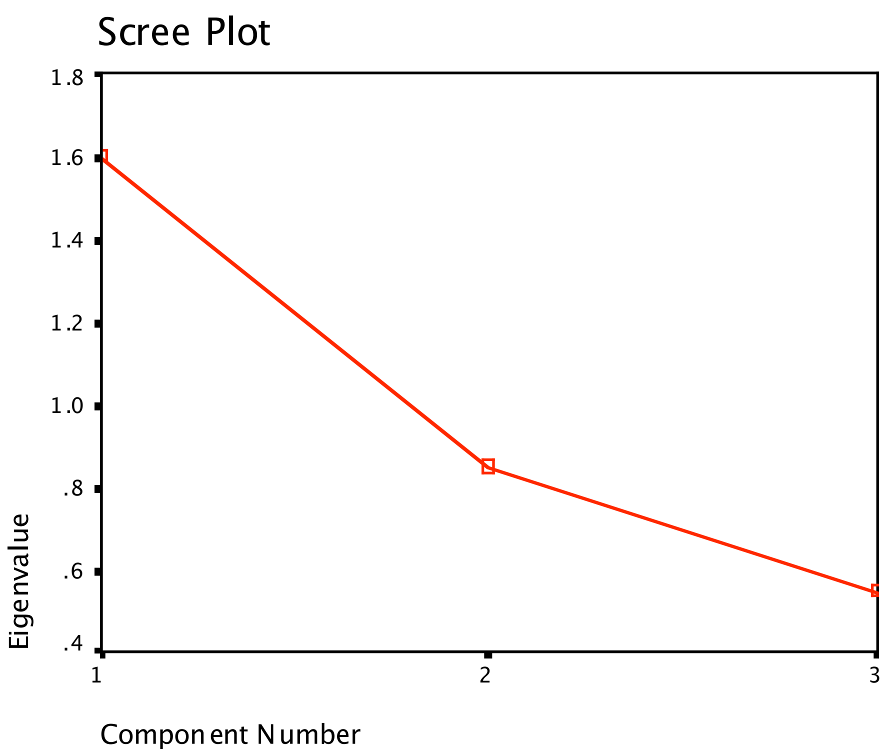
Extraction Method: Principal Component Analysis.

Component Transformation Matrix

Componen t	1	2
1	.881	-.473
2	.473	.881

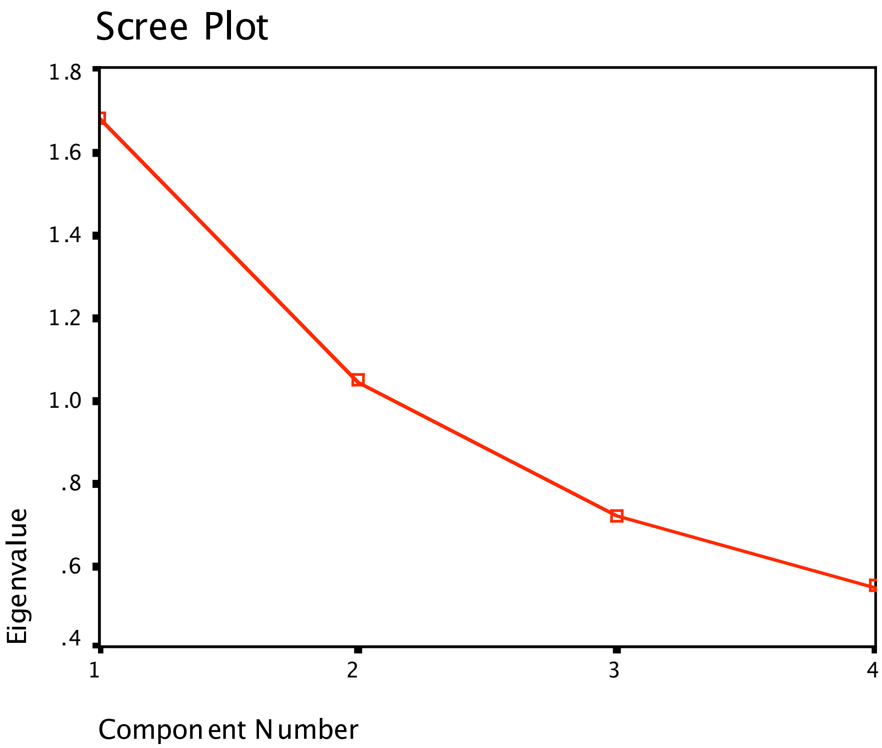
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

SAFETY ONLY



Component Matrix
a 1 components extracted.

AESTHETICS ONLY



Component Matrix
a 2 components extracted.

Rotated Component Matrix

	Component	
	1	2
J2	.874	-4.077E-02
J1	.762	.258
J4	-6.382E-02	.873
J6	.302	.677

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 3 iterations.

Total Variance Explained

	Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %
1	1.441	36.013	36.013
2	1.289	32.219	68.231

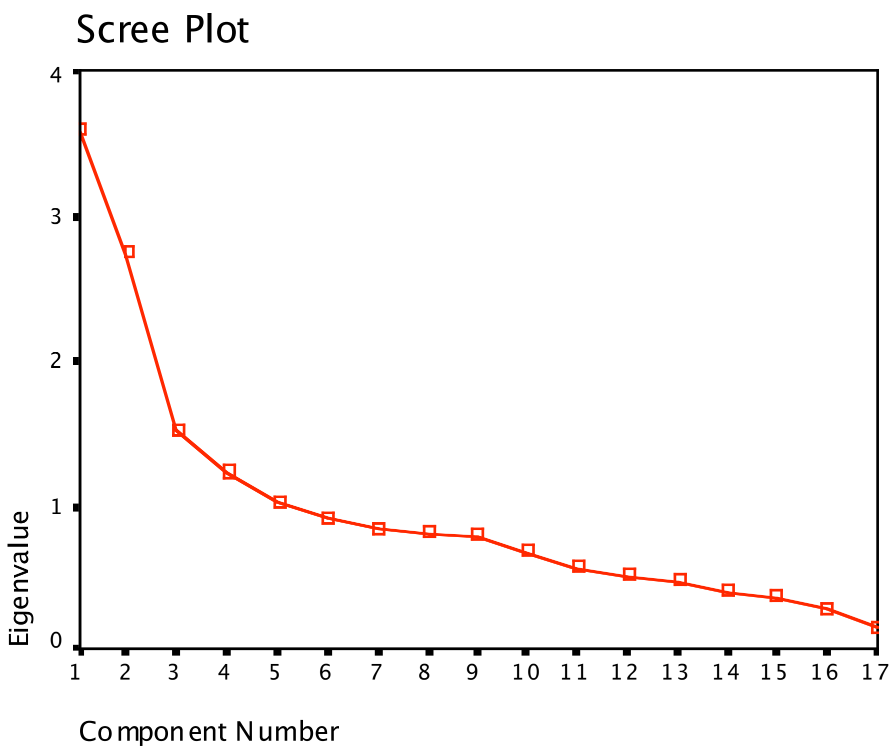
Extraction Method: Principal Component Analysis.

Component Transformation Matrix

Component	1	2
1	.787	.617
2	-.617	.787

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

ALL MEASURES



Component Matrix
a 6 components extracted.

Rotated Component Matrix

	Component					
	1	2	3	4	5	6
G2	.917	7.903E-02	-1.397E-02	2.811E-03	6.187E-02	-4.356E-02
G1	.879	5.782E-02	2.134E-02	-2.718E-02	2.506E-02	8.286E-02
nfacilities	.829	5.760E-02	.125	-4.373E-02	.148	-7.784E-02
G4	.817	8.193E-02	2.735E-02	7.354E-02	.237	-3.809E-02
I2	3.679E-02	.817	-.240	.110	-6.835E-02	-1.090E-04
I1	.167	.806	-5.110E-02	-3.734E-02	-.109	1.951E-02
K5	8.618E-02	5.575E-02	.747	-5.094E-02	-8.410E-02	8.012E-02
K1	7.859E-02	-.238	.725	-.107	.183	-6.827E-02
K2	-3.987E-02	-.176	.592	-.115	2.205E-02	-.299
J2	-3.461E-02	4.534E-04	-.131	.825	8.619E-02	-8.207E-02
J1	1.749E-02	7.460E-02	-9.600E-02	.792	-5.745E-02	.136
H1	8.621E-02	-.211	-.101	-.122	.710	-.250
J3	.129	.283	1.446E-02	.314	.610	.278
H4	.242	-.114	.159	1.586E-02	.601	-4.407E-02
J4	6.818E-02	6.164E-02	-.103	4.746E-02	-.131	.748
G5	.319	.175	5.593E-02	9.961E-02	5.055E-02	-.559
J6	.106	.409	7.863E-03	.312	.244	.531

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 7 iterations.

Total Variance Explained

	Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %
1	3.215	18.910	18.910
2	1.771	10.420	29.329
3	1.588	9.342	38.671
4	1.580	9.292	47.963
5	1.466	8.626	56.589
6	1.438	8.458	65.047

Extraction Method: Principal Component Analysis.

Component Transformation Matrix

Component	1	2	3	4	5	6
1	.916	.230	.075	.099	.303	-.011
2	-.104	.572	-.511	.462	-.132	.412
3	-.192	-.380	.037	.611	.664	.052
4	-.035	.050	.671	-.006	-.071	.736
5	-.163	.466	.531	.410	-.144	-.534
6	-.291	.506	.015	-.485	.651	-.003

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Appendix F: Descriptive Statistics of Survey and Audit Measures

Descriptive Statistics of Audit (objective) Measures

		Bethesda		Forest Glen		Four Corners		Layhill		Olney	
Audit Measure	**Code for each segment**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Office/ Institutional	1 = Present 0 = Not Present	0.28	0.13	0.08	0.10	0.04	0.09	0.03	0.08	0.04	0.08
Restaurant/ Commercial	1 = Present 0 = Not Present	0.24	0.18	0.00	0.00	0.03	0.06	0.00	0.00	0.03	0.10
Industrial/ Vacant	1 = Present 0 = Not Present	0.01	0.02	0.11	0.13	0.02	0.06	0.07	0.10	0.14	0.16
3 or 4 way Intersections	1 = Present 0 = Not Present	0.68	0.14	0.99	0.02	0.96	0.07	0.63	0.22	0.81	0.22
Pedestrian Facilities	1 = Present 0 = Not Present	0.90	0.11	0.75	0.16	0.34	0.14	0.57	0.29	0.89	0.17
Path Condition/ Maintenance	1= Good or Under Repair 0 = Poor or Fair	0.54	0.16	0.67	0.12	0.31	0.15	0.25	0.30	0.62	0.22
Min number of lanes	Continuous	3.25	0.65	2.63	1.03	2.16	0.49	2.26	0.63	2.04	0.17
Parking Lot	0= No 1= Yes	0.27	0.13	0.07	0.04	0.04	0.07	0.02	0.04	0.04	0.09
Traffic control devices	1= traffic light or stop sign or traffic circle or speed bump or chicane/choker 0 = Not Present	0.57	0.18	0.50	0.11	0.59	0.20	0.29	0.27	0.45	0.17
Crosswalks	1= Crosswalks (1-2, 3,-4, >4) 0 = Not Present	0.48	0.18	0.26	0.20	0.11	0.13	0.02	0.06	0.16	0.23
Crossing aids	1= Yield paddle or ped signal or traffic island or over/underpass or ped crossing sign or flashing warning or share the road warning 0 = none	0.09	0.06	0.10	0.16	0.01	0.02	0.04	0.09	0.06	0.07
Tree cover	0= none or very few, 1= some 2= many/dense	0.65	0.15	0.19	0.25	0.13	0.14	0.09	0.14	0.10	0.12

Degree of enclosure	0= little or no enclosure 1= some enclosure 2= highly encl.	0.82	0.20	0.89	0.10	0.73	0.19	0.54	0.30	0.67	0.25
cleanliness & building maint.	0 = Poor or Fair 1= Good	0.90	0.20	0.91	0.14	0.71	0.14	0.68	0.28	0.61	0.36
Building height	0 = Short 1 = Medium or Tall	0.83	0.11	0.97	0.03	0.86	0.10	0.94	0.06	0.92	0.12
Bus Stop	1= Bus stop with shelter, bench or sign only 0=none	0.84	0.11	0.33	0.25	0.01	0.03	0.28	0.35	0.77	0.31

Descriptive Statistics of Survey (perceptual) measures

		Bethesda		**Forest Glen**		**Four Corners**		**Layhill**		**Olney**	
Survey Measure	**Meas.***	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Facilities (distance to 23 amenities)	5 point	3.64	0.43	2.01	0.46	2.55	0.60	2.00	0.56	2.40	0.72
Shopping “can do most of my shopping at local stores”	5 point	3.64	0.61	1.75	0.89	2.46	1.15	1.75	1.06	2.77	1.27
Stores “stores are within easy walking distance of my home”	5 point	3.83	0.43	2.23	1.08	3.01	0.91	2.10	1.08	2.96	1.16
Destinations “ there are many places to go within easy walking distance of my home”	5 point	3.96	0.20	2.39	1.02	3.04	0.96	2.25	1.03	2.99	1.13
Sidewalks “There are sidewalks on most of the streets in my neighborhood.”	4 point	3.62	0.64	2.89	1.04	2.39	1.04	2.80	1.14	3.58	0.72
Sidewalk Maintenance “The sidewalks in my neighborhood are well maintained.	4 point	3.51	0.83	3.23	0.86	3.19	0.86	3.40	0.77	3.82	0.39
Intersections “There are many four-way intersections in my neighborhood.”	4 point	3.17	0.94	2.98	1.05	3.00	0.85	2.07	0.83	1.70	0.92
Cul-de-sac “The streets in my neighborhood do not have many cul-de-sacs.”	4 point	3.57	0.58	3.23	1.03	3.22	0.87	2.23	1.02	2.72	0.99
Bus Stops "It's easy to walk to a bus stop from my home."	5 point	3.89	0.31	3.91	0.47	3.76	0.63	3.56	0.65	3.45	0.91

Traffic/Own Street “There is so much traffic on the street I live on that it makes it difficult or unpleasant to walk in my neighborhood”	4 point	1.98	0.97	1.73	0.92	1.45	0.63	1.44	0.72	1.28	0.59
Traffic/Nearby Streets “There is so much traffic on nearby streets that it makes it difficult or unpleasant to walk in my neighborhood”	4 point	2.47	0.98	2.80	1.05	2.01	0.93	2.05	1.02	1.84	0.89
Traffic Speed “Most drivers exceed the posted speed limit while driving in my neighborhood”	4 point	3.32	0.76	2.88	1.01	2.76	0.94	2.85	0.93	3.26	0.81
Interesting Things “There are many interesting things to look at while walking in my neighborhood”	4 point	3.53	0.65	2.98	0.82	3.34	0.64	2.98	0.79	3.16	0.79
Litter “My neighborhood is generally free from litter”	4 point	3.74	0.57	3.34	0.68	3.55	0.61	3.75	0.47	3.69	0.55
Attractive Buildings “There are attractive buildings/homes in my neighborhood”	4 point	3.45	0.69	3.00	0.65	3.21	0.51	3.44	0.56	3.57	0.60
Trees “There are trees along most of the streets in my neighborhood”	4 point	3.79	0.55	3.75	0.44	3.96	0.21	3.85	0.36	3.82	0.45
Shade “Trees give shade for the sidewalks in my neighborhood”	4 point	3.45	0.72	3.50	0.73	3.78	0.42	3.60	0.62	3.42	0.80
N		**47**		**44**		**67**		**61**		**74**	

*Note: all measures are (1= negative, 4 or 5 = positive)

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