SAFETY AND THERMAL COMFORT CONCERNS FOR ACTIVE TRAVEL TO SCHOOL: AS MEDIATORS AND CORRELATES

A Dissertation

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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December 2014

Major Subject: Urban and Regional Science

ABSTRACT

Children's active travel to school (ATS), considered a regular source of physical activity, is influenced heavily by their parents' perceived barriers to ATS such as safety and thermal comfort concerns. This dissertation focuses on environmental correlates of parental concerns of safety and thermal comfort and of children's ATS to identify effective environmental interventions. This cross-sectional study utilizes data from 4,602 parental surveys from 20 elementary schools in the Austin Independent School District and objectively measured environmental data derived from geographic information systems and a remote sensing program.

In Study 1, environmental correlates of parental safety and thermal comfort concerns were identified. The results from multivariate analyses, ordinary least square regressions for the safety concern outcome variable and stereotype logistic regressions for the thermal comfort concern outcome variable, showed that unsafe and thermally uncomfortable environments increased concerns for safety and thermal comfort. Children of low-income parents were more likely to be exposed to undesirable environments, and thereby their parents had higher safety and thermal comfort concerns.

In Study 2, built and natural environmental correlates of ATS and potential differences in the correlates for different distance ranges were examined. The results from spline regressions identified environmental correlates of ATS: bike lanes (+), playgrounds, parks (+), tree heights (+), highways (-), crash hotspots (-), and steep slopes (-). The negative relationship between distance and ATS was significant until

1.49 miles and was no longer significant beyond 1.5 miles. Furthermore, the varying impacts of environmental variables on ATS across home-to-school distance ranges were also shown in regular regressions.

In Study 3, the mediating roles of safety and thermal comfort concerns in the environment-ATS relationship were examined using structural equation models (SEMs). In the safety SEM model, social support (+), intersections (-), crime (-), and bike lanes (+) were indirectly associated with ATS through its relationship with safety concerns. In the thermal comfort SEM model, perceived tree shadiness (+) was directly associated with lower parental thermal comfort concerns and indirectly increased the probability of ATS. In both SEM models, the objectively-measured tree canopy variable was shown to be a strong facilitator of ATS, directly reducing both parental concerns.

This dissertation research provided additional knowledge about parental safety and thermal comfort concerns as important barriers to children's ATS; showed specific environmental factors contributing to increase or decrease those concerns; and explored their important roles as mediators in the environment-ATS relationship. Furthermore, findings of this study suggested that effective environmental intervention strategies should consider different home-to-school distance ranges.

DEDICATION

To my parents and my four sisters

for their endless love, support and encouragement

ACKNOWLEDGEMENTS

Foremost, I would like to express my deepest appreciation to my chair, Dr. Chanam Lee, for her patience, encouragement, and guidance throughout my study. She has always led me into the way where I could grow as a researcher. I want to tell her that I have been truly happy and fortunate to have worked with her and the time that I have spent in the Design Research for Active Living Lab for the last five years has been such an honorable and valuable experience that I can't ever repay her.

I also thank my committee members, Dr. Xuemei Zhu, Dr. Andrew Klein, and Prof. Bruce Dvorak for their immense knowledge, critical points, and excellent feedback on my dissertation analyses. Without their assistance, I would not be able to complete this dissertation successfully. I want to extend my gratitude to team members in the lab for sharing statistical analysis ideas and working together on many research projects.

Most importantly, I would like to express my sincere appreciation to my parents and my four sisters for their encouragement, trust, sacrifice, and endless love. Thank you for always being there for me and listening to my voice.

NOMENCLATURE

ATS	Active Travel to School
AISD	Austin Independent School District
CHM	Canopy Height Model
DEM	Digital Elevation Model
DOQQ	Digital Orthophoto Quarter Quads
DSM	Digital Surface Model
HTS	Home to School
LIDAR	Light Detection and Ranging
NDVI	Normalized Difference Vegetation Index
SRTS	Safe Routes to School
WTS	Walking to School

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1. INTRODUCTION

1.1 BACKGROUND

In the US, among the most important public health concerns are childhood overweight and obesity (Centers for Disease Control and Prevention, 2008; C. L. Ogden, Flegal, Carroll, & Johnson, 2002). Many reasons may account for the increase in childhood obesity, but one key factor is a lack of daily exercise. One opportunity that could contribute to increasing children's daily exercise is active travel (i.e., walking or bicycling) to school. Several studies have shown the roles of children's active travel to school (ATS) in increasing their daily physical activity and thereby improving health conditions (Davison, Werder, & Lawson, 2008; Faulkner, Buliung, Flora, & Fusco, 2009; Napier, Brown, Werner, & Gallimore, 2011; Southward, Page, Wheeler, & Cooper, 2012). Despite the health benefits of ATS, the percentage of children who engage in walking or bicycling to school has dramatically declined over the last few decades, from 47.7% in 1969 to 12.7% in 2009 (N. C. McDonald, Brown, Marchetti, & Pedroso, 2011).

Children usually cannot participate in ATS without their parents' permission. Therefore, addressing parental factors, such as their perceived barriers to their children's ATS, are important determinants of children's participation. According to the Centers for Disease Control and Prevention (CDC), the top three deterrents of walking to school ranked by parents are long distance to school, crime or traffic related safety concerns, and weather (thermal comfort) concerns (Centers for Disease Control and Prevention, 2002). Unlike such barriers as long distance, which require long-term, multi-level interventions, safety and thermal comfort concerns can be addressed with relatively feasible environmental interventions (Lee et al. 2013, Abiodum et al. 2014). For example, street trees, walkway surface materials, and landscaped buffers, if proven effective to reduce safety and thermal concerns, are considered more manageable interventions than zoning laws or school siting policy changes which are necessary to address the long distance barrier (Mayer, Kuppe, Holst, Imbery, & Matzarakis, 2009; Shashua-Bar, Pearlmutter, & Erell, 2011). It seems to make logical sense to start with more readily modifiable improvements that are still shown to help lift or reduce some of the major barriers to ATS.

Most previous empirical studies on environmental correlates of children's ATS focused on 'built' environmental characteristics such as land use mix, sidewalk availability, traffic volume, school location, and neighborhood quality (Larsen et al., 2009; Panter, Jones, Van Sluijs, & Griffin, 2010b). In contrast, little evidence is available on the roles of the 'natural' environment (green space, tree-canopy, temperature, etc.) in promoting ATS. As such, studies examining both built and natural environmental correlates of children's ATS are necessary to provide a more complete understanding of environmental factors associated with ATS and to propose more effective strategies for environmental interventions to encourage ATS.

In terms of dealing with the distance effect on ATS, which has been identified as the strongest predictor, a large number of studies have shown a consistently negative relationship between long distance and ATS (C. Lee, Zhu, Yoon, & Varni, 2013; N. C. McDonald, 2008a; R. Mitra, Building, & Roorda, 2010; Napier et al., 2011; Rodriguez

& Vogt, 2009; Schlossberg, Greene, Phillips, Johnson, & Parker, 2006; Su et al., 2013; Yarlagadda & Srinivasan, 2008; Yelavich et al., 2008; Zhu & Lee, 2009). Most previous studies using a home-to-school (HTS) distance variable assumed a continuous linear association with ATS, and little has been explored when it comes to the potentially varying effects of different HTS distance ranges on ATS. One study used a categorical distance variable with four different distance range categories, instead of a continuous distance variable, <1 mile (reference category), 1 to <1.5 miles, 1.5 to <2.5 miles, and 2.5+ miles, to examine their relationships with ATS (Schlossberg et al., 2006). This study showed that children living in longer distance ranges (1 to <1.5 miles, 1.5 to <2.5 miles, and 2.5+ miles) were less likely to walk to school than children living less than one mile from school (Schlossberg et al., 2006), which simply confirmed what the previous studies have reported on the distance's effect on ATS. If and how the impacts of different distance ranges on ATS vary require further exploration. It is possible that the roles of distance within a certain distance range may be stronger or weaker than in other ranges, and beyond a certain distance threshold, distance no longer has a significant impact on walking at all as it is well beyond a walkable distance by any children. Studies identifying potentially different associations between distance ranges and ATS can help identify proper target groups of children to more feasibly promote ATS as well as a proper distance standard for school bus service.

Furthermore, empirical knowledge is limited about the roles of parental concerns about safety and thermal comfort as mediators in the built/natural environment-ATS relationships because, as mentioned above, parents perceived those as the most significant barriers to ATS after the distance factor. Also, no matter how good the safety and thermal comfort conditions are along HTS routes, children's ATS cannot be achieved if children live too far from school. Therefore, it is necessary to control the undue influence of distance when examining whether parental safety and thermal comfort concerns play a mediating role between the built/natural environments and ATS.

In sum, this dissertation considers several critical issues important to successfully promote children's ATS that have been insufficiently examined in previous studies, which include (1) correlates of parental safety and thermal comfort concerns, (2) the consideration of natural environment in examining environment-ATS relationships, (3) the different roles of HTS distance ranges in affecting ATS, and (4) the mediating effects of parental safety and thermal comfort concerns in the environment-ATS relationships. This dissertation also explores the spatial variations of built and natural environmental risks by income status that may affect parental perceptions of safety and thermal comfort and children's ATS behaviors. Findings from this dissertation will contribute to developing community-specific interventions that promote ATS and active lifestyles among children and families.

1.2 OBJECTIVES AND SIGNIFICANCE

The objective of this dissertation research is to assess the associations that the built and natural environments have with both parental safety and thermal comfort concerns and with children's ATS behaviors. This research uses parental surveys and objectively measured environmental data from 20 elementary schools in Austin, Texas, collected as part of a larger project supported by the Robert Wood Johnson Foundation. The data on natural environment has been newly collected for this dissertation study, from geographic information system (GIS) and remote sensing software. Utilizing these rich primary and secondary data, this dissertation investigates the following specific objectives.

Objective 1: To examine associations between built/natural environments and parental concerns about safety and thermal comfort. The main objective of this study is to identify which built and natural environmental factors are associated with parental safety and thermal comfort concerns, which were the second and the third most frequently reported barriers to ATS after the long distance barrier (Centers for Disease Control and Prevention, 2002). This study further investigates the disproportionately distributed environmental risk factors related to safety and thermal comfort by income status. The following three hypotheses are developed to address this objective:

- Hypothesis 1: Walking friendly built environments and thermally comfortable natural environments will be associated with decreased parental safety and thermal comfort concerns.
- Hypothesis 2: Low-income parents are more likely to be exposed to undesirable built and natural environments, and thereby will have higher concerns for safety and thermal comfort.

- Hypothesis 3: Positive behaviors and attitudes toward walking and positive social supports will be associated with decreased parental safety and thermal comfort concerns.

Objective 2: To examine associations between built/natural environments and children's ATS behaviors, and the effect of different HTS distance ranges on ATS. The objective of this study is to identify the effects of built and natural environmental variables on children's ATS behaviors and to examine the potentially varying effects of different HTS distance ranges on ATS. This study also examines the potentially different relationships of built/natural environmental variables with ATS at different HTS distance ranges. The following three exploratory hypotheses are developed to address this objective:

- Hypothesis 1: Unsafe and thermally uncomfortable built/natural environments will be associated with lower levels of ATS.
- Hypothesis 2: Each HTS distance range variables will have different impacts on ATS (shorter distance ranges will have stronger impact on ATS).
- Hypothesis 3: The relationship between built/natural environments and ATS will vary by the distance ranges.

Objective 3: Examine the mediating roles of parental safety and thermal comfort concerns in the environments-ATS relationships. Focusing on the students living within a walkable distance of their schools, this objective examines whether parental safety concerns and thermal comfort concerns play significant mediating roles in the built/natural environments-ATS relationships. The following three hypotheses are developed for this objective:

- Hypothesis 1: Objectively-measured built and natural environments will be directly associated with parental safety and thermal comfort concerns and indirectly associated with ATS.
- Hypothesis 2: Longer HTS distances will be associated with increased parental safety and thermal comfort concerns for ATS.
- Hypothesis 3: Positive attitudes toward walking and positive social support will decrease safety and thermal comfort concerns, and promote children's ATS.

This dissertation research aims to make several contributions to the field of environment and human behavior studies. First, it systematically evaluates the effects of the built and natural environments on parental perceived barriers to children's ATS. Second, it contributes to developing effective and feasible intervention strategies to improve children's ATS behaviors by examining modifiable built and natural environmental factors. Third, it identifies the potential varying roles of HTS distance ranges on ATS, which will guide the development of effective interventions for proper target groups and provide cues for school bus policy. Fourth, it examines parents' perceptions of safety and thermal comfort as mediators between environment-ATS relationships; such a consideration facilitates a better understanding of the nature and mechanism of the relationships.

1.3 STRUCTURE OF THE DISSERTATION

Section 1 of this dissertation includes the background, objectives, and significance of this dissertation research. Section 2 is the literature review discussing the benefits of ATS and several relevant theories from health behavior change literature, and summarizing previous work about parental perceived barriers to ATS, safety and weather concerns, as the main determinants that need to be adjusted to efficiently promote children's ATS. Section 2 to further goes over a large number of previous empirical studies to classify correlates of ATS into personal and social factors, built environmental factors, and natural environmental factors. Section 3 establishes the research foundation for the empirical investigation of this dissertation research, proposing a conceptual framework, introducing the study area and population, and presenting data collection methods and measures. Section 4 focuses on Study 1 examining the associations between built/natural environments and two major parental concerns (safety and thermal comfort) on children's ATS. Section 5 focuses on Study 2 which examines the built and natural environmental correlates of children's ATS. Section 6 focuses on a subset of data for the students living within a walkable distance of school to examine the mediating roles of parental safety and thermal comfort concerns in the environment-ATS relationships. For each study in Sections 4 through 6, the conceptual framework, introduction, research design, analytical methods, results, conclusion, limitation, and discussion sub-sections are included. Section 7 summarizes the main conclusions from each study, overall contributions of this dissertation research, and implications for the development of environmental and policy interventions.

2. LITERATURE REVIEW

The literature review covers a broad range of theoretical and practical issues related to children's active travel to school behaviors and deals with several fundamental points that need to be considered for building a healthy environment for school-aged children. The literature review consists of the following sections: (1) benefits of ATS, (2) theoretical approaches to health-related behavioral changes, (3) perceived barriers to ATS, (4) correlates of ATS, and (5) summary.

The first section of the literature review addresses benefits that can be gained from walking or bicycling to school, which are primarily related to weight management and physical activity.

The second section describes behavioral and social science theories associated with health-related behavior changes that are most commonly used in the previous ATS studies. The theories address key factors relevant to promoting healthy behaviors from individual, social, and environmental points of view. Furthermore, several empirical studies related to the theories of health behavior are reviewed, followed by an explanation of the concepts of the theories. This section also points out several issues that the behavioral theories overlook when addressing children's behavioral changes.

The third section focuses on the major parental perceived barriers (safety concerns and thermal comfort concerns) to children's active travel to school behaviors, which have not been examined sufficiently in previous studies. Especially, this section explains why weather or thermal comfort is important to consider when promoting outdoor activities among school-aged children like walking to school, and discusses what modifiable environmental features contribute to increasing thermal comfort levels. Further, this section also deals with the potential impacts of the natural environment on BMI and physical activity, which have not been fully examined in the previous empirical studies related to children's ATS.

The last part of the literature review focuses on the previous empirical studies dealing with the individual, social, and built and natural environmental correlates of children's ATS behavior.

2.1 BENEFITS OF ACTIVE TRAVEL TO SCHOOL

Previous empirical studies targeting adult populations have shown that moderate physical activities such as walking and bicycling have significant health benefits by decreasing long-term mortality risks (Kujala, Kaprio, Sarna, & Koskenvuo, 1998) and chronic diseases such as diabetes (F. B. Hu et al., 1999). Compared to strenuous physical activities such as aerobic exercise and playing tennis or golf, which involve expenses for fees, etc., or require a significant time commitment, walking and bicycling are readily accessible and easy to engage in by adults and children for utilitarian, exercise, and leisure purposes. Daily commuting behaviors such as walking to school offer valuable opportunities for children to increase their daily physical activity levels.

A number of studies regarding the benefits of children's ATS (e.g. walking or bicycling to school) have identified the contribution of ATS to increasing overall daily physical activity levels (Davison et al., 2008; Faulkner et al., 2009; Southward et al., 2012). Further, a study by Cooper et al. (2003) reported that children who walked to school were more likely to engage in physical activity after school and throughout the evening than those who were driven to school (712.0±206.7 vs. 629.9±207.2 accelerometer counts per minute, $p=0.05$). Similar findings from a study based on a sample of 1,518 Filipino adolescents indicated that the amount of energy expenditure generated by physical activity was higher for children who walked to school than those who used motorized transport (44.2 kcal/day for male adolescent, $p<0.001$; 33.2 kcal/day for female adolescents, $p<0.001$) (Tudor-Locke, Ainsworth, Adair, & Popkin, 2003). Alexander et al. (2005) also examined the differences in daily minutes of moderate to vigorous physical activity (MVPA) between two groups ("students who used motorized travel modes (car, bus, or train) both ways" versus "students who walked both ways" to and from school) for the following time periods: entire weekday, school day, morning break, lunch break, and outside school. The results showed that students who walked both ways accrued on average 25.9 more minutes of MVPA on weekdays, 8.9 more minutes of MVPA on school days, 6.0 more minutes of MVPA on lunch breaks, and 17.0 more minutes of MVPA outside school than those using inactive travel modes both ways.

In terms of the effects of children's ATS on their health, especially BMI, the results of previous studies were inconsistent. Most previous studies have shown insignificant results (Cooper, Andersen, Wedderkopp, Page, & Froberg, 2005; Cooper et al., 2003; Cooper et al., 2006; Ford, Bailey, Coleman, Woolf-May, & Swaine, 2007; Loucaides & Jago, 2008; Metcalf, Voss, Jeffery, Perkins, & Wilkin, 2004; Saksvig et al., 2007; Sirard, Riner, McIver, & Pate, 2005; Tudor-Locke et al., 2003). However, a few studies showed significant associations between children's ATS and BMI. One study assessed the differences in BMIs measured at baseline and the change in BMIs over two years between an active commuting (walking, bicycling, and skateboarding) to school group and a non-active group, using 1,083 students in the fourth grade and 924 students in the fifth grade (Rosenberg, Sallis, Conway, Cain, & McKenzie, 2006). The results showed that boys in the fourth grade who actively commuted to school had lower BMIs than those using non-active travel modes, but changes in BMIs over two school years were not statistically different between the two travel groups among boys and girls. A study utilizing a regression analysis showed that although a small sample (N=146) was used due to many missing cases of the BMI variable, children's walking to school behavior was associated with decreased BMIs after controlling for parents' education, homeownership, number of rooms in the home, parents' preference on their children's walking to school, whether it is a walkable vs. less walkable community, and network distance to school (Napier et al., 2011). Their study also showed that adding the BMI variable improved the overall model fit, holding other variables' significance consistent.

In summary, children's ATS has the benefit of increasing their overall physical activity levels, but whether or not it contributes to decreasing children's body weight is not clear. Children's BMIs are affected by both physical activity and diet. Thus, the lack of a consistent link between BMI and ATS may contribute to the lack of diet variables in previous studies.

2.2 THEORIES OF HEALTH-RELATED BEHAVIOR CHANGE

How to effectively promote people's active behavior has been one of the critical issues for researchers, and a broad range of factors including personal, social, and physical environments have been considered in conjunction with the theories related to behavior change. In this section, selected health behavior theories are discussed which guided the development of a conceptual framework for this dissertation study.

2.2.1 Learning Theories and Health Belief Model

One of the individual-level behavior change theories that can offer some helpful insights for this dissertation is the learning theory. Learning theories emphasize the consequences of behavior, which can induce the behavior again later (Skinner, 1965). According to Skinner, human behavior is reinforced by receiving rewards as a result of the behavior. Individual pleasure or satisfaction after a certain behavior can be an example of rewards (Skinner, 1965). However, it is not easy for beginners to achieve a daily exercise such as bicycling or jogging and to change their life styles from inactive to active within a short time period. In this sense, Skinner emphasized that human operant behavior needs to be shaped by a continuous and gradual process. Health-related behavior can be established first with a small amount of activity and then maintained or reinforced by learning or understanding many of the benefits resulting from an active behavior, which is called "rewards" in learning theories. Rewards or incentives given for health-related behavior accomplishment include physically looking better, developing self-gratification or proudness, and receiving praise from others (Manley, 1996).

Another theory focusing on the individual aspects is the Health Belief Model which has been frequently employed in explaining the associations between individual perceptions and behavior changes. This model's concepts underline individual perceptions in terms of (a) concerns about becoming ill, (b) severity of an illness for a given behavior, (c) benefits from behavior changes, and (d) barriers to implementing a health action (Hochbaum, 1958; Rosenstock, 1960). In addition to the individual beliefs, the Health Belief Model includes 'cues to action' in the conceptual framework. The concept of cues to action is based on the belief that taking an action can be instigated by bodily events such as media publicity (i.e., a poster or a reminder to oneself) (Champion & Skinner, 2008).

Few empirical studies on the heath belief model, however, have been conducted because it mainly focuses on the individual perception and self-regulation. Even though the health belief model incorporated cues to action, the element has not been sufficiently examined because of measure limitations (Champion & Skinner, 2008). In a study to investigate the efficiency of self-management instruction in an aerobics class, a total of 105 respondents were surveyed (Owen, Lee, Naccarella, & Haag, 1987). To check the effects of the efficiency of the interventions, a single package with instructions for self-management was given to the intervention group and was not provided to the control group. Results showed that there was no significant difference in physical activity levels between the two groups (Owen et al., 1987). This result may reveal a limitation of the health belief model for targeting only individual perception and self-regulation. That is why this theory has not been sufficiently examined in empirical studies. Behavior change operates in more complex relationships beyond individual perception.

2.2.2 Social Support and Social Cognitive Theory

Social learning theories including social support and social cognitive theory should be included when addressing the social aspects of behavior change. Social support includes four functional types of support that can bring about behavioral changes: (a) emotional- emotional encouragement to take an action, (b) instrumental- suggestion of possible services that can be directly used, such as a program, (c) informational- provision of advice about the importance of healthy behavior, and (d) appraising- provision for feedback that can provide incentives for a given behavior and a self-evaluation check (Cooper et al., 2005; Worsley & Crawford, 1985). In social science theories, social cognitive theory is the main application because it deals with self-efficacy and outcome expectation concepts that are most important in taking an action (Bandura, 1986). Self-efficacy indicates that people have a willingness to take an action even if some personal or environmental conditions hinder their action (i.e., long distance, hot weather, low safety, high traffic volume, etc.) (Bandura, 1989). Outcome expectations are the consequences expected for changing health-related behaviors, such as body weight loss, self-satisfaction, and improvement of social cohesion (Bandura, 2004). Further, the social cognitive theory also emphasizes the concept of observational learning from the activities of neighbors and peers (Bandura, 1986).

On the topic of social learning theory in empirical studies, many researchers have examined the effectiveness of self-efficacy and social support for behavior change. McAuley and colleagues (1994) examined the utility of self-efficacy as an intervention to prove whether it is associated with the encouragement of children's walking behavior. One intervention group of children received the efficacy-based information on "mastery accomplishments, social modeling, social persuasion, and physiological response," and a control group did not receive this information. This study discovered that self-efficacy information plays an important role in promoting children's walking (McAuley et al., 1994). In another study conducted by Owen and colleagues (Owen, Bauman, Booth, Oldenburg, & Magnus, 1995), messages such as mass-media-based campaigns to promote walking were used to examine whether people who were aware of the messages were walking more compared to their counterparts. The study showed that messages play a significant role in promoting walking among older adults (Owen et al., 1995). Outcome expectations, a central construct in social cognitive theory, have frequently been tested for the relationships with behavior changes. Several studies showed the positive relationships of outcome expectations (perceived benefits) with physical activity (Resnick, 2000, 2001; Williams & Bond, 2002), while one study showed insignificant results (James F Sallis, Hovell, Hofstetter, & Barrington, 1992).

2.2.3 Social Ecological Theory

To the concept of individual perception and the influence of social support, social ecological theory added the elements of physical environments as well as policy or institutional factors for a better understanding of behavior change (McLeroy, Bibeau, Steckler, & Glanz, 1988). The initial social ecological theory conceptualized the environmental impacts on human behavior into multiple levels such as micro-system (individuals' interactions), meso-system (groups' interactions), exo-system (social structures), and macro-system (cultural beliefs) (Bronfenbrenner, 1977). However, this conceptual model merely showed how human behavior was associated with social influences, with less attention paid to the influence of physical environments. Later, the social ecological theory for health promotion added to the initial model the environmental and institutional influences on health behavior change, dividing them into the five categories: (a) intrapersonal factors, involving individual demographics or body condition (b) interpersonal factors, interacting with family or peer influences (c) community factors, affected by social groups (d) institutional factors, as in providing organizational events such as a school walking program, and (e) policy factors, as in establishing regulations for enhancing healthy behavior (McLeroy et al., 1988). Because the social ecological theory synthetically deals with every aspect of factors related to behavior change, a conceptual framework based on this theory has been popularly utilized in the public health and planning fields since its initial introduction (Stokols, 1992).

Based on the basic concepts of the social ecological theory, a broad range of empirical studies related to children's WTS behavior has been conducted. In terms of interpersonal factors such as parental support and peer influences, several studies showed a positive relationship with children's WTS (Hohepa, Scragg, Schofield, Kolt, & Schaaf, 2007). Regarding community factors, several studies have addressed the role of neighborhood social cohesion and community groups in promoting children's WTS behavior (N. C. McDonald, 2007; Ward et al., 2007). Further, in a study to identify the efficiency of institutional or policy factors, pre-post evaluation surveys were conducted with a sample of 1,244 parents at 10 elementary schools in California (Boarnet, Anderson, Day, McMillan, & Alfonzo, 2005). Their results showed that Safe Routes to School legislation improved the actual built environmental conditions such as sidewalks, crossings, and traffic control, which in turn encouraged more children to walk to school.

One important thing to be addressed in the social ecological model is that several basic environmental settings or behavior patterns can be detrimental to people in a low socioeconomic status (J. F. Sallis & Owen, 1999), and more consideration for this situation is necessary. If the social and environmental conditions hindering health-related behavior are concentrated in a minority area or one with a vulnerable population, the problems can become more serious because these people are less likely to be aware of how problematic their current health-related behavior is (Worsley & Crawford, 1985) and chances for them to obtain modifiable knowledge on risk factors are very limited (Halloran, Dunt, & Young, 1993). Therefore, it is necessary to understand the environments of specific high-risk groups, in which many social and physical environmental conditions are not well built to foster healthy behaviors.

2.3 PERCEIVED BARRIERS TO ACTIVE TRAVEL TO SCHOOL

When connecting the ideas of the behavioral change theories mentioned in the previous section to children's behaviors, one needs to be careful because unlike adults who can freely make their own decisions, children's behaviors are determined primarily by parents or other adult guardians. Therefore, it is essential to understand what parents perceive as barriers to their children's active travel to school.

According to a report by the Center for Diseases Control and Prevention in 2002 (Centers for Disease Control and Prevention, 2002), unsafe conditions (related to traffic and crime) and adverse weather conditions were the most frequently reported by parents as barriers to their children's walking and biking to school, after the distance barrier (Figure 1). To modify the long distance factor which is the top barrier to ATS, it requires a zoning code change and/or adjustment of school siting policies which tend to take a long time and require coordinated efforts by multiple agencies/sectors. However, parental concerns of safety and thermal comfort can be relatively easily modified for more immediate results. Therefore, a comprehensive understanding of the ATS behavior mechanisms related to perceived safety and weather barriers require further attention as they can lead to the development of more immediately implementable interventions to increase the proportions of walking or bicycling trips to school.

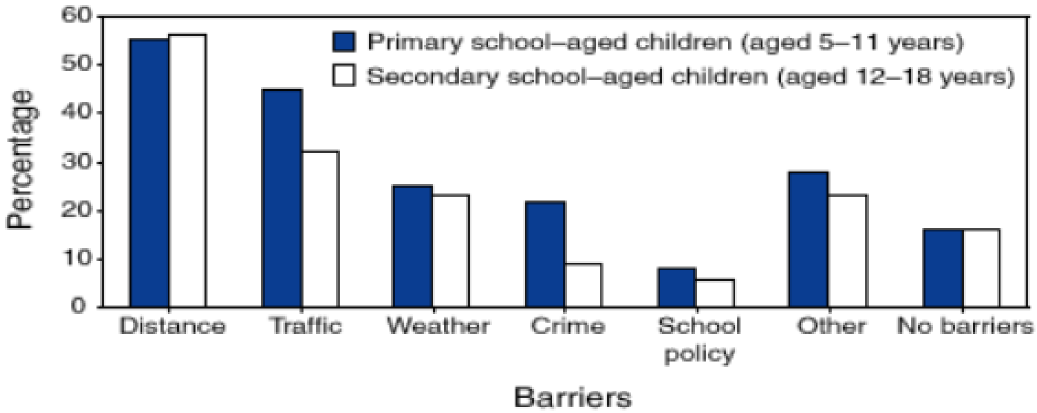


Figure 1
Parents' Perceptions of Barriers to Children's Active Travel to School
Source: HealthStyles Survey, as reported in the Centers for Disease Control and Prevention 2002, pp.701–704.

2.3.1 Significance of Safety Concerns

Many ATS studies revealed a negative relationship between parental safety concerns and children's ATS. Safety concerns include traffic concerns (C. Lee et al., 2013; Tracy E McMillan, 2007; Panter, Jones, van Sluijs, & Griffin, 2010a; Anna Timperio et al., 2006), perceptions of an unsafe neighborhood (Fulton, Shisler, Yore, & Caspersen, 2005; Tracy E McMillan, 2007; Panter et al., 2010a; Rodriguez & Vogt, 2009; Voorhees et al., 2010), traffic volume (Giles-Corti et al., 2011; Su et al., 2013), safety concerns used as a factor variable (Napier et al., 2011; Zhu & Lee, 2009), and crime concerns (Panter et al., 2010a). The following studies show the detailed results regarding the relationships between parental safety concerns and children's ATS.

A cross-sectional study of 2,064 children aged 9-10 years from schools in the UK showed the relationships between parental perceptions of traffic and crime dangers and their children's ATS, which were stratified into three distance ranges (<1 km, 1-2 km,

>2+ km) (Panter et al., 2010a). The study showed that children living within 1 km or 1-2 km radius of schools were less likely to walk or bike to school if their parents worried about dangerous traffic en route to school.

In a study by Timperio and colleagues (2006) it was reported that children whose parents perceived 'few other children in the neighborhood' and 'no lights or crossings' were less likely to engage in ATS. This study suggested that providing perceptions of safety by taking advantage of an initiative such as "Walking School Bus," which may help provide social support and safety, as well as creating a walking-friendly environment such as pedestrian crossings or traffic wardens is necessary to alleviate parental safety concerns and facilitate active trips to school (Anna Timperio et al., 2006).

In addition to the associations of parental safety concerns with ATS, parental perceptions about neighborhoods have been dealt with in children's walking or bicycling trips to local destinations. In a study of children aged 5-6 years (n=291) and 10-12 years (n=919) from 19 schools in Australia, 10- to 12-year-old boys were less likely to walk or bicycle to local destinations if their parents had concerns about 'no lights or crossings' (A. Timperio, Crawford, Telford, & Salmon, 2004). The study also identified that parental perceptions of "have to cross several roads" were negatively associated with the likelihood of active transport to local destinations among 10- to 12-year-old girls.

In sum, parental concerns of traffic and crime dangers have played a significant role in parents making a decision to allow or not to allow their children to actively travel to school as well as to local destinations. Therefore, finding ways to decrease parental concerns about traffic and crime dangers are necessary to increase the likelihood of children's participation in active school travels. Several insights for doing this may be found from the aspects of neighborhood environments because parental safety perceptions are usually affected by surrounding neighborhood conditions (Austin, Furr, & Spine, 2002). The potential neighborhood environment that may contribute to helping shape parental safety perceptions include the actual crime and crash incidents; undesirable infrastructure, such as unsafe crossings, lack of sidewalks, highway presence, and high traffic volume or high speed limits; and their perception, knowledge, and attitude about safety related issues. Thus, public health and comprehensive planning should address such environments associated with parental safety concerns to facilitate active journeys to school.

2.3.2 Significance of Thermal Comfort Concerns

Weather sometimes acts as a barrier to outdoor activities due to uncomfortable environmental conditions (e.g. too hot or too cold). The term 'thermal comfort' indicates the level of pleasantness or unpleasantness in the weather when participating in outdoor activities. The thermal comfort levels are affected by climate conditions such as air temperatures, wind speeds, humidity, and solar radiation (Givoni et al., 2003) and can be improved by physical environments such as trees, grass, and shading devices on building's facades (Ali-Toudert & Mayer, 2007). Thus, this dissertation focuses on using the term 'thermal comfort' rather than 'weather' as it is related to psychological adaptations to outdoor activities and time of exposure and can be adjusted by physical environmental improvements. Under uncomfortable thermal conditions such as very high or low temperatures outside, parents might not allow their children to engage in outdoor activities. Like the results of the CDC report released in 2002 (Figure 1), the ConsumerStyles surveys from the CDC also reported that parental thermal comfort concerns (no protection from the weather) was ranked third after distance to school and traffic-related dangers as barriers to children's walking to or from school (Figure 2) (Centers for Disease Control and Prevention, 2005). For parents whose children walked to or from school at least once per week during a usual week, however, the weather barrier was most significantly reported (Figure 2) (Centers for Disease Control and Prevention, 2005). This indicates that these parents were of more concerns about their children not being protected from the weather than about traffic- or crime-dangers and distance. Therefore, it is necessary to understand the importance of weather or thermal comfort in relation to walking behavior and what environmental factors or features can increase the thermal comfort level.

According to Belkin et al. (1995) and Armstrong (2004), sun exposure causes skin cancer due to high amounts of ultraviolet radiation and it is more serious in childhood. Children are at a high risk for sunburn, which can lead to skin cancer such as melanoma later in life (Lew, Sober, Cook, Marvell, & Fitzpatrick, 1983; Weinstock et al., 1989). Further, because children have a greater heat transfer between the environment and the body (Blum, Bresolin, & Williams, 1998) and easily ignore the significance of heat-related problems, providing them with thermally comfortable environments is important to ensure their health and safety outdoors.

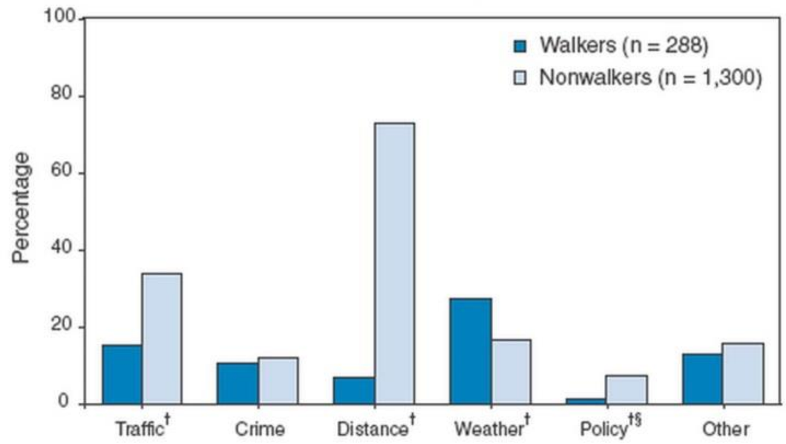


Figure 2
Percentage of Parents Reporting Barriers to Children's Walking to or from School, by Walkers and Non-Walkers
Source: ConsumerStyles Survey, as reported in the Centers for Disease Control and Prevention 2005, pp.949–952.

Thermal comfort, which is normally affected by thermal temperature (Givoni et al., 2003), can be decreased by overexposure to the sun and increased by exposure to green environments. To uncover the details of the associations between heat stress and environmental conditions, several quantitative studies were conducted utilizing the level of human thermal comfort. As one of the environmental interventions to mitigate uncomfortable weather conditions and improve human thermal comfort, the positive effects of street trees and grass have been documented (Mayer et al., 2009; Shashua-Bar et al., 2011). Further, the shading effect of a tree has been shown to increase with older and taller trees with a wide canopy (Picot, 2004). The greater tree shade also helps in sidewalk maintenance because it reduces pavement fatigue cracking, rutting, shoving, and other distress to the surface (McPherson & Muchnick, 2005) and therefore it helps provide pedestrians with better walking conditions.

Through many studies, it has been proved that children's outdoor activities are strongly associated with the natural environment (Ingunn Fjørtoft, 2001), green spaces (Wheeler, Cooper, Page, & Jago, 2010), and park spaces (Potwarka, Kaczynski, & Flack, 2008; Roemmich et al., 2006). Almanza and colleagues (2012) reported that children who experienced higher average minutes of daily exposure to greener spaces engaged in more physical activities. Further, Fjørtoft's study (2004) conducted in Norway showed that being outdoors in natural environments motivates children's motor fitness. Moreover, more green spaces in the neighborhood have also shown to be linked with lower body mass index values among children in several studies (Bell, Wilson, & Liu, 2008; Liu, Wilson, Qi, & Ying, 2007; Wolch et al., 2011).

In sum, weather or thermal comfort is an important factor to be considered for promoting children's ATS and other healthy outdoor activities. Thermal comfort levels can be increased by natural elements of the environment, such as trees, landscaped buffers, and parks. Therefore, more research is needed to examine the roles of weather or thermal comfort related to natural environmental conditions in promoting children's ATS.

2.4 CORRELATES OF ACTIVE TRAVEL TO SCHOOL

The subject of finding ways to promote children's ATS has been addressed from a broad range of aspects such as individual, social, and environmental perspectives. This section describes the previous literature regarding correlates of ATS, grouping them into four classes: personal, social, built environmental, and natural environmental aspects.

2.4.1 Personal Correlates

In the personal correlates of children's ATS, many researchers found that most children from low income households were more likely to use an active transportation to school such as walking (Larsen et al., 2009; Martin, Lee, & Lowry, 2007; N. C. McDonald, 2007, 2008b). One of the reasons why low-income children were more likely to engage in ATS may be because they have limited access to other alternative means of transportation such as cars or school bus (Ewing, Schroeer, & Greene, 2004; Tudor-Locke et al., 2003; Yelavich et al., 2008). In contrast, Timperio et al. (2006) showed that 10- to 12-year-old children who lived in an area with medium and high levels of SES engaged in more ATS compared to those living in an area with the low levels of SES (unadjusted model, controlling for clustering of children by school only).

Regarding ethnicity, Baig et al. (2009) discovered that White children who lived in deprived communities were more likely to walk to school than non-White children. In contrast, Zhu and Lee (2009) discovered that Hispanic children were more likely to walk to and from school than non-Hispanic children.

Regarding personal behavioral and attitudinal factors, a study conducted by Robertson-Wilson et al. (2008) showed that high school students who were in the moderate or low percentile of physical activity levels and were daily smokers were less likely to walk to school. Further, parents' and children's positive attitudes toward walking (i.e., walking is a good way for children to improve physically and leads to social interaction) and regular walking behaviors were also positively associated with children's walking to school (Zhu & Lee, 2009). In contrast, personal barriers regarding time and ease of driving were negatively associated with children's walking to school (Zhu & Lee, 2009).

2.4.2 Social Correlates

Neighborhood social environments are also to be considered for children's ATS. McDonald (2007) determined that a high neighborhood social cohesion had a positive effect on children's walking to school when the distance from home to school was less than 1.6 km. Ward et al. (2007) also discovered that children who lived in community groups involved in walking to school implementation were more likely to take advantage of the walking to school program. Also, children who were supported by a friend's or parental encouragement were more likely to walk to school compared to those who didn't receive any encouragement (Panter et al., 2010a). In Panter et al.'s study, the significance of social support from parents was shown regardless of home-to-school distance, whereas a friend's encouragement was only significant in the relationship of walking to school when the distance was less than 1 km. Positive peer influences by other kids or other parents' daily walking also showed a positive relationship with children's walking to school (Zhu & Lee, 2009). Further, school events or programs such as Walk and Bike to School Days have served to promote children's walking to school and decrease driving trips to school (Staunton, Hubsmith, & Kallins, 2003). In terms of school bus availability, Rodriguez and Vogt (2009) reported that students who had access to a school bus were less likely to actively commute to school.

2.4.3 Built Environmental Correlates

Among the built environmental correlates of children's ATS, distance from home to school has been considered one of the main factors. Most literature on the subject determined that the longer the distance to school, the less likely a child was to choose walking (C. Lee et al., 2013; N. C. McDonald, 2008a; R. Mitra et al., 2010; Napier et al., 2011; Rodriguez & Vogt, 2009; Schlossberg et al., 2006; Su et al., 2013; Yarlagadda & Srinivasan, 2008; Yelavich et al., 2008; Zhu & Lee, 2009) and ATS (Babey, Hastert, Huang, & Brown, 2009; Larsen et al., 2009; N. C. McDonald, 2008a; Mendoza et al., 2010; Nelson, Foley, O'Gorman, Moyna, & Woods, 2008; Salmon, Salmon, Crawford, Hume, & Timperio, 2007; Voorhees et al., 2010; Yeung, Wearing, & Hills, 2008).

The next crucial set of correlates of children's ATS is related to neighborhood environment. In terms of population or residential density, several US-based studies presented a positive association with children's ATS (Braza, Shoemaker, & Seeley, 2004; Dalton et al., 2011; Kerr et al., 2006) but studies conducted in non-US locations including England and Ireland showed a negative relationship (Larsen et al., 2009;

Nelson et al., 2008). In terms of land use mix, previous studies also showed inconsistent or insignificant results. Several US studies that used subjectively-measured land use mix variables found that a higher proportion of street segments in an area with mixed land use was associated with increased odds of children's ATS (Kerr et al., 2006; Tracy E McMillan, 2007). However, other US studies that used objectively-measured land use mix variables showed negative (Su et al., 2013) and insignificant (Voorhees et al., 2010) relationships with children's ATS. Thus, more detailed and exact measures of the land use mix variable are needed to better understand the relationships between land use mix and children's ATS. Regarding neighborhood walkability, several studies showed that neighborhood walkability was a positive correlate of ATS (Kerr et al., 2006; Napier et al., 2011; Ward et al., 2007). Similarly, several studies showed that living in suburban or rural areas where the walkability score was generally low compared to living in an urban area decreased the prevalence of children's ATS (Babey et al., 2009; Martin et al., 2007).

In addition to the neighborhood environment, roadway or home-to-school route conditions have been examined to analyze children's active travel modes. Some desirable physical environments related to roadway conditions, including sidewalks, crossings, and traffic control have been presented as facilitators to children's ATS (Boarnet et al., 2005; Dalton et al., 2011; Ewing, Forinash, & Schroeer, 2005; Ewing et al., 2004; Fulton et al., 2005; Oluyomi et al., 2014). Further, street connectivity (Kerr et al., 2006; Mota et al., 2007) and pedestrian or bicycle facilities (Kerr et al., 2006) also played a role in increasing the probability of children's ATS. In contrast, undesirable roadway structures such as railroad tracks (Schlossberg et al., 2006) and highways (Zhu

& Lee, 2009) have been presented as barriers. In terms of route directness, two studies including Timperio et al. (2006) and Panter et al. (2010b) showed a negative relationship, while a study by Salmon et al. (2007) presented a positive relationship with children's ATS. One possible reason for the inconsistent results may be associated with different measurement methods used in these studies because the two studies showing a negative association with ATS measured the route directness objectively while the latter study showing a positive association measured it subjectively.

Regarding school environmental correlates of children's ATS, students attending public schools were more likely to actively commute to school than students attending private schools (Babey et al., 2009; Robertson-Wilson et al., 2008). Compared to students attending schools located in urban areas, students attending rural schools were less likely to engage in ATS (Robertson-Wilson et al., 2008), likely because rural schools located further away from students' homes. Further, in a study by Cui, Bauman, and Dibley (2011), it was reported that the probability of children's ATS increased if schools were located in the local community. In terms of the school size, a study conducted by Braza et al. (2004) found that increase in total enrollment size was negatively associated with children's ATS. Table 1 presents a summary of built environmental correlates of children's ATS, which were stratified by study type, study setting, population (young children or adolescents), and behavior type indicating whether it focused on walking trips only or considered both walking and bicycling to school.

Table 1
Built Environmental Correlates of Active Travel to School

Class	Environmental Variable	Study Type	Measure Type	Setting (US or not)	Population		Outcome		Source
					Young children included (elementary school students)	Adolescents only (middle/ high school students)	WTS (Walking To School only)	ATS (Active Travel to School; walking or bicycling)	
Travel distance	Home-to-school distance / travel time	Cross-sectional	O	US		√		(–)	(Babey et al., 2009)
		Cross-sectional	O	US		√	(–)		(Schlossberg et al., 2006)
		Cross-sectional	O	US	√			(–)	(Mendoza et al., 2010)
		Cross-sectional	O	US	√			(–) in girls	(Voorhees et al., 2010)
		Cross-sectional	O	England	√			(–)	(Larsen et al., 2009)
		Cross-sectional	O	US	√		(–)		(N. C. McDonald, 2008a; Napier et al., 2011; Su et al., 2013; Yarlagadda & Srinivasan, 2008)
		Cross-sectional	O	New Zealand	√		(–)		(Yelavich et al., 2008)
		Cross-sectional	O	Canada	√		(–)		(R. Mitra et al., 2010)
		Cross-sectional	PP	US	√			(–)	(N. C. McDonald, 2008a; Yeung et al., 2008)
		Cross-sectional	PP	US	√		(–)		(C. Lee et al., 2013; Zhu & Lee, 2009)
		Cross-sectional	CP	US	√		(–)		(Rodriguez & Vogt, 2009)
		Cross-sectional	PP	Australia	√			(–)	(Salmon et al., 2007)
		Cross-sectional	CP	Ireland		√		(–)	(Nelson et al., 2008)

Table 1
Built Environmental Correlates of Active Travel to School (continued)

Class	Environmental Variable	Study Type	Measure Type	Setting (US or not)	Population		Outcome		Source
					Young children included (elementary school students)	Adolescents only (middle/ high school students)	WTS (Walking To School only)	ATS (Active Travel to School; walking or bicycling)	
Roadway or HTS route conditions	Sidewalks, crossings, traffic control	Cross-sectional	PP	US	√		(+)		(Boarnet et al., 2005; Oluyomi et al., 2014)
	Sidewalk coverage	Cross-sectional	O	US	-		(+)		(Ewing et al., 2005; Ewing et al., 2004)
		Cross-sectional	O	US	√			(+)	(Dalton et al., 2011)
	Presence of sidewalks	Cross-sectional	CP	US	4^{th}–12^{th} grades			(+)	(Fulton et al., 2005)
	Street connectivity	Cross-sectional	PP	US	√			(+)	(Kerr et al., 2006)
		Cross-sectional	CP	Portugal		√		(+)	(Mota et al., 2007)
	Walking or bicycling facilities	Cross-sectional	PP	US	√			(+)	(Kerr et al., 2006)
	Presence of railroad tracks	Cross-sectional	PP	US		√	(–)		(Schlossberg et al., 2006)
	Presence of highways	Cross-sectional	PP	US	√		(–)		(Zhu & Lee, 2009)
	Presence of bus stops en route	Cross-sectional	PP	US	√		(–)		(Zhu & Lee, 2009)
	Street lights	Cross-sectional	PP	Australia	√			(+)	(Anna Timperio et al., 2006)
		Cross-sectional	O	England	√			(–) bicycling only	(Panter et al., 2010b)
	Route directness	Cross-sectional	O	Australia	√			(–) in 5-6 years age group	(Anna Timperio et al., 2006)
		Cross-sectional	PP	Australia	√			(+)	(Salmon et al., 2007)
		Cross-sectional	O	England	√		(–)		(Panter et al., 2010b)

Table 1
Built Environmental Correlates of Active Travel to School (continued)

Class	Environmental Variable	Study Type	Measure Type	Setting (US or not)	Population		Outcome		Source
					Young children included (elementary school students)	Adolescents only (middle/ high school students)	WTS (Walking To School only)	ATS (Active Travel to School; walking or bicycling)	
Neighborhood environment	Population density	Cross-sectional	O	US				(+)	(Braza et al., 2004; Dalton et al., 2011; Kerr et al., 2006)
		Cross-sectional	O	US	√		(+)		(N. C. McDonald, 2008a)
		Cross-sectional	O	England	√			(–)	(Larsen et al., 2009)
		Cross-sectional	CP	Ireland		√		(–)	(Nelson et al., 2008)
	Mixed land use	Cross-sectional	PP	US	√			(+)	Kerr et al., 2006
		Cross-sectional	PP	US	√			(+)	(Tracy E McMillan, 2007)
		Cross-sectional	O	US	√		(–)		(Su et al., 2013)
		Cross-sectional	O	US	√			ns	(Voorhees et al., 2010)
		Cross-sectional	O	England	√			(+)	(Larsen et al., 2009)
	Government or institutional land use	Cross-sectional	O	US	√		(+)		(Su et al., 2013)
	Neighborhood setting 1 (Suburban/rural vs. urban*)	Cross-sectional	O	US		√		(–)	(Babey et al., 2009)
	Neighborhood setting 2 (Metro suburban, second city, town, and rural vs. urban*)	Cross-sectional	O	US	√			(–)	(Martin et al., 2007)
	Walkability	Cross-sectional	O	US	√			(+)	(Kerr et al., 2006)
		Cross-sectional	O	US	√		(+)		(Napier et al., 2011)
		Cross-sectional	OT3	US	√		(+)		(Ward et al., 2007)
		Cross-sectional	PP	England	√			(+)	(Panter et al., 2010a)

Table 1
Built Environmental Correlates of Active Travel to School (continued)

Class	Environmental Variable	Study Type	Measure Type	Setting (US or not)	Population		Outcome		Source
					Young children included (elementary school students)	Adolescents only (middle/ high school students)	WTS (Walking To School only)	ATS (Active Travel to School; walking or bicycling)	
Neighborhood environment (continued)	Intersection density	Cross-sectional	O	US		√	(–)		(Schlossberg et al., 2006)
		Cross-sectional	CP	Portugal		√		(+)	(Mota et al., 2007)
	Road density	Cross-sectional	O	England	√		(+)		(Panter et al., 2010b)
	Smaller sized blocks	Cross-sectional	O	US	√			(+) in girls	(Voorhees et al., 2010)
	Neighborhood social cohesion	Cross-sectional	CP	US	√		(+)		(N. C. McDonald, 2007)
	Neighborhood sense of community	Cross-sectional	CP	England	√			(+)	(Panter et al., 2010a)
	Community group	Cross-sectional	OT3	US	√		(+)		(Ward et al., 2007)
	Building continuity (adjacent vs. scattered*)	Cross-sectional	O	US	√			(+)	(Dalton et al., 2011)
School environment	School type (public vs. private*)	Cross-sectional	O	US		√		(+)	(Babey et al., 2009)
		Cross-sectional	OT1	Canada		√		(+)	(Robertson-Wilson et al., 2008)
	School location (rural vs. urban*)	Cross-sectional	OT1	Canada		√		(–)	(Robertson-Wilson et al., 2008)
	School location (local community vs. not local community*)	Cross-sectional	OT2	China	√			(–)	(Cui et al., 2011)
	School size (total school enrollment)	Cross-sectional	O	US				(–)	(Braza et al., 2004)
	School bus access	Cross-sectional	CP	US	√			(–)	(Rodriguez & Vogt, 2009)

O: objectively measured variable, CP: children's perception variable, PP: parental perception variable, OT1: other 1 (administrator at each school), OT2: other 2 (leaders of communities), OT3: other 3 (coordinators)
*: reference group

2.4.4 Natural Environmental Correlates

Most previous studies regarding natural environmental correlates have focused on children's physical activity rather than on children's ATS. Therefore, the review in this section expands the outcomes linked to natural environmental factors to include children's physical activity, body mass index (BMI, indicator of weight status), and ATS (Table 2).

Relationship between Natural Environment and Children's Physical Activity

The natural environmental correlates have been focused on children's physical activity, and less on children's ATS. Almanza et al.(2012) verified that children who experienced higher average minutes of daily exposure to greener spaces measured by the Normalized Difference Vegetation Index (NDVI) engaged in more moderate-to-vigorous physical activity compared to those with nearly zero minutes of exposure to greener spaces. Further, several studies have identified a positive association between the accessibility to a greenness area (e.g. parks) and children's physical activity (Cohen et al., 2006; Epstein et al., 2006; Pate et al., 2008).

According to Fjørtoft's study (2004), being outdoors in a natural environment improves children's motor fitness and children utilize the natural environment for play. A quasi-experimental method was employed utilizing an experimental group of 46 children who were offered free play and versatile activities in natural environments, and a reference group of 29 children of the same age who used their traditional outdoor playground. The play activities (i.e., flaming balance − standing on one foot, Indian skip

– clapping right knee with left hand and vice versa) were measured by pre- and post-tests in two groups, and paired-t tests were conducted. The results showed significant differences in the amount of physical activity between the two groups in favor of the experimental group (number of instabilities in 30 seconds for flamingo balance play = 3.8 for experimental group and 0.9 for comparison group, number of repetitions in 30 seconds for Indian skip play = 20.6 for experimental group and 10.5 for comparison group).

Relationship between Natural Environment and Children's Weight Status

In addition to the roles of natural environment in promoting children's physical activity, several studies have examined the relationship between natural environment and children's body mass index (BMI) (Bell et al., 2008; Liu et al., 2007; Wolch et al., 2011). Liu et al.'s study (2007) showed that living in a greener residential area (based on NDVI) was associated with decreased BMI among children residing in higher population density regions. In a longitudinal study of children and youths aged 3-16 years, controlling for baseline BMI z-scores and personal factors, BMI z-scores measured at follow-up and BMI change in two years were predicted by greenness (Bell et al., 2008). The results of the study indicated that higher neighborhood greenness measured by NDVI was associated with lower BMI z-scores at follow-up and lower odds of children's increasing BMI z-scores over two years (Bell et al., 2008). In a study by Potwarka et al. (2008), children's health weight status was examined with objectively-measured environmental data such as proximity to park space, proximity to park facilities, number of parks, and park size. The results revealed that none of the park related variables were significantly associated with childhood weight, except for the park with playground(s) variable. The presence of a park with a playground within 1km was shown to increase the likelihood of children being a healthy weight status by five times (Potwarka et al., 2008).

Relationship between Natural Environment and Children's ATS

In terms of natural environmental correlates of ATS, a small number of studies have been conducted so far. In a study of students aged 11-13 years from 21 schools in London and living within 1 mile of school (n=614), the relationship between physical environmental characteristics and children's mode of travel to school was investigated (Larsen et al., 2009). As a natural environmental variable, the number of street trees was measured through field audits by the city's forestry group. The results showed that more street trees increased the likelihood of children's non-motorized travel (walking, bicycling, and rollerblading) to school only, not travel from school (Larsen et al., 2009).

There have been several additional attempts to examine the potential of natural environmental characteristics in promoting children's ATS, which unfortunately resulted in insignificant relationships. Evenson and colleagues (2006) utilized survey items regarding the aesthetics of the perceived environment (trees, things to look at, smells, and garbage) among 480 sixth to eighth grade girls and found that a better perception of trees was insignificantly associated with the girls' ATS (Evenson et al., 2006). Moreover, in studies by Robertson-Wilson et al. (2008) and Sirard et al. (2005) weather conditions indicating four seasons (spring, summer, fall, and winter) and temperature were utilized as natural environmental variables for an analysis regarding the prevalence of children's ATS. Although both studies showed insignificant relationships between the weather conditions/temperature and children's ATS, these studies brought attention to the importance of natural environmental conditions that may impact parental concerns about weather and children's ATS. For a more detailed and accurate understanding of the effects of natural environmental characteristics on children's ATS, additional information is needed on what and how the natural environmental variables are measured.

There are many potential natural environmental elements (e.g. landscaped buffers separating pedestrian sidewalks from car roads, wide-canopy trees providing shade on sidewalks) en route to school that can facilitate children's ATS as they create a safe, pleasant, and aesthetically pleasing environment. Therefore, it is necessary to explore the natural environmental correlates to children's ATS, which have not been sufficiently examined.

Table 2
Natural Environment Correlates of Physical Activity, Body Mass Index, and Active Travel to School

Natural environmental variables	Study Type	Measure Type	Setting (US or not)	Children's outcome variables			Source
				Physical activity	BMI	WTS or ATS	
Normalized difference vegetation index (NDVI)	Cross-sectional	O	US	(+)			(Almanza et al., 2012)
	Longitudinal	O	US		(−)		(Bell et al., 2008)
	Cross-sectional	O	US		(−)		(Liu et al., 2007; Wolch et al., 2011)
Playgrounds with natural environments	Cross-sectional	O	Norway	(+)			(I. Fjørtoft, 2004)
Park playground(s)	Cross-sectional	O	Canada		(−)		(Potwarka et al., 2008)
Accessibility to parks and recreational facilities	Cross-sectional	O	US	(+)			(Roemmich et al., 2006)
Outdoors in green space (measured by GPS)	Cross-sectional	O	England	(+)			(Wheeler et al., 2010)
Dense trees and shrubs	Cross-sectional	O	Stockholm	(+)			(Boldemann et al., 2006)
Trees	Cross-sectional	O	England			(+)	(Larsen et al., 2009)
Weather conditions	Cross-sectional	O	US			ns	(Sirard, Ainsworth, et al., 2005)
Weather conditions (Fall vs. Winter (reference group))	Cross-sectional	O	Canada			(−)†	(Robertson-Wilson et al., 2008)
Temperature	Cross-sectional	O	Canada			ns	(Robertson-Wilson et al., 2008)
	Cross-sectional	O	US			ns	(Sirard, Ainsworth, et al., 2005)
Steep slope	Cross-sectional	O	Australia			(−)‡	(Anna Timperio et al., 2006)

(+): positive association, (-) negative association, ns: not significant, †: significant in urban schools, ‡: significant in 5-6 years age group
O: objectively-measured variables, CP: children's perceived variables
BMI: body mass index, WTS: walking to school, ATS: active travel to school (e.g. walking and bicycling)

2.5 SUMMARY

The literature review section investigated a broad range of topics and issues related to children's ATS including theoretical and methodological approaches. Children's ATS behavior is not a simple matter. It is influenced by multiple inter-related factors including personal, social, and environmental variables. This literature review section discussed previous empirical studies carried out in the following subjects: benefits of ATS, theoretical approaches (health-related behavior change and environmental justice), parental perceived barriers to ATS, and correlates of ATS. Based on this review, several critical gaps that have previously been overlooked but are important determinants affecting children's ATS behavior have emerged.

First, overall daily physical activity can be improved by facilitating ATS among children. A number of previous studies have found that children who walked or bicycled to school were more likely to participate in more moderate to vigorous physical activity during week days than children who used inactive travel modes. The results of the associations between children's ATS and BMI, however, were inconsistent. Most previous studies showed insignificant results, but a few studies also presented the significant roles of children's ATS in decreasing their BMI. For a more detailed relationship between ATS and children's health such as BMI, other potential factors that may affect children's body weight status, including their diet habits, food availability at home, and active/sedentary behaviors at home, need to be controlled. Furthermore, more longitudinal cohort studies are needed to effectively detect or track long-term changes in BMI.

Second, theory-based approaches regarding health-related behavior change helped understand how an active behavior can be facilitated or promoted overcoming difficulties or barriers to healthy behaviors. The theories were investigated at the three levels: individual, social, and environmental. At the individual level, two theories including learning theory and the health belief model were presented. At the social level, social support and social cognitive theory were introduced. At the environmental level, the social ecological theory was described. Although these theories proposed several fundamental strategies to facilitate health-related behavior, it requires more carefulness to connect the ideas of the theories to children's ATS because children's ATS behavior is determined primarily by their parents' permission.

Third, following the distance barrier to children's ATS, safety and thermal comfort concerns were the second and the third most highly reported barriers by parents, discouraging them from allowing their children's ATS. While a large number of empirical studies have proven the roles of parental safety concerns in relation to children's ATS, few studies have been conducted in terms of the effects of weather or thermal comfort concerns on the outcome although the thermal comfort concern was the most frequently reported barrier among parents whose children were walkers (Centers for Disease Control and Prevention, 2005). Therefore, studies on both parental safety and thermal comfort concerns in relation to ATS are necessary, and exploring what built and natural environmental factors are associated with these concerns will help find practical ways to alleviate the parental concerns and promote children's ATS.

Fourth, correlates of children's ATS were investigated from four different aspects including personal, social, built environmental, and natural environmental. Regarding the personal correlates of ATS, studies using income and ethnicity variables showed inconsistent results while a few studies about the effect of behavioral or attitudinal factors showed consistent results representing a positive association between them. In terms of the social correlates of ATS, several studies have identified that neighborhood social cohesion and social support from parents or community served to increase the likelihood of actively commuting to school. In terms of environmental correlates of ATS, most previous studies have focused on the built environment such as travel distance, roadway or HTS route conditions, neighborhood environment, and school environment, and paid less attention to the natural environment. While a large number of studies have confirmed the role of the natural environment in promoting children's physical activity and decreasing their BMI (Bell et al., 2008; Liu et al., 2007; Wolch et al., 2011), little evidence is available when it comes to its relationship with ATS. Therefore, more studies about the associations between natural environment and ATS need to be conducted by utilizing proper methods to measure the natural environment such as tree canopy cover, surface temperatures, steep slopes, etc.

3. RESEARCH CONCEPT AND DESIGN

3.1 RESEARCH GAPS AND CONCEPTUAL FRAMEWORK

This dissertation research proposes to address two main research gaps in the literature. First, this research examines the effects of the built and natural environments on parents' perceived barriers to ATS, two of which are safety and thermal comfort concerns. Second, so as to promote children's active travel to school, it proposes to contribute to developing specific and tailored environmental interventions for different community contexts/populations. This research is based on an assessment of the spatial distribution of the existing built and natural environments along with the socio-economic status of the populations.

Based on the literature review of the theories of health-related behavior change and empirical studies on children's ATS, this dissertation research proposes a novel conceptual framework that considers parents' perceived barriers to ATS as mediators between the environments and children's ATS (Figure 3). Given the difficulty in directly applying the constructs (e.g., rewards and cues to action) from individual-level theories including learning theory and the Health Belief Model to children's behavior change because these theories mainly focus on the adult population who can make their own decisions on behavior change, this dissertation uses the individual-level variables such as gender, grade, ethnicity, and walking behaviors and attitudes as confounders. Social support (e.g., family and friends' support) and social interactions addressed in social cognitive theory are also used as confounders. Built and natural environmental characteristics addressed from the perspective of social ecological theory are the main independent variables. Parental perceived barriers to children's ATS, safety and thermal comfort concerns, are used as mediators between the environment-ATS relationships. Therefore, the conceptual framework is to test whether parents' perceptions are affected by environmental conditions and whether they are correlated with their children's ATS behaviors.

As explained in the previous section, this conceptual framework includes three primary objectives as follows:

- Objective 1: To examine associations between built/natural environments and parental safety and thermal comfort concerns for children's ATS.
- Objective 2: To examine associations between built/natural environments and children's ATS behaviors.
- Objective 3: Examine mediating roles of parental safety and thermal comfort concerns in built/natural environments-ATS relationships.

More details for each objective's study design and method are noted in Chapter 4 for Study 1, Chapter 5 for Study 2, and Chapter 6 for Study 3.

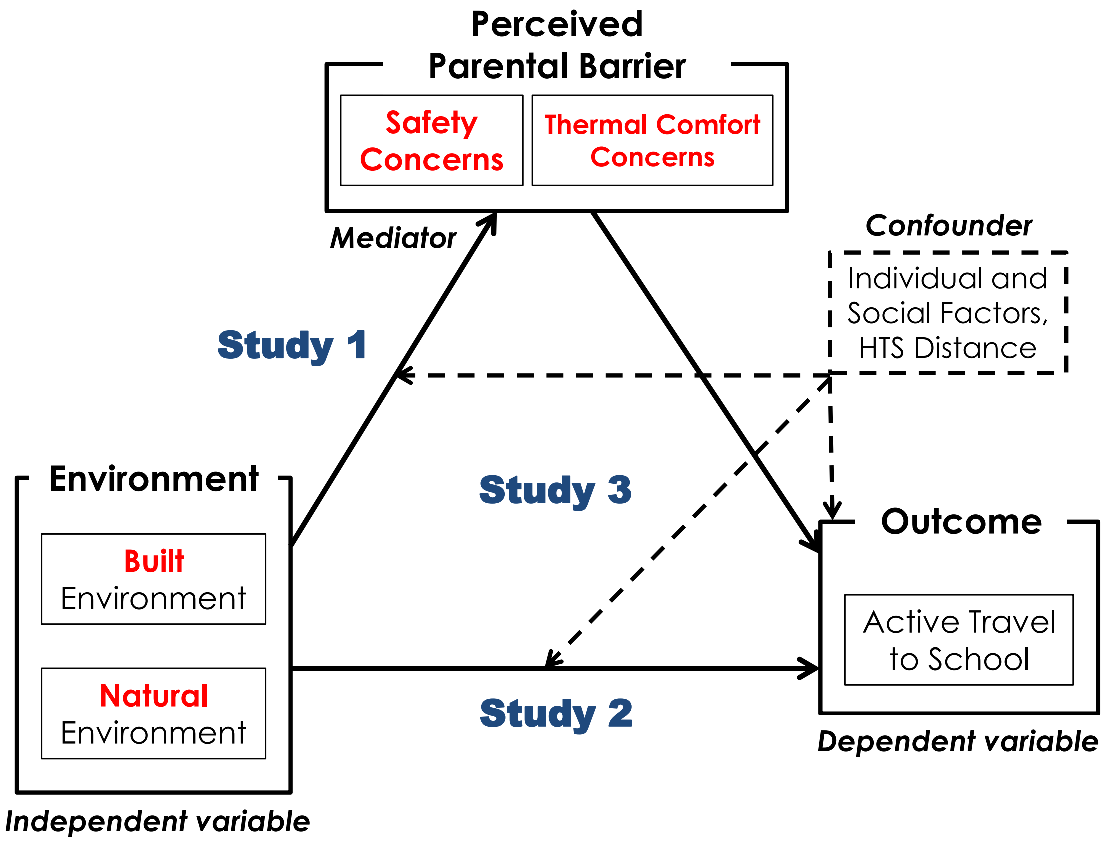


Figure 3
Conceptual Framework

3.2 STUDY AREA AND POPULATION

The study area was the Austin Independent School District (AISD) which covers most of the land area within the city of Austin, Texas (Figures 4). Selected for this study were 20 out of 81 elementary schools in AISD, to ensure spatial distribution of the study schools, environmental settings, and Hispanic ratios of students. Table 3 provides the characteristics of the study schools. A total of 4,270 parental surveys from 20 schools, which gave the full address information for geocoding, were used in this study.

Table 3
School Socio-Demographics

School Name	Education (median)	Income (median)	Hispanic (%)	ATS (%)
Andrew EL	Middle school	\$10,000 - \$19,999	80.08 %	32.97 %
Barton Hills EL	College graduate/Bachelor's degree	\$80,000 - \$99,999	22.67 %	29.49 %
Blanton EL	Middle school	\$10,000 - \$19,999	86.05 %	30.00 %
Brooke EL	High school or GED	\$10,000 - \$19,999	93.91 %	22.95 %
Casis EL	Graduate/professional degree	\$100,000 or more	10.43 %	28.57 %
Clayton EL	Graduate/professional degree	\$100,000 or more	15.65 %	19.26 %
Cunningham EL	Some college/Associate degree	\$20,000 - \$39,999	59.65 %	21.95 %
Harris EL	Middle school	\$10,000 - \$19,999	83.95 %	61.91 %
Highland Park EL	Graduate/professional degree	\$100,000 or more	13.27 %	15.48 %
Houston EL	High school or GED	\$10,000 - \$19,999	93.98 %	58.04 %
Kiker EL	Graduate/professional degree	\$100,000 or more	12.88 %	31.05 %
Langford EL	High school or GED	\$10,000 - \$19,999	90.94 %	66.34 %
Linder EL	High school or GED	\$10,000 - \$19,999	88.26 %	24.46 %
Metz EL	High school or GED	\$10,000 - \$19,999	91.72 %	29.82 %
Mills EL	College graduate/Bachelor's degree	\$100,000 or more	18.94 %	36.59 %
Sanchez EL	High school or GED	\$10,000 - \$19,999	93.15 %	14.57 %
Sunset Valley EL	High school or GED	\$20,000 - \$39,999	78.29 %	36.84 %
Travis Heights EL	Some college/Associate degree	\$20,000 - \$39,999	65.03 %	29.94 %
Wooten EL	High school or GED	\$10,000 - \$19,999	87.86 %	44.98 %
Zilker EL	College graduate/Bachelor's degree	\$60,000 - \$79,999	31.67 %	35.90 %

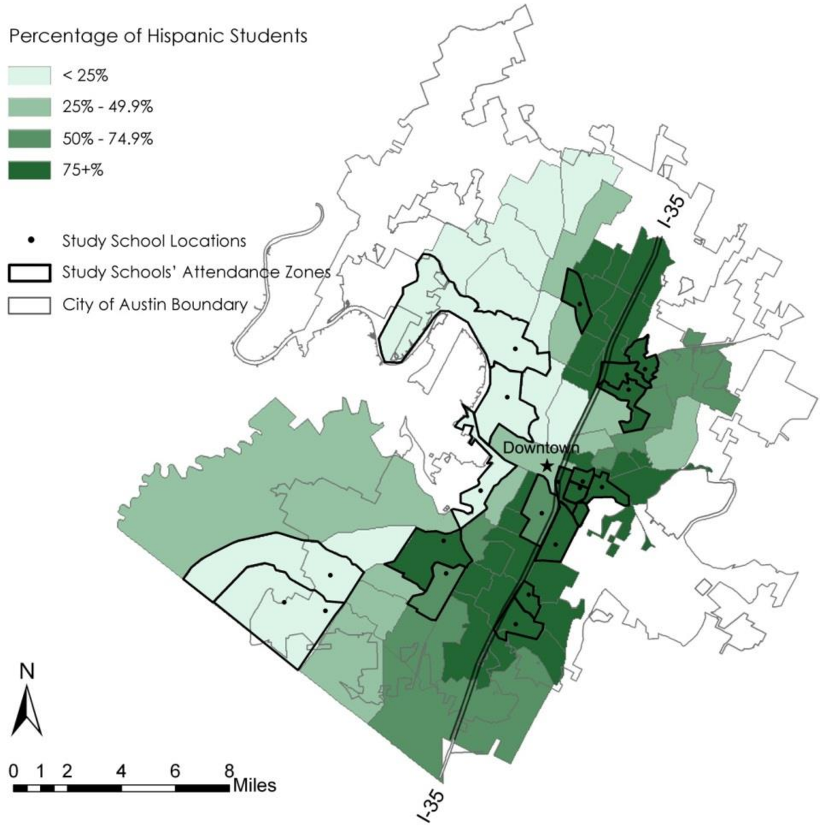


Figure 4
School Locations and Percentage of Hispanic Students in AISD, Austin, Texas

Figure 4 shows that Hispanic students are concentrated in the east area of AISD, mirroring to some degree the distribution patterns of economically disadvantaged students. Further investigation of the spatial distribution patterns of various built and natural environmental features/elements, and the assessment of potentially inequitable distributions of supportive and hostile features/elements for ATS can help develop priorities for environmental interventions that can reduce disparities while at the same time promoting ATS.

3.3 DATA COLLECTION AND MEASURES

This research was a cross-sectional study and made use of an existing dataset collected for another research study supported by a grant from the Robert Wood Johnson Foundation's Active Living Research in 2010 (Grant ID: 65539). From this dataset, students' socio-demographic information and parents' concerns about safety and thermal comfort regarding their children's ATS were obtained. Furthermore, it utilized macro-scale built environmental variables captured in GIS. All natural environmental data from GIS and remote sensing software were newly collected for this dissertation study.

The objectively measured built environmental data included street conditions (e.g., highways, sidewalks, intersections, speed limits) from the City of Austin, crime data from the Texas Department of Public Safety, and crash data from the Austin Police Department. For the objectively measured natural environments, the following data sources were utilized: a digital orthophoto quarter quads (DOQQ) image for land cover such as trees, grass, and urbanized areas; a digital elevation model (DEM) for topography; and a Landsat 5 TM for surface temperature and normalized difference vegetation index (NDVI). Further, light detection and ranging (LiDAR) was utilized to obtain more detailed data about the natural environments, especially for tree heights. Table 4 represents all the study variables organize by personal, social, built environment, and natural environment.

Table 4
Variable List Stratified by Personal, Social, Built Environment, and Natural Environment

Category	Variables	Measures	Data Source	Variable Type
Personal variables	Child gender	Female and male	SRTS survey[1]	Binary
	Child grade	PK-K, 1st-3rd, 4th-6th grade	SRTS survey	Categorical
	Child ethnicity	White, Hispanic, Others	SRTS survey	Categorical
	Child language	English, Spanish, Others	SRTS survey	Categorical
	Free or reduced school lunch	Whether or not children received free or reduced-priced meals at schools	SRTS survey	Binary
	Walking behaviors	I walk quite often in my daily routine	SRTS survey	Likert scale
	Walking attitudes	Walking is a good way to exercise	SRTS survey	Likert scale
		I (would) enjoy walking with my child to/from school	SRTS survey	Likert scale
	Safety concerns	Mean score of 8 survey items related to parental safety concerns for children's walking to school	SRTS survey	Continuous
	Thermal comfort concerns	Parental perceptions of thermal comfort for children's walking in neighborhood	SRTS survey	Likert scale
Social variables	Peer influence	My family and friends like the idea of walking to school	SRTS survey	Likert scale
		Other kids walk to/from school in my neighborhood	SRTS survey	Likert scale
	Social connectivity	I feel connected to people in my neighborhood	SRTS survey	Likert scale
	School bus availability	Whether or not the school provide bus service for your child	SRTS survey	Binary

[1] The Safe Route to School (SRTS) survey was conducted in 2010 and was developed for the "Whys" and "Why Nots" of Active Living research project. The main aim of this project was to identify multi-level barriers and motivators of children's walking-to-school behavior among high-risk groups of children. The author of this dissertation worked on the research project as a research assistant in 2010 – 2011 in charge of data coding, GIS data collection, and advanced multivariate statistical analyses.

Table 4
Variable List Stratified by Personal, Social, Built Environment, and Natural Environment (continued)

Category	Variables	Measures	Data Source	Variable Type
Built environmental variables	HTS distance	The shortest home-to-school distance	Network analysis	Continuous
	Sidewalks	Length of sidewalks divided by total street length within HTS route buffer after multiplying by 100	City of Austin	Continuous
	Bike lanes	Whether the percentage of bike lanes within HTS route buffer is greater than the mean of total bike lane percentage (zero percentage excluded for the mean calculation)	City of Austin	Binary
	Playgrounds	Presence of playgrounds within HTS route buffer	City of Austin	Binary
	Intersections	Number of intersections per acre within HTS route buffer	City of Austin	Continuous
	Highways	Whether the HTS route was intersected by highways	City of Austin	Binary
	Railroads	Whether the HTS route was intersected by railroads	City of Austin	Binary
	High speed street	Length of high speed streets (>30 mph) divided by total street length within HTS route buffer after multiplying by 100	City of Austin	Continuous
	Crime hotspots	Mean of crime hotspot z-scores within HTS route buffer	Austin Police Dept.	Continuous
	Crash hotspots	Mean of all crash hotspot z-scores within HTS route buffer	Texas Dept. of Public Safety	Continuous
		Mean of pedestrian- and biker-related crash hotspot values		Continuous
	Sex-offenders	Presence of sex-offender home locations within HTS route buffer	Austin Police Dept.	Binary
Natural environmental variables	Parks	Presence of parks within HTS route buffer	City of Austin	Binary
	Water features	Presence of water features within HTS route buffer	City of Austin	Binary
	Steep slopes	Steep slope area (>5% or >8.33%) divided by total area of HTS route buffer area after multiplying by 100 (%)	Columbia Center (DEM data)	Continuous
	Urbanized area	Urbanized area divided by total area of HTS route buffer area (%)	USGS (DOQQ image)	Continuous
	Tree canopy	Tree canopies divided by total area of HTS route buffer area (%)		Continuous
	Grass cover	Grass cover divided by total area of HTS route buffer area (%)		Continuous
	Temperature	Mean of temperature measured within HTS route buffer (°C)	USGS (Landsat 5TM)	Continuous
	NDVI	Mean of NDVI measured within HTS route buffer		Continuous
	Tree heights	Mean of tree heights measured within HTS route buffer (feet)	CAPCOG	Continuous

USGS: United States Geography Survey, CAPCOG: Capital Area Council of Governments

3.3.1 Crime and Crash Hotspots

Objective measures regarding crime and crash safety were captured utilizing GIS based on individually geocoded crime and crash location data from 2004 to 2010. The time frame for the crime and traffic crash data was based on the survey time which was 2010. This study also assumed that the crime and crash information for 7 years can better capture the general crime- and crash-related safety conditions in the neighborhoods, compared to the one based on short time periods such as 1 or 2 years. Crime and crash hotspot variables indicated by Z-scores were generated to further assess the spatial patterns of incidents along the GIS-generated shortest HTS routes[2].

For a crime hotspot analysis, the Hot Spot Analysis Tutorial (Environmental Systems Research Institute, 2009) released in 2010 was implemented and crime incident data of only sexual assault and abduction between 2004 and 2010 were used. A new model builder available in the Hot Spot Tools toolbox in ArcGIS, which allows several geo-processing steps to be done in sequence, was generated to get crime hotspot values. By using the integrate tool in ArcGIS, a total number of crime incidents within a threshold of 200 feet, assuming that those within 200 feet reflect the same general geographic location, were aggregated (Environmental Systems Research Institute, 2009). Then, the weighted crime point features were generated by utilizing the collect events tool. Next, the spatial weight matrix tool function was added into the model to create a spatial weights matrix file which improves Hotspot performance and is good for larger datasets (Environmental Systems Research Institute, 2009). As its modeling parameters,

[2] The threshold of the z-score was ±1.65 (i.e. confidence interval at 90%) which identifies high or low crime and crash locations, namely “hot spots” or “cold spots” (ESRI 2013).

Manhattan for the distance method, which is appropriate for analyses in an urban setting, was selected and a K nearest neighbors conceptualization method based on eight numbers of neighbors, which allow the eight closest neighbors around the target feature to be used for computations, was included (Environmental Systems Research Institute, 2009). Finally, changing the conceptual method to get spatial weights from the file and using the weighted matrix file previously created, the hot spot analysis (Getis-Ord GI*) tool was utilized to get finalized z-scores that indicate the weighted crime feature. Figure 5 presents the geo-processing steps used in the model builder.

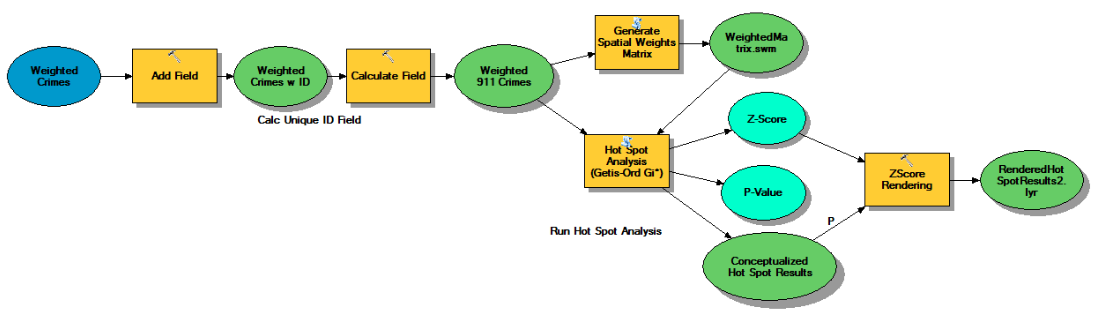


Figure 5
A Model Builder Used for Crime Hotspot Analysis
Source: Hot Spot Analysis – A Tutorial (ESRI 2009)

After using the Z-score rendering tool from the spatial statistics tool in ArcGIS, the rendered crime points were generated indicating the features colored from blue to red (Figure 6). Then, by using the interpolation tool in the spatial analyst toolbox, a rendered and interpolated surface based on the GiZscore values was created (Figure 7).

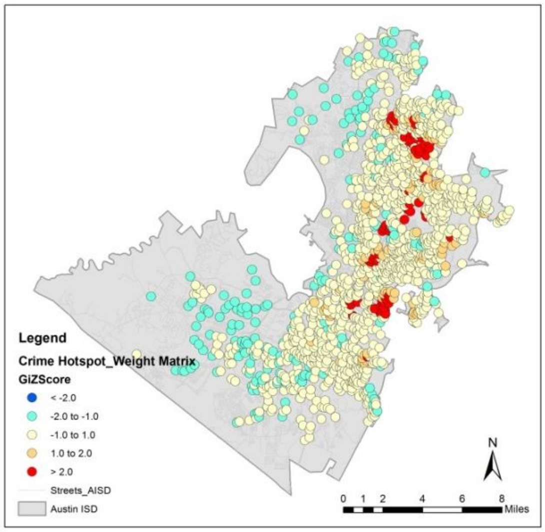


Figure 6
Weighted Crime Points in AISD, Austin, Texas

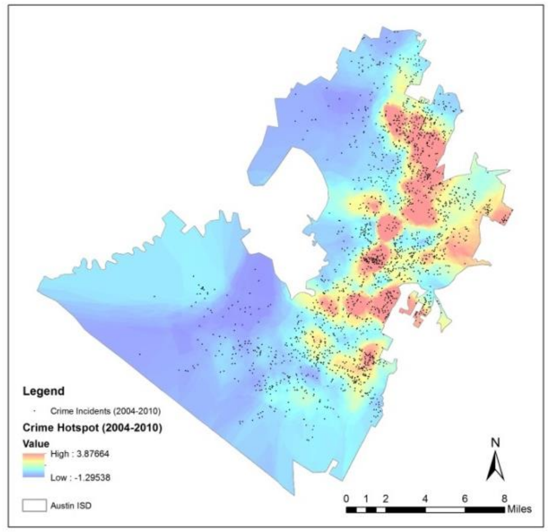


Figure 7
Crime Hotspot Map Interpolated in AISD, Austin, Texas

For the crash hotspot variable, a model builder was not utilized because crash incidents usually occurred along the streets and interpolated surface values based on the crash point data may not be accurate or even wrong. Instead, the general hot spot analysis (Getis-Ord Gi*) was used, which utilized street data including crash ratio information. Crash data reported between 2004 and 2010 were utilized. A total of 78,423 crash incidents were spatially joined with street lines by employing “closest to it” in a tag of the function tool, and thereby each street included the information of how many crash incidents occurred along the streets. Since longer distance street segments are more likely to have more crash incidents, the number of crash incidents in a street segment was divided by the length of the street. This crash ratio value was applied to it as an input field in the hot spot analysis (Getis-Ord Gi*), choosing the “zone of inference” as a conceptualization of the spatial relationships, and selecting the “Euclidean” distance. Figure 8 shows the crash hotspot map.

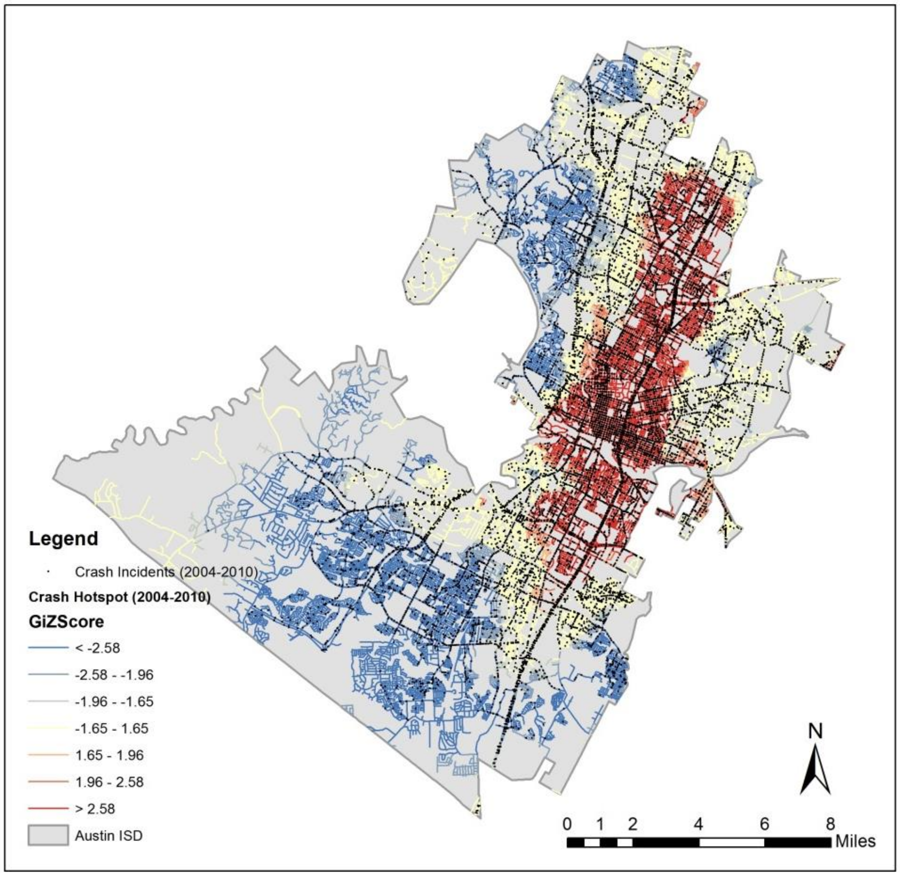


Figure 8
Crash Hotspot Map in AISD, Austin, Texas

3.3.2 Tree Canopy

DOQQ aerial images produced by the United States Geological Survey (USGS) and taken on June, 2010, were used for tree canopy coverage classification. Since the DOQQ images have been geometrically rectified to remove distortion and have a pixel size of 1 meter, it is appropriate to merge multiple aerial images and produce a high quality image. Four general steps, (a) merge images based on a pixel-based image segmentation, (b) classify classes, (c) group classes, and (d) post classification, were taken in ENVI. First, as a pre-processed basic step, multiple DOQQ aerial images were merged by a pixel-based image segmentation in ENVI, a process to group multiple images into an object based on geometric longitude and latitude locations. Second, the merged aerial image covering the AISD study area was classified utilizing an iterative self-organizing data analysis (ISODATA) in ENVI, an unsupervised classification method that does not require a priori ground reference information and groups pixels based on similar spectral characteristics (Jensen, 2005). ISODATA parameters were determined as follows: the maximum number of classes = 20, the maximum iterations = 5, the change threshold % = 2, the minimum number of pixels in each class = 1, the maximum class standard deviation = 1, the minimum class distance = 5, and the maximum number of merge pairs = 2. Third, the classified image including 20 classes was grouped into five classes (no data [shade, water, and non-study area]), urbanized area, tree canopy, grass coverage, and bare ground). To place the twenty classes generated in step 2 into one of the five classes, the originally merged image (step 1) was used as a reference image to identify the class types. Last, a post classification processing through sieving and clumping classes was conducted to eliminate isolated pixels that cause erroneous noise in the data. These methods were to determine any isolated or incorrectly assigned pixels into the same class based on the neighboring 4 or 8 pixels. Figure 9 shows the outputs from the four steps for image classification, and the clumped image.

The classification accuracy was calculated using 1,687 reference pixels randomly selected from the original DOQQ image (urbanized area = 495 pixels, tree canopy = 347, grass = 347, and bare ground = 372). The number of reference pixels for each class was large enough for the accuracy assessment test because a minimum number of pixels that are generally accepted is 50 (Congalton, 1991). The overall classification accuracy of the finalized four classes, except for one class indicating shade, water, and non-study area, were 94.0% and the kappa coefficient was 0.91 (Table 5).

Table 5
Overall Accuracy Assessment of the Four Land Cover Classes

Classified pixels	Reference pixels					
	Urbanized area	Tree canopy	Grass	Bare ground	Row total	User's accuracy (%)
Urbanized area	95	0	0	0	95	100.0
Tree canopy	0	426	0	0	426	100.0
Grass cover	0	67	346	4	417	82.9
Bare ground	0	0	1	259	260	99.6
Column total	95	493	347	263	1198	
Producer's accuracy (%)	100.0	86.4	99.7	98.5	-	

Overall accuracy = 93.99%; kappa coefficient = 0.914

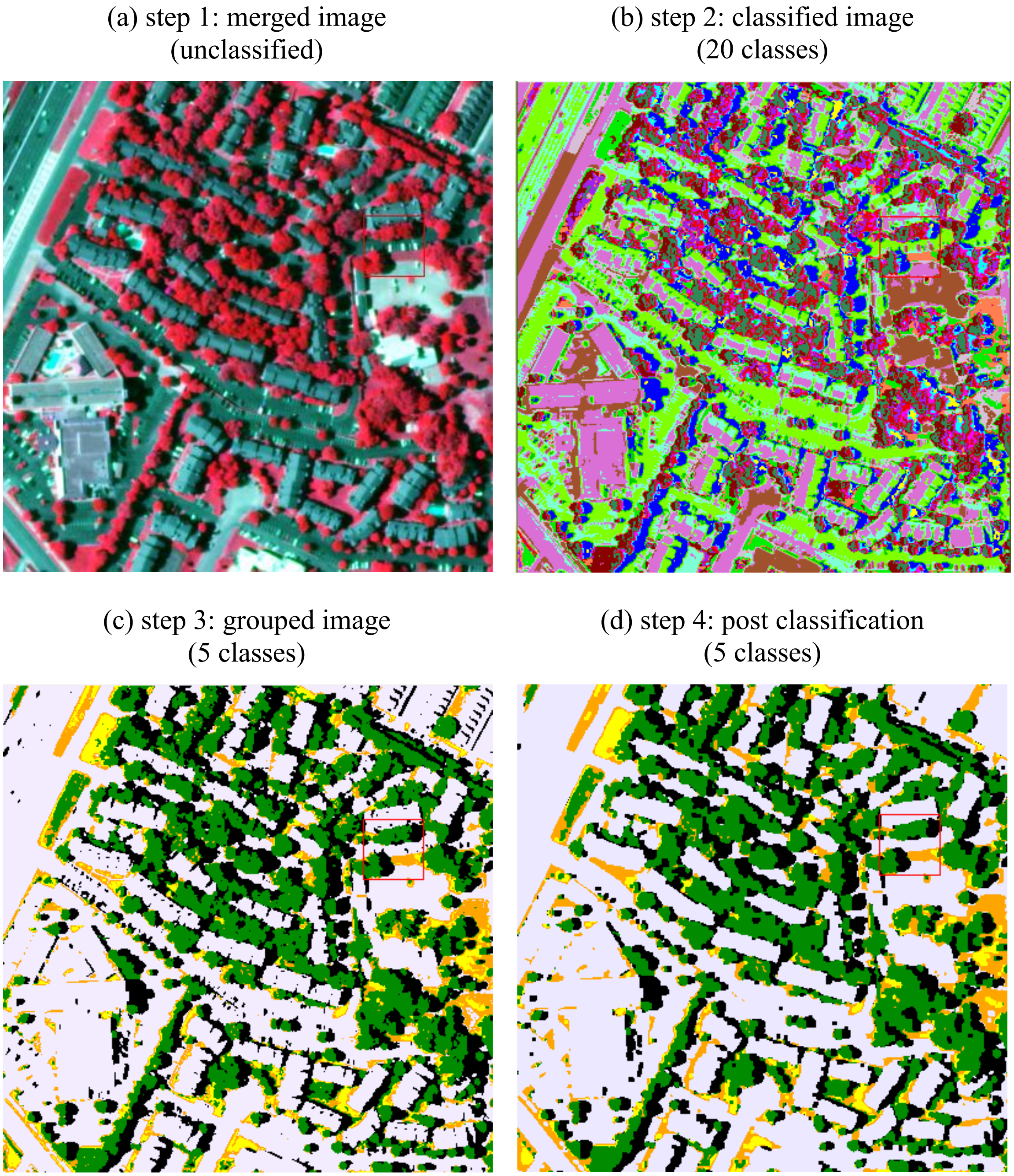
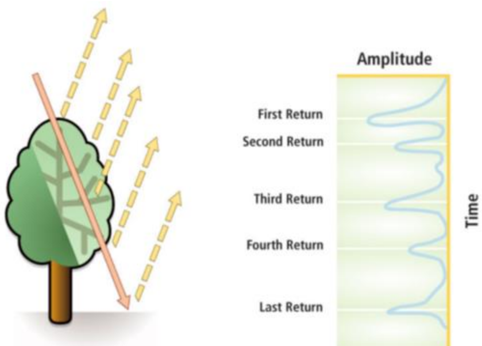


Figure 9
Tree Canopy Classification

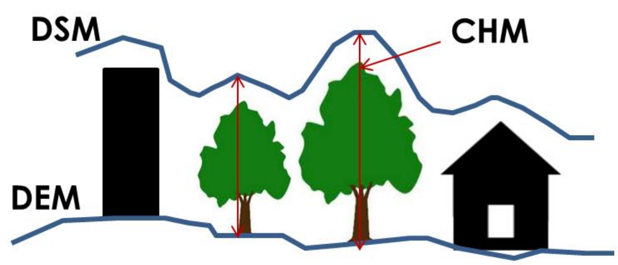
3.3.3 Tree Heights

Tree canopy heights were derived from LiDAR data provided from the Capital Area Council of Governments, which is characterized by multiple points that include height information over an area. To extract the height information from the LiDAR data, the following steps were taken as referring to the LiDAR analysis tutorial released in 2010 from ESRI (Sumerling, 2011). First, the raw LiDAR data were converted into a format ArcGIS by utilizing the LAS To Multipoint tool in ArcGIS because the data is based on the LASer (LAS) file format. The tool loaded the raw LiDAR data into a multipoint feature class. However, since the point layer extracted from the function, LAS to Multipoint, included multiple points (n=3500) in a row, they were converted into single points by utilizing the Multipart to Singlepart tool. Second, the next task was to select points within the tree canopy coverage classified by ISODATA processing because the points included height information of other artificial materials (buildings, highways, and other infrastructure). Third, the point data were then loaded into raster format to create a digital surface model (DSM) and a digital elevation model (DEM), utilizing the Point to Raster tool in ArcGIS. Since the DSM and DEM include tree canopy height information gathered from the first return and ground height information acquired from the last return respectively (Figure 10 (a)), tree canopy heights representing a canopy height model (CHM) was measured by subtracting the DEM values from the DSM values (Figure 10 (b)). The cell size of CHM, DEM, and DSM was 15 feet (about 4.5 meters). Any potential outlier cells indicating non-tree canopy coverage (e.g. tall building roofs) and the cells whose values were lower than 3.5 feet (about 1 meter) that might indicate bushes or grass were excluded (Figure 11). An example of finalized tree heights excluding the non-tree canopy areas is presented in Figure 12.



(a) Visual example of LiDAR data process

Source: Lidar Analysis in ArcGIS 10 for Forestry Applications (Sumerling, 2011)



(b) Canopy height model measure

(CHM = DSM – DEM)

Figure 10

Tree Heights Extracted from LiDAR Data

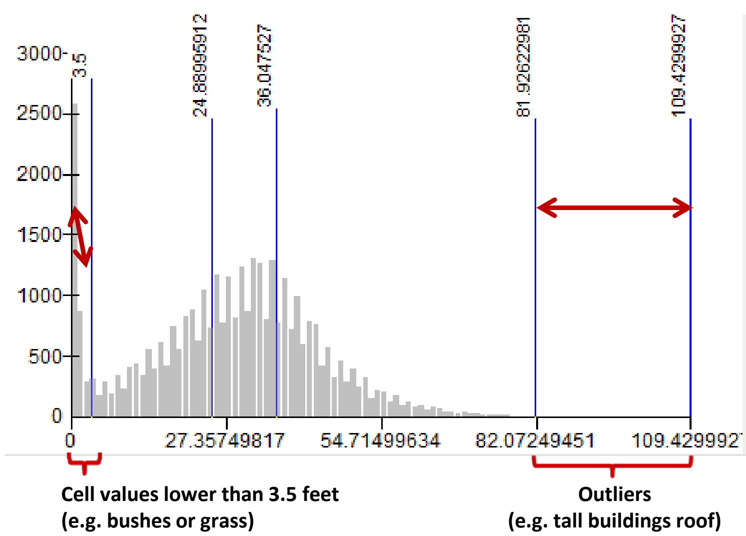


Figure 11
Example of Exclusion of Non-Trees and Outliers

Figure 12
Visual Example of Tree Heights Expressed by Grid Format

3.3.4 NDVI and Temperature

The normalized difference vegetation index (NDVI) is a simple indicator which quantifies the amount of green vegetation in an area and is derived from Landsat TM band 3 (red band) and band 4 (near-infrared). The Landsat 5 TM image taken from June 4, 2010, was used for the NDVI calculation. The reason for selecting the image taken in June was because the image did not have any cloudiness obstruction and it was consistent with the survey time. The NDVI calculations are based on the fact that greener plants reflect radiation in the near infrared (band 4) while absorbing radiation in the red band (band 3). Thus, the satellite remote sensor stores high values of the near infrared band and low values of the red band for an area of dense green vegetation. The

NDVI for a pixel (30x30m) was calculated based on the following formula (Jensen, 2005):

$$NDVI = \frac{Band\ 4\ (near\ infrared) - Band3\ (red)}{Band\ 4\ (near\ infrared) + Band3\ (red)}$$

This formula yields a value ranging from -1 (usually water) to 1 (dense green vegetation). For the NDVI calculation, the raster calculator tool in ArcGIS was utilized. Figure 13 shows the finalized NDVI map for the study area.

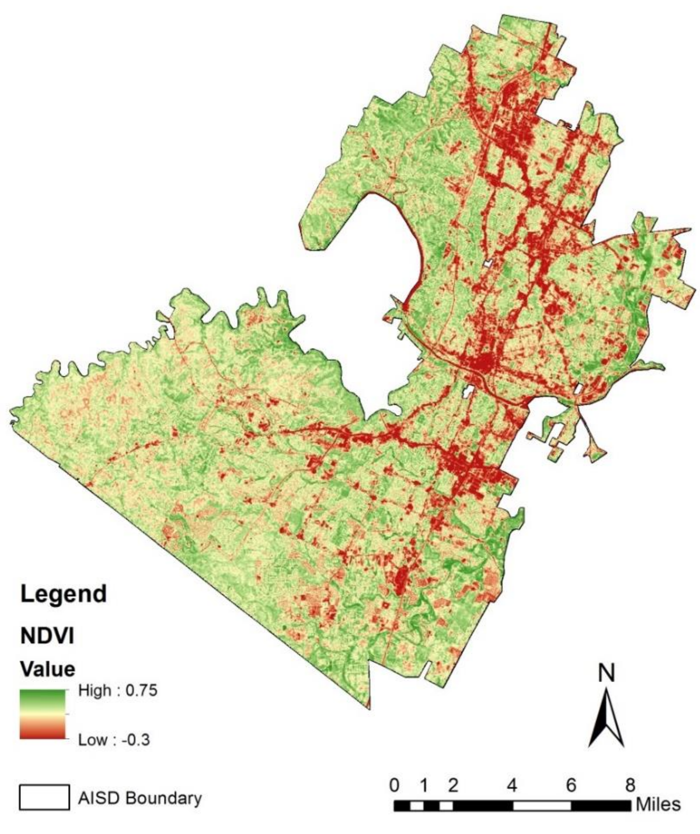


Figure 13
NDVI Map for the Study Area

Temperature data was also derived from the Landsat 5 TM, but using the thermal band (band 6). The thermal band from the Landsat 5 TM stores temperature information as a digital number (DN), and thus the DNs needed to be converted into degrees Celsius using a three step process (Yale Center for Earth Observation, 2010). The first step was to convert the DNs to radiance values using this formula:

$$CV_R = G(CV_{DN}) + B$$

Where:

CV_R is the cell value as radiance

CV_{DN} is the cell value digital number

G is the gain

B is the bias (or offset)

The following formula with specific values was entered in the raster calculator tool in ArcGIS: *0.05518 * (DN) + 1.2378*, where DN was matched with the thermal band.

The second step was to convert the Radiance values to temperature as degrees Kelvin using the following formula:

$$T = \frac{K_2}{\ln(\frac{K_1 * \mathcal{E}}{CV_R} + 1)}$$

Where:

T is degrees Kelvin

CV_R is the cell value as radiance

$\mathcal{E}$ is emissivity (typically 0.95)

K_1 is 607.76 for Landsat TM sensor

K_2 is 1260.56 for Landsat TM sensor

The following formula with specific values was entered in the raster calculator tool in ArcGIS: *1260.56 / Ln((607.76 * 0.95) / Radiance + 1*), where *Radiance* was matched with the radiance band created in the preceding step.

The third step was to convert the values of degrees Kelvin to degrees Celsius by subtracting 273.15 from the degrees Kelvin. The following formula was entered in the raster calculator tool in ArcGIS: *Degrees Kelvin – 273.15*, where *Degrees Kelvin* was matched with the output created above. Figure 14 shows the finalized temperature map based on degrees Celsius for the study area.

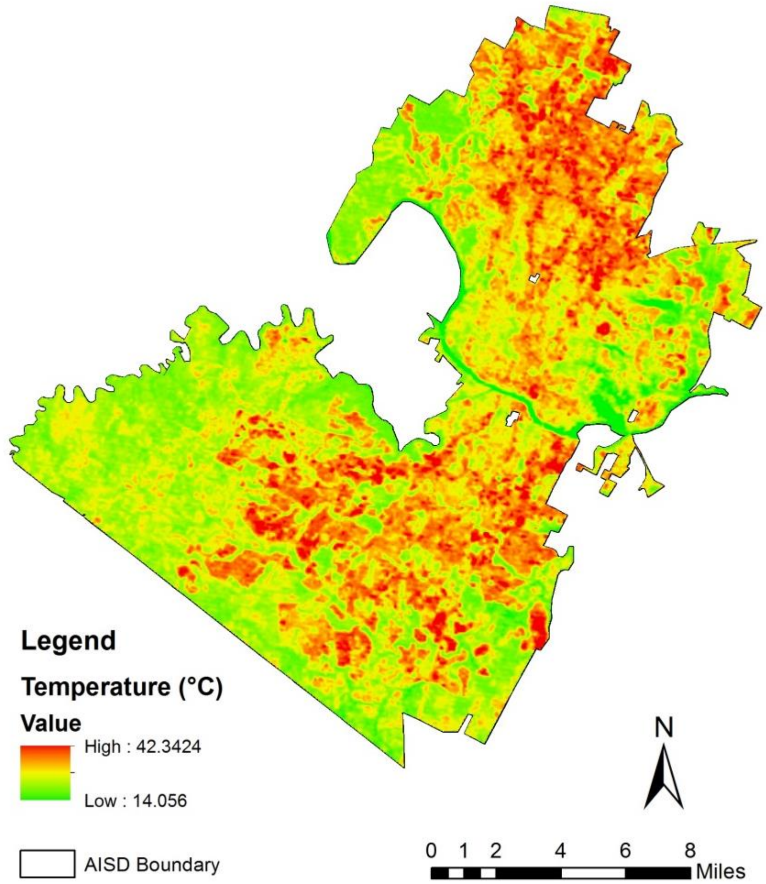


Figure 14
Temperature Map for the Study Area

4. STUDY ONE:

PARENTAL CONCERNS FOR CHILDREN'S ACTIVE TRAVEL TO SCHOOL: SAFETY AND THERMAL COMFORT

4.1 INTRODUCTION

Physical activity among children is necessary to improve their health, and the U.S. Department of Health and Human Services issued the *Physical Activity Guidelines for Americans* in 2008 that helps children improve their health through appropriate physical activities and recommends 60 minutes or more of daily physical activity (U.S. Department of Health and Human Services, 2008). Most children in the U.S., however, do not meet the recommended level of physical activity. As a feasible way to increase children's daily physical activity level, walking and bicycling to school has received wide attention of the public. The significant evidence that walking and bicycling to school among school-aged children contributes to increasing their overall daily physical activity levels was present in many studies (Davison et al., 2008; Faulkner et al., 2009; Southward et al., 2012). Rates of walking and bicycling to school, however, have decreased over the last few decades, from 47.7% in 1969 to 12.7% in 2009 (N. C. McDonald et al., 2011).

To identify the reasons why some children walked or bicycled to school but others did not, a number of studies examined the direct relationships between environmental factors such as roadway conditions, sidewalk availability, transportation infrastructure, urban form, etc. and children's active travel behaviors such as walking and bicycling, controlling for personal and social factors that are involved with the behaviors (Dalton et al., 2011; Larsen et al., 2009; R. Mitra et al., 2010; Panter et al., 2010b). Most of the previous studies have represented how each environmental variable is positively or negatively associated with children's walking and bicycling behaviors. Children's active travel to school (ATS), however, is determined primarily by parental decisions based on their perceptions or concerns about surrounding neighborhood environmental conditions and safety issues (Faulkner, Richichi, Buliung, Fusco, & Moola, 2010). Therefore, it is important to understand what concerns parents may have for their children's ATS.

In the HealthStyles Survey by the Centers for Disease Control and Prevention in 2002, safety (related to traffic- and crime-danger) and weather (or thermal comfort) issues were ranked as the second and the third most frequently reported barriers to ATS among parents, after the long distance barrier. While the distance barrier to children's ATS needs a long term zoning policy to be addressed, safety and thermal comfort are more readily modifiable factors that can be improved with proper planning or design strategies. Therefore, understanding what physical environmental features influence parental perceptions of safety and thermal comfort is important for developing effective and feasible interventions to mitigate their perceived barriers to children's ATS.

In previous studies, parental safety concerns have been identified as one of the main factors impeding children's ATS. The specific variables used to capture parental safety concerns that are shown to be negatively associated with children's ATS included: neighborhood safety problems (Ahlport, Linnan, Vaughn, Evenson, & Ward, 2008;

Greves et al., 2007), strangers in neighborhoods (Greves et al., 2007), traffic dangers (Greves et al., 2007; Panter et al., 2010a; Zhu & Lee, 2009), and hostile transportation infrastructure for walking such as highways or railroads (Zhu & Lee, 2009). Although a number of studies have identified the relationships between parental safety concerns and ATS, little is known about how parental safety concerns are associated with surrounding environmental conditions. In a study by Lee and Kim (2012), parental safety concern was considered as an intermediate outcome between built environmental factors and children's walking to school. This study showed that destination land uses, non-residential land uses and hostile infrastructure such as highways and busy traffic roads increased parental safety concerns and were indirectly associated with children's walking to school through their influences on parental concerns. The direct link between parental safety concern and children's walking to school was not found in their study. More studies are needed to better understand specific environmental features linked to reducing or increasing parental safety concerns and to identify intervention strategies that target this important parental perceived barrier that appear to be a prerequisite to ATS promotion.

Parental concerns about weather are primarily about thermal discomfort when their child engages in ATS behaviors in hostile/unpleasant weather conditions. Whether the weather is pleasant or unpleasant influences the level at which children engage in outdoor activities in general. A low level of thermal comfort (e.g. too hot or too cold) often acts as a barrier to ATS. According to a 2005 report from the Centers for Disease Control Prevention, the concerns about lacking adequate protection from weather were the top-most barrier to children's walking to or from school among parents whose children were walkers and were ranked third after distance to school and traffic danger barriers among parents whose children were non-walkers (Centers for Disease Control and Prevention, 2005). In studies conducted by Robertson-Wilson et al. (2008) and Sirard et al. (2005), seasonal variations and air temperatures that influence the weather or thermal comfort conditions were examined as potential correlates of active commuting to school. Though these weather- or thermal comfort-related variables were not statistically significant, it brought attention to weather and thermal comfort issues which may be potentially important but understudied in research related to children's walking to school. Studies identifying environmental features that may affect thermal conditions are necessary to mitigate parental concerns about thermal comfort and successfully promote children's ATS behavior.

Given the shortage of previous studies focusing on parental perceptions of safety and thermal comfort, this study examines how built and natural environmental conditions are associated with parental safety and thermal comfort concerns, controlling for personal, attitudinal, and social factors. Further, this study investigates the spatial distribution of the built and natural environments by income status, testing a hypothesis that the environmental risks related to safety and thermal comfort are not equal across different income groups.

4.2 METHODS

4.2.1 Conceptual Framework

The main objective of this study is to examine associations between built/natural environments and parental concerns about safety and thermal comfort. A conceptual framework responding to the first objective of this dissertation is presented in Figure 15. This conceptual framework shows the direct relationships between objectively-measured environments and parental safety and thermal comfort concerns, controlling for socio-demographic, attitudinal, and social factors.

The conceptual framework describes three hypotheses that will be examined in this study, including:

- Hypothesis 1: Walking friendly built environments and thermally comfortable natural environments will be associated with decreased parental safety and thermal comfort concerns.
- Hypothesis 2: Low-income parents are more likely to be exposed to undesirable built and natural environments, and thereby will have higher concerns for safety and thermal comfort.
- Hypothesis 3: Positive behaviors and attitudes toward walking and positive social supports will be associated with decreased parental safety and thermal comfort concerns.

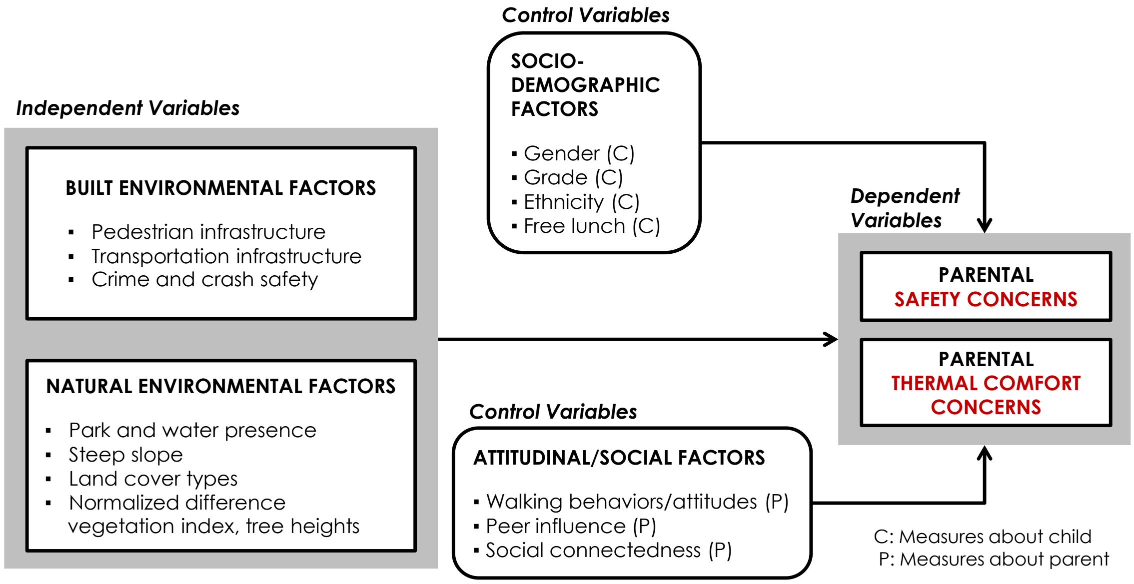


Figure 15
Conceptual Framework for Study 1

4.2.2 Study Setting and Sample

The study area is the Austin Independent School District (AISD) which covers most of the City of Austin, Texas. A total of 4,602 parents from 20 elementary schools out of 81 in the AISD answered the Safe Routes to School (SRTS) survey in 2010. Among them, a total of 4,270 geocoded parental surveys were used for the study. The study schools in AISD were selected based on the following four criteria: 1) school location, 2) environmental settings, 3) socio-economic status, and 4) research approval from AISD and the individual schools. As shown in Figures 16, the selected study schools and areas have a wide range of economic conditions.

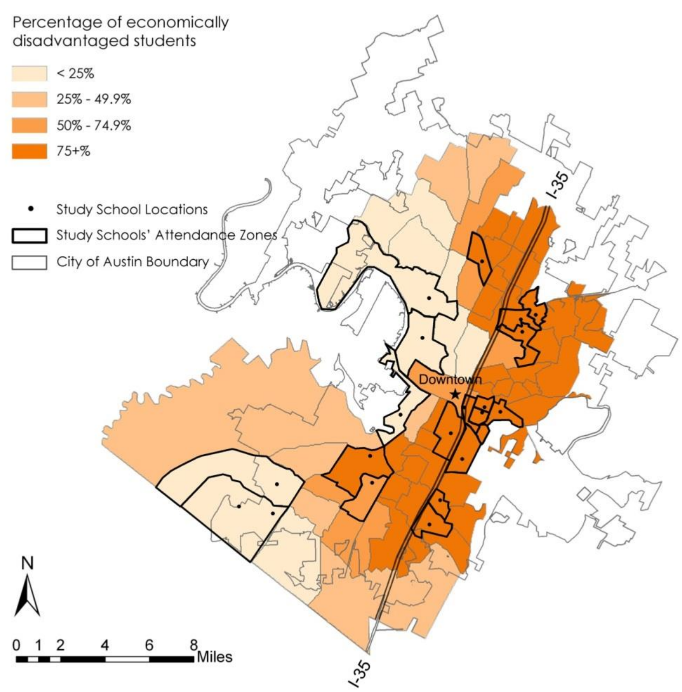


Figure 16
School Locations and Percentages of Economically Disadvantaged Students in AISD, Austin TX

4.2.3 Data Collection and Measures

This cross-sectional study was based on the SRTS survey data collected in 2010 from the “Whys” and “Why Nots” of Active Living project, funded by the Robert Wood Johnson Foundation’s Active Living Research Program. The Active Living Research was 5-year project led by Chanam Lee from 2008 to 2012 that examined multi-level barriers and motivators influencing walking to school behaviors among high-risk groups of children. This dissertation study used part of the survey data including socio-economic variables, social factors, and parental concerns about safety and thermal comfort. The objectively-measured built and natural environment data derived from the Geographic Information System (GIS) and Environment for Visualizing Images (ENVI) for 2012 – 2013 were used for this study.

Outcome Variables: Parental Concerns about Safety and Thermal Comfort

Parental safety concerns consist of responses to eight specific survey items to the question of safety concerns about walking to school. The items were (a) my child may get lost, (b) my child may be taken or hurt by a stranger, (c) my child may get bullied, teased, or harassed, (d) my child may be attacked by stray dogs, (e) my child may be hit by a car, (f) exhaust fumes may harm my child’s health, (g) no one will be able to see and help my child in case of danger, and (h) my child may get injured by falling (due to drainage ditches, uneven walking surfaces, etc.). These items related to parental safety concerns were developed from existing survey measures and previous studies (Forman et al., 2008; Hume, Ball, & Salmon, 2006; Tracy Elizabeth McMillan, 2003). The answer options to the survey items included a 5-point Likert scale coded from 1 for 'strongly disagree' to 5 for 'strongly agree.' Higher scores indicate greater parental safety concerns for children's ATS. For the safety concern outcome variable, a composite measure computing the mean of the eight Likert-scale items was utilized, and the output was treated as a continuous variable for statistical analysis (Wood, Frank, & Giles-Corti, 2010). Principal-component factor analysis based on the eight survey items loaded only one factor having an Eigenvalue of greater than 1 (Eigenvalue = 4.54) and showed that all the factor loadings for each item were greater than 0.7. It confirmed the validity of combining the eight survey items into one composite scale variable (Acock, 2008). For the parental thermal comfort concern variable, a single survey question about walking in the neighborhood, "My child gets too hot and sweaty." was used. This variable was treated as an ordinal outcome variable for a statistical analysis because the survey answers were composed of a 5-point Likert scale coded from 1 for 'strongly disagree' to 5 for 'strongly agree.' Table 5 shows the descriptive statistics of the two outcome variables.

Explanatory Variables: Built and Natural Environments

The objectively-measured built environmental variables included transportation infrastructure (e.g., bike lanes, sidewalks, highways, railroads, intersections) derived from the Texas Department of Transportation, crime types and locations from the Texas Department of Public Safety, crash incidents from the Austin Police Department, and playgrounds and traffic volume from the City of Austin. For the crime and crash variables, hotspot analysis (expressed by z-scores) was undertaken using a model builder in ArcGIS.

The objectively-measured natural environmental variables included parks from the City of Austin, steep slopes derived from a digital elevation model, land cover types (urbanized area, tree canopy, and grass cover) classified from a digital orthophoto quarter quads image through ENVI, tree heights derived from light detection and ranging, and surface temperature and normalized difference vegetation index (NDVI) derived from a remotely-sensed image from Landsat 5TM.

As explained, the survey items related to parental safety concerns were associated with “walking to school” while the survey item related to parental thermal comfort concerns was about “walking in the neighborhood.” Thus, the built and natural environmental characteristics for parental safety concern analysis were measured by home-to-school route buffers (buffer sizes: 100 feet and 200 feet) while for thermal comfort concern analysis the environmental characteristics were measured by home buffers (buffer sizes: a quarter mile and a half mile). The reason for utilizing the different spatial units was because they might produce different statistical results (Raktim Mitra & Buliung, 2012).

Tables 7 and 8 represent the descriptive statistics of the built and natural environmental variables measured within 200 feet HTS route buffer and a quarter mile home buffer respectively. The bivariate tests reported in these tables show how the environmental conditions are disproportionately distributed by income status.

Confounding Factors

Data on student gender, grade, ethnicity, and free or reduced school lunch service qualification were collected from the parental survey questionnaire. To represent the economic status of parents, a dummy variable indicating whether or not students received free or reduced school lunch service was used as a proxy of income status.

Parents were also asked about their attitudes and social support toward walking in the neighborhood. Five response options, using a 5-point Liket scale from 'strongly disagree' to 'strongly agree', were used for the variables. The four attitudinal factors measured were a) Walking is a good way to exercise, b) I walk quite often in my daily routine, (c) I (would) enjoy walking with my child to/from school, and (d) My family and friends like the idea of walking to school. Two social factors measured were a) Other kids walk to/from school in my neighborhood and b) I feel connected to people in my neighborhood.

4.2.4 Data Analysis

Built and natural environment disparities by income status were examined through chi-square tests for categorical variables and t-tests for continuous variables. As a proxy of income status to classify low- vs. high-income, a survey item asking whether a child was eligible for free or reduced-price school lunch was used. If a child received the service at school, the student was assigned to a low-income group. Further, a series of GIS maps were generated to visually assess spatial disparities of built and natural environmental conditions. Moran's I (value ranging from -1 to 1), based on feature locations and attribute values at the school district level, represented how dispersed or clustered the environmental features were. Positive Moran's I values reflected the presence of spatial clustering of the environmental features, while negative values indicated spatially dispersed conditions (Environmental Systems Research Institute, 2012).

Statistical analyses were undertaken using STATA, version 12, to examine the relationships between the built and natural environments and parental concerns about safety and thermal comfort. In order to assess the association between the built/natural environmental variables and parental safety concerns, an ordinary least square (OLS) regression model was used as the outcome variable was computed by the means of eight survey items and was treated as a continuous variable. For the associations between the built/natural environments and parental thermal comfort concerns, a stereotype logistic model (SLM) was utilized to accommodate the ordinal nature of the outcome variable coded by a 5-point Likert scale. The SLM does not require a parallel regression assumption of the ordered logit model in which the coefficients are the same across the outcome categories and the assumptions are often violated in practice (Scott Long & Freese, 2006). Unlike the multinomial model estimating all the possible combination relationships of the predictors between the different levels of the outcome variable, the SLM allows a one dimensional model (one regression model) to reduce the number of parameters by imposing ordering constraints to the outcome categories (Lunt & Unit, 2001). In the SLM, two types of parameters are used for the interpretation of the effects of independent variables on the outcome, including β coefficients for each independent variable and φ scaling factors for each outcome category. To ensure the ordinal nature of the outcome categories, the SLM assumes that $1 = \varphi_1 \geq \varphi_2 \geq \ldots \geq \varphi_k = 0$. By multiplying the β coefficients by the φ scaling factors, the relationships between the predictors and outcome across the outcome categories are measured, simplifying the regression model without losing the adequacy of the fit. This is the main strength of using the SLM for the ordinal outcome variable, rather than utilizing the multinomial logistic regression.

4.2.5 Modeling Process

The regression modeling involved the following five steps. First, a base model including all significant personal, attitudinal and social factors was generated for each outcome variable. Second, each built and natural environmental variable was added to the base model one at a time (one-by-one tests). Third, all significant built environmental (BE) variables from the one-by-one tests were added together to the base model to develop the BE model (Model 1) which included those most significant built environmental variables after considering their theoretical significance based on the proposed conceptual framework, and statistical significance and multicollinearity issues. Fourth, utilizing all significant natural environment (NE) variables from the one-by-one tests, the same process was applied to generate the NE multivariate model (Model 2). Finally, all significant variables from Model 1 and Model 2 were added together to generate the final model (Model 3), which included all significant built and natural environmental variables at the 0.05 level. Figure 17 visually shows the regression modeling steps mentioned above.

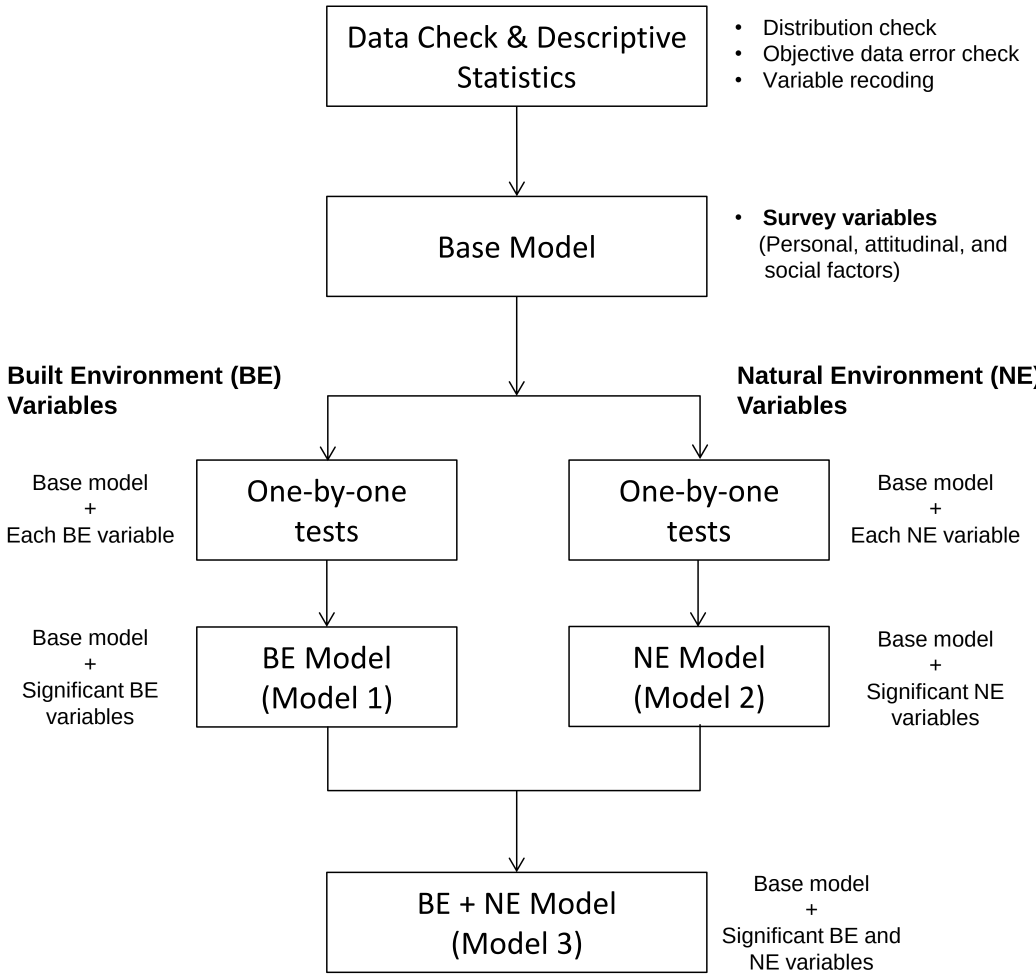


Figure 17
Modeling Process

4.3 RESULTS

4.3.1 Sample Characteristics

Table 6 shows the sample characteristics. Students were gender balanced (51.4% female, 48.6% male). Given the sample variations of the variables, grade was categorized as PK-K (26.0%), 1^{st} – 3^{rd} (49.5%), and 4^{th} – 6^{th} (24.2%), excluding 7^{th} – 12^{th} grade group due to the small sample cases (N=15, 0.3%). Child's ethnicity was categorized as non-Hispanic white (25.5%), Hispanic (63.9%), and others (10.6%). About 64.4% of students qualified for the special (reduced price or free) school lunch program and were considered as a low income group in this study.

Table 6
Descriptive Statistics of Outcome Variables and Confounding Factors

Variables	N	Mean	SD
Outcome variables‡			
Parental Safety Concerns	4,498	3.28	1.06
(mean score of following 8 items with 5-point Likert scale)			
(a) my child may get lost.	4,354	2.97	1.52
(b) my child may be taken or hurt by a stranger.	4,371	3.74	1.33
(c) my child may get bullied, teased, or harassed.	4,326	3.26	1.39
(d) my child may be attacked by stray dogs.	4,365	3.30	1.41
(e) my child may be hit by a car.	4,387	3.85	1.32
(f) exhaust fumes may harm my child's health.	4,287	2.94	1.35
(g) no one will be able to see and help my child in case of Danger.	4,323	3.20	1.36
(h) my child may get injured by falling (due to drainage ditches, uneven walking surfaces, etc.).	4,327	2.98	1.39
Parental Thermal Comfort Concerns (5-point Liket scale) My child gets too hot and sweaty.	4,349	3.19	1.32
Socio-demographic factors†			
Student Gender	0: Female (2,309, 51.4%), 1: Male (2,181, 48.6%)		
Grade	11: PK-K (1,164, 26.1%), 12: 1st-3rd (2,215, 49.6%), 13: 4th-6th (1,084, 24.3%)		
Free or Reduced Lunch Qualification	0: No (1,474, 35.6%), 1: Yes (2,672, 64.4%)		
Student Ethnicity	1: White (1,095, 25.5%), 2: Hispanic (2,746, 63.9%), 3: Others (454, 10.6%)		
Attitudinal/social factors†‡			
Walking is a good way to exercise.	4,464	4.74	0.74
I walk quite often in my daily routine.	4,370	3.93	1.20
I (would) enjoy walking with my child to/from school.	4,365	4.09	1.21
My family and friends like the idea of walking to school.	4,355	3.73	1.27
Other kids walk to/from school in my neighborhood.	4.374	3.78	1.22
I feel connected to people in my neighborhood.	4,357	3.72	1.26

†: These variables were used as confounding factors for the final regression models.
‡: These variables indicate the respondents' feelings about walking and their neighborhood, and were treated as continuous variables coded by 1 for "strongly disagree," 2 for "somewhat disagree," 3 for "neither disagree nor agree," 4 for "somewhat agree," and 5 for "strongly agree."

4.3.2 Built and Natural Environmental Characteristics

Tables 7 and 8 represent the descriptive statistics of the built and natural environmental variables measured by 200 feet home-to-school route buffer and a quarter mile home buffer, respectively. The tables also include the results of the bivariate tests comparing the mean or the frequency of the environmental conditions between high- and low-income groups of respondents.

In terms of the built environmental conditions, neighborhoods from the high-income group had more bike lanes and sidewalks, while neighborhoods from the low-income group had more crimes, crashes, highways and railroads, and streets with higher speeds (Table 8). These results showing the safer environmental conditions for the high-income group were also examined visually through comparative GIS maps (Figures 16, 18 and 19). As shown in Figure 16, a higher portion of economically disadvantaged students lived in the eastern part of AISD, where rates of crimes and higher crashes were reported to be higher than those in AISD other areas (Figures 18 and 19).

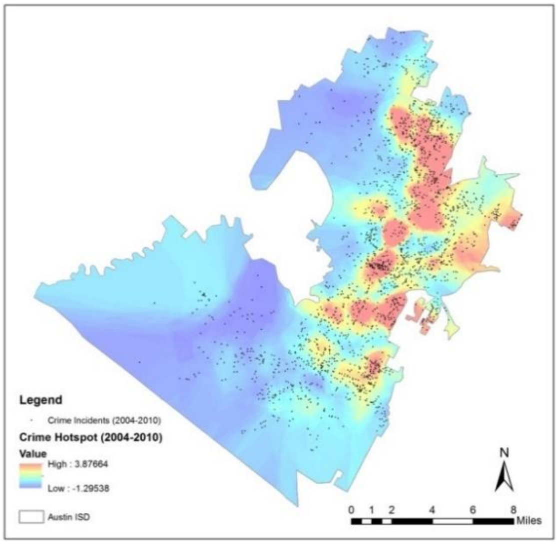


Figure 18
Crime Hotspots in AISD, Austin TX

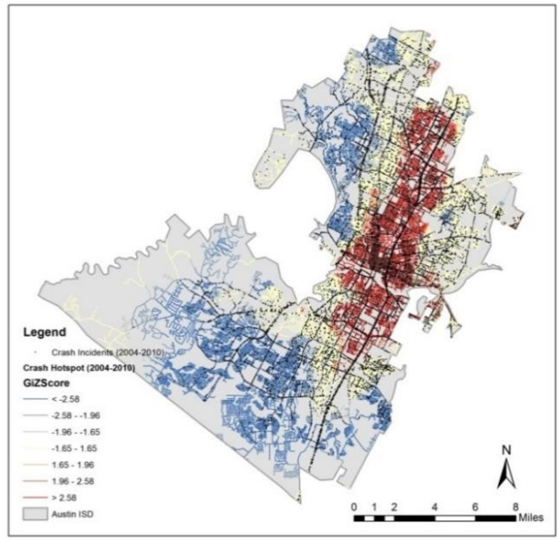
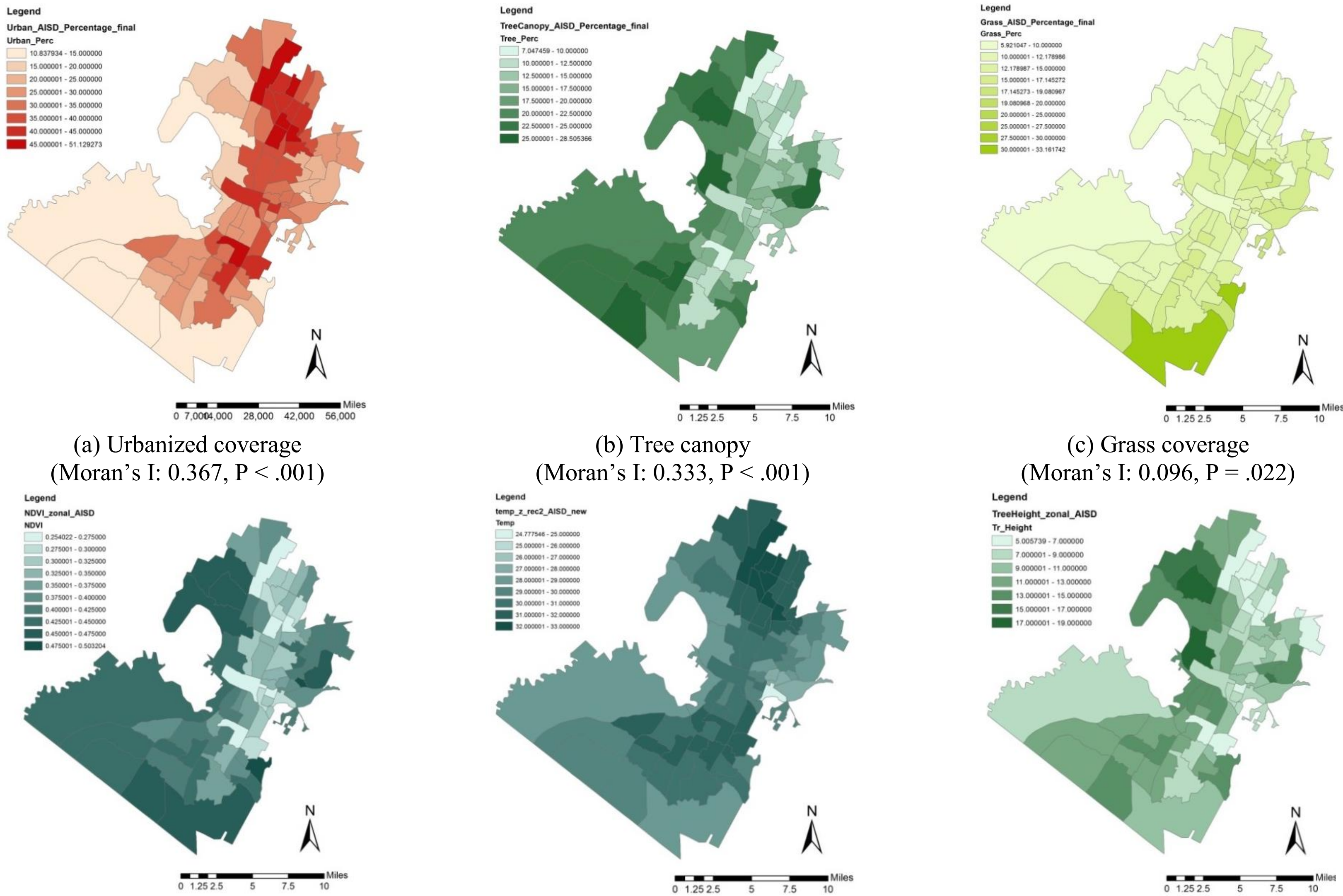


Figure 19
Crash Hotspots in AISD, Austin TX

Among the natural environmental factors, more parks, steeper slope areas, more tree canopies, higher NDVI, and higher tree heights were reported for the high-income group neighborhoods, while higher rates of urbanized area and higher temperatures were observed for the low-income group (Tables 7 and 8). These results were also supported by a series of GIS maps (Figure 20). Hostile natural environmental conditions (more urbanized coverage, higher temperature, lower NDVI, lower tree canopy, and lower tree heights) were distributed more heavily in the east area of AISD where higher proportions of economically disadvantaged students lived.



(a) Urbanized coverage
(Moran's I: 0.367, P < .001)

(b) Tree canopy
(Moran's I: 0.333, P < .001)

(c) Grass coverage
(Moran's I: 0.096, P = .022)

(d) NDVI
(Moran's I: 0.353, P < .001)

(e) Temperature
(Moran's I: 0.657, P < .001)

(f) Tree height
(Moran's I: 0.273, P < .001)

Figure 20
Spatial Distributions of the Natural Environmental Factors in AISD, by School Attendance Zone Area

Table 7
Descriptive Statistics and Bivariate Tests by Income Status (200-feet HTS route buffer)

Variables	Description	Total Freq. Mean	Total % (SD)	Low income Freq. Mean	Low income % (SD)	High income Freq. Mean	High income % (SD)	Bivariate test: Test	Bivariate test: Sig.
Built Environmental Variables									
Bike lanes (ratio)	Length of bike lanes divided by total street length	0.26 (0.29)		0.28 (0.31)		0.22 (0.24)		T	<.001
Sidewalks (ratio)	Length of sidewalk lanes divided by total street length	0.72 (0.20)		0.71 (0.22)		0.74 (0.17)		T	<.001
Crime – hotspot	Average z-scores of crime hotspots	0.03 (0.79)		0.39 (0.61)		-0.67 (0.58)		T	<.001
Crash – hotspot	Average z-scores of crash hotspots with total crashes	1.08 (3.91)		2.63 (3.33)		-1.84 (3.20)		T	<.001
Playgrounds (presence)	Presence of playgrounds	401	10.3	331	13.0	70	5.2	χ^2	<.001
Intersections – density	Number of intersections per acre	0.26 (0.08)		0.27 (0.08)		0.24 (0.08)		T	<.001
Highways (presence)	Presence of highways	810	20.9	474	18.7	336	24.9	χ^2	<.001
Railroads (presence)	Presence of railroads	465	12.0	282	11.1	183	13.6	χ^2	<.001
% of high speed streets (>30mph)	Percentage of streets with speeds over 30 mph	63.10 (23.68)		66.80 (21.16)		56.13 (26.45)		T	<.001
Natural Environmental Variables									
Parks (%)	Total area of parks divided by neighborhood area*100	3.96 (5.59)		3.58 (5.88)		4.67 (4.92)		T	<.001
Parks (presence)	Presence of parks	2,600	66.9	1,470	57.9	1,130	83.9	χ^2	<.001
Water features	Presence of water features	1,029	26.5	746	29.4	283	21.0	χ^2	<.001
Mean slopes	Average steep slope of neighborhood area	3.77 (2.50)		3.40 (2.27)		4.48 (2.75)		T	<.001
Steep slopes > 5% (%)	Total area of slope greater than 5%, divided by buffer area*100	24.13 (24.16)		21.38 (24.69)		29.31 (22.24)		T	<.001
Steep slopes > 8.33% (%)	Total area of slope greater than 8.33%, divided by neighborhood area*100	10.48 (16.09)		10.11 (15.08)		11.20 (17.84)		T	0.045
Urbanized area (%)	Total area of urbanized coverage divided by neighborhood area*100	36.76 (10.03)		38.57 (10.33)		33.34 (8.44)		T	<.001
Tree canopy (%)	Total area of tree canopy divided by neighborhood area*100	15.73 (6.36)		13.31 (5.18)		20.30 (5.84)		T	<.001
Grass cover (%)	Total area of grass coverage divided by neighborhood area*100	11.68 (3.51)		11.63 (3.68)		11.78 (3.16)		T	0.225
Temperature (°C)	Average temperature in neighborhood area	31.29 (1.44)		31.34 (1.57)		31.22 (1.14)		T	0.011
NDVI (ranging from -1 to 1)	Average NDVI in neighborhood area	0.35 (0.07)		0.33 (0.07)		0.39 (0.06)		T	<.001
Tree heights (feet)	Average tree heights in neighborhood area	9.82 (3.86)		8.69 (3.25)		11.96 (4.00)		T	<.001

Note: Low and high income children were classified by a survey question of "free or reduced lunch service." If a child received the free or reduced school lunch service, the student was placed in the low income category.
Freq.: Frequency, SD: Standard deviation, T: T-test, χ^2: Chi-squared test

Table 8
Descriptive Statistics and Bivariate Tests by Income Status (1/4-mile home buffer)

Variables	Description	Total		Low income		High income		Bivariate test	
		Freq. Mean	% (SD)	Freq. Mean	% (SD)	Freq. Mean	% (SD)	Test	Sig.
Built Environmental Variables									
Bike lanes (presence)	Presence of bike lanes	484	12.5	249	9.8	235	17.5	χ^2	<.001
Sidewalks (ratio)	Length of sidewalk lanes divided by total street length	0.82	(0.19)	0.80	(0.19)	0.86	(0.17)	T	<.001
Crime – hotspot	Average z-scores of crime hotspots	0.17	(0.99)	0.62	(0.84)	-0.66	(0.66)	T	<.001
Crash – hotspot	Average z-scores of crash hotspots with total crashes	1.07	(3.92)	2.51	(3.34)	-1.65	(3.46)	T	<.001
Playgrounds (presence)	Presence of playgrounds	514	13.2	363	14.3	151	11.2	χ^2	0.007
Intersections – density	Number of intersections per acre	0.15	(0.07)	0.15	(0.06)	0.16	(0.06)	T	0.003
Highways (presence)	Presence of highways	885	22.8	659	25.9	226	16.8	χ^2	<.001
Railroads (presence)	Presence of railroads	344	8.9	251	9.9	93	6.9	χ^2	<.001
% of high speed streets (>30mph)	Percentage of streets with speeds over 30 mph	48.79	(21.43)	54.50	(19.57)	38.04	(20.65)	T	<.001
Natural Environmental Variables									
Parks (%)	Total area of parks divided by neighborhood area*100	5.76	(9.03)	3.76	(6.26)	9.53	(11.82)	T	<.001
Parks (presence)	Presence of parks	2,785	71.7	1,613	63.50	1,172	87.01	χ^2	<.001
Water features	Presence of water features	1,161	29.9	816	32.1	345	25.6	χ^2	<.001
Mean slopes	Average steep slope of neighborhood area	4.60	(3.27)	4.26	(2.76)	5.24	(3.99)	T	<.001
Steep slopes > 5% (%)	Total area of slope greater than 5%, divided by neighborhood area*100	28.92	(25.38)	27.42	(25.37)	31.74	(25.17)	T	<.001
Steep slopes > 8.33% (%)	Total area of slope greater than 8.33%, divided by neighborhood area*100	14.72	(19.88)	14.54	(18.01)	15.05	(22.98)	T	0.446
Urbanized area (%)	Total area of urbanized coverage divided by neighborhood area*100	33.77	(12.12)	37.59	(11.71)	26.60	(9.29)	T	<.001
Tree canopy (%)	Total area of tree canopy divided by neighborhood area*100	17.79	(7.98)	14.35	(6.02)	24.26	(7.16)	T	<.001
Grass cover (%)	Total area of grass coverage divided by neighborhood area*100	11.63	(3.61)	11.63	(3.68)	11.63	(3.49)	T	0.954
Temperature (°C)	Average temperature in neighborhood area	31.22	(1.55)	31.45	(1.58)	30.78	(1.39)	T	<.001
NDVI (ranging from -1 to 1)	Average NDVI in neighborhood area	0.37	(0.09)	0.34	(0.08)	0.43	(0.06)	T	<.001
Tree heights (feet)	Average tree heights in neighborhood area	10.91	(4.65)	9.29	(3.65)	13.94	(4.80)	T	<.001

Note: Low and high income children were classified by a survey question of "free or reduced lunch service." If a child received the free or reduced school lunch service, the student was placed in the low income category.
Freq.: Frequency, SD: Standard deviation, T: T-test, χ^2: Chi-squared test

4.3.3 Correlates of Safety Concerns

Table 9 shows the results from the OLS regressions estimating the built and natural environmental correlates of parental safety concerns, controlling socio-demographic, attitudinal and social confounders. The table includes the results from the one-by-one models, Model 1 (the BE model), Model 2 (the NE model), and Model 3 (the BE and NE model). The regression results reported here were based on the 200 feet HTS route buffer measures because they showed a better overall model fit, with more significant environmental correlates. The results based on the 100 feet HTS route buffer measures are presented in Appendix B-1.

Personal, Attitudinal and Social Correlates of Parental Safety Concerns

All the covariates across the model presented the same results in terms of the statistical significance and the direction of association with the outcome. Thus, the results here were reported based on Model 3 which included both the built and natural environmental variables.

Parents who had $1^{st} – 3^{rd}$ grade children and $4^{th} – 6^{th}$ grade children had lower safety concerns than parents who had pre-kindergarten or kindergarten children (Coef. = − 0.095, p = 0.019 for $1^{st} – 3^{rd}$ grade, Coef. = − 0.223, p < 0.001 for $4^{th} – 6^{th}$ grade). Parents whose children were Hispanic and received free or reduced-price school lunch (low-income) had higher safety concerns than parents whose children were non-Hispanic white and were not eligible for the free lunch service (high-income) (Coef. = 0.242, p < 0.001 for Hispanic, Coef. = 0.105, p = 0.043 for low-income).

The two attitudinal variables, 'walking is a good way to exercise (Coef. = 0.251, p = <.001)' and 'I walk quite often in my daily routine (Coef. = 0.050, p = 0.001)', were associated with increased parental safety concerns. In contrast, the following four social factors, 'I (would) enjoy walking with my child to/from school (Coef. = -0.053, p = 0.005)', 'My family and friends like the idea of walking to school (Coef. = -0.045, p = 0.016)', 'Other kids walk to/from school in my neighborhood (Coef. = -0.054, p < .001)', and 'I feel connected to people in my neighborhood (Coef. = -0.090, p < .001)', were shown to be correlated with reduced safety concerns.

Environmental Correlates of Parental Safety Concerns

Model 1 shown in Table 9 presents the results from the regression model that identified significant "built" environmental variables associated with parental safety concerns, controlling for the socio-demographic, attitudinal and social variables (R-squared = 0.1349). Built environmental variables significantly associated with the parental safety concern outcome variable included: bike lane ratio (Coef. = 0.131, p = 0.027), sidewalk ratio (Coef. = -0.310, p = 0.002), intersection density (Coef. = -0.741, p = 0.001), presence of highways (Coef. = 0.163, p = 0.001), presence of railroads (Coef. = 0.127, p = 0.024), crime hotspots (Coef. = 0.117, p = <.001), and presence of sex-offenders (Coef. = 0.143, p = 0.004).

Model 2 in Table 9 showed the results from the regression model that identified significant "natural" environmental variables associated with parental safety concerns, controlling for the covariates (R-squared = 0.1315). The significant natural environmental variables included: water features (Coef. = 0.214, p = <.001), steep slopes (Coef. = 0.031, p = <.001), and tree canopy (Coef. = -0.017, p = <.001).

Model 3 was the final regression model generated by combining Model 1(the BE model) with Model 2 (the NE model) and retaining only the significant variables. The predictor variables included Model 3 accounted for 14.1% of the variance in safety concerns, which was slightly higher than the variances accounted for in Model 1 (13.5%) and Model 2 (13.2%). The statistical significance of sidewalk ratios, the presence of highways and crime hotspot variables associated with the parental safety concern outcome variable in Model 1 disappeared in Model 3, while the three natural environmental variables associated with parental safety concerns in Model 2 retained their statistical significances in Model 3. Based on the results of Model 3, more bike lanes (Coef. = 0.107, p = 0.073), the presence of highways (Coef. = 0.099, p = 0.051), the presence of railroads (Coef. = 0.136, p = 0.019), and the presence of sex-offender home locations (Coef. = 0.145, p = 0.001) along HTS route were associated with increased parental safety concerns, while higher street intersection density (higher number of intersections per acre) (Coef. = -0.328, p = 0.007) was correlated with decreased their safety concerns. Among the natural environmental variables, the presence of water features (Coef. = 0.123, p = 0.008) and greater steep slopes (Coef. = 0.036, p = < .001) were positively associated with parental safety concerns while greater tree canopy (Coef. = -0.021, p = <.001) was negatively associated with parental safety concerns.

Table 9
Safety Concerns Regression Models

Ordinary least square regressions	One-by-one models[a]		Model 1		Model 2		Model 3	
	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|
Built environmental variables								
Bike lanes (ratio)	0.123	0.035	0.131	0.027			0.107	0.073
Sidewalks (ratio)	-0.222	0.011	-0.310	0.002			-	-
Playgrounds (presence)	0.018	0.748	-	-			-	-
Intersections (density, num./acre)	-0.728	0.001	-0.741	0.001			-0.642	0.003
Highways (presence)	0.204	0.000	0.163	0.001			0.099	0.051
Railroads (presence)	0.240	0.000	0.127	0.024			0.136	0.019
High speed streets (>30mph) (%)	0.002	0.014	-	-			-	-
Crime – hotspots	0.136	0.000	0.117	0.000			-	-
Crash – hotspots	0.016	0.002	-	-			-	-
Sex offenders (presence)	0.236	0.000	0.143	0.004			0.145	0.001
Natural environmental variables								
Parks (presence)	0.082	0.031			-	-	-	-
Water features (presence)	0.251	0.000			0.214	0.000	0.117	0.007
Steep slopes (degrees)	0.027	0.000			0.031	0.000	0.034	0.000
Urbanized area (%)	0.004	0.048			-	-	-	-
Tree canopy (%)	-0.016	0.000			-0.017	0.000	-0.014	0.000
Grass cover (%)	-0.001	0.785			-	-	-	-
Surface temperature (%)	-0.018	0.121			-	-	-	-
Normalized Difference Vegetation Index (NDVI) (min: -1, max: 1)	-0.010	0.000			-	-	-	-
Tree heights (feet)	-0.017	0.000			-	-	-	-
Covariates								
Socio-demographic variables								
Student gender (male vs. ref. female)			-0.046	0.166	-0.052	0.123	-0.048	0.149
Student grade (ref. PK-K)								
1st – 3rd			-0.092	0.024	-0.089	0.029	-0.095	0.019
4th – 6th			-0.214	0.000	-0.220	0.000	-0.223	0.000
Free or reduced lunch (yes vs. ref. no)			0.095	0.083	0.096	0.059	0.105	0.043
Student ethnicity (ref. White)								
Hispanic			0.235	0.000	0.229	0.000	0.242	0.000
Others			0.032	0.618	0.033	0.611	0.033	0.617
Attitudinal/social variables‡								
Walking is a good way to exercise.			0.249	0.000	0.255	0.000	0.251	0.000
I walk quit often in my daily routine.			0.052	0.001	0.051	0.001	0.050	0.001
I (would) enjoy walking with my child to/from school.			-0.055	0.004	-0.054	0.004	-0.053	0.005
My family and friends like the idea of walking to school.			-0.045	0.015	-0.046	0.014	-0.045	0.016
Other kids walk to/from school in my neighborhood.			-0.056	0.000	-0.063	0.000	-0.054	0.000
I feel connected to people in my neighborhood.			-0.092	0.000	-0.091	0.000	-0.090	0.000
Total N				**3,291**		**3,291**		**3,291**
R^2				**0.1349**		**0.1315**		**0.1412**

Note: [a]The one-by-one model indicates a model estimated by which an environmental variable was entered one at a time into the model including all the covariates. Values of all the covariates, total N and R^2 generated from each one-by-one model were not included in the table due to space considerations.

4.3.4 Correlates of Thermal Comfort Concerns

Table 11 shows the results from the SLM regression models estimating the associations between built and natural environmental variables and the parental thermal comfort concern outcome variable, controlling for socio-demographic, attitudinal and social factors. The results include the one-by-one models, Model 1 (the BE model), Model 2 (the NE model), and Model 3 (the BE and NE model) based on the quarter mile home buffer measures. Appendix B-2 shows the regression results based on the half mile home buffer measures. The reason for selecting the quarter mile models to report in this section, instead of the half mile results, was to efficiently discriminate the environmental characteristics for each respondent while reducing the spatial autocorrelation problems (Figure 21), and the overall model fit of the final multivariate model.

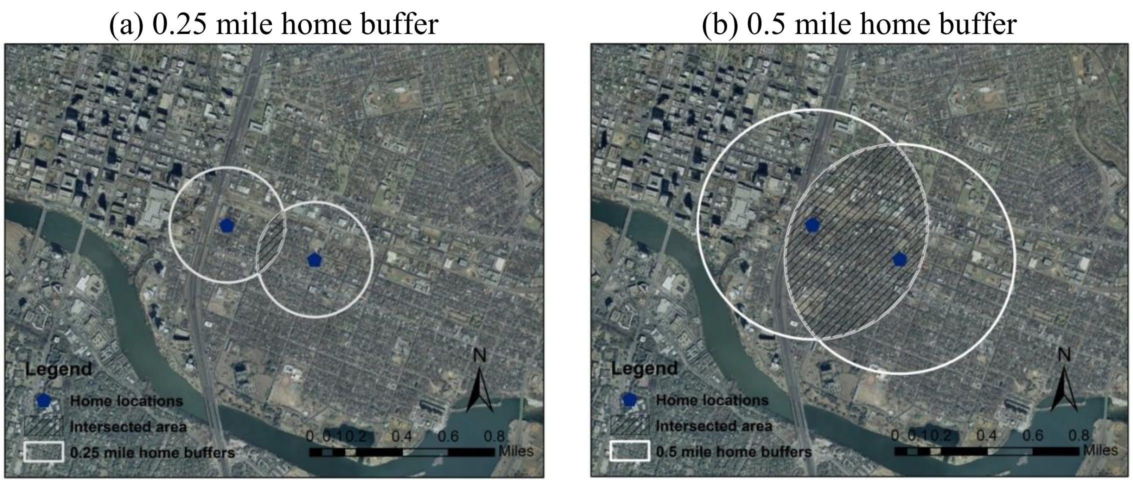


Figure 21
Comparison of Buffer Size and Intersected Area

In terms of the interpretation of the SLM regression results, it is necessary to understand the following information. The coefficients for each of the predictors and the covariates reported in Table 11 are the predicted log-odds (based on traditional logit models) of being 'strongly agree' to parental thermal comfort concerns (scaling factor = 0) versus 'strongly disagree' (scaling factor = 1), for a one-unit change in the predictor variable. Since the coefficients are transformed by log, exponentiating the log-odds produces the odds ratio (OR) which can facilitate the interpretation of the result. The following formula shows how to compute the odds ratio of one category versus another for a one-unit change in the predictor variable:

$$\boldsymbol{\Omega}_{\mathrm{m/j}} = \exp[(\Phi_{\mathrm{j}} - \Phi_{\mathrm{m}})\beta_{\mathrm{k}}],$$

Where:

$\boldsymbol{\Omega}_{\mathrm{m/j}}$ is the odds of being category m versus j

Φ_j is the scaling factor of reference category

Φ_m is the scaling factor of interest category

β_k is the coefficient of the predictor

exp is the exponential function

One can compute the odds ratio for any two categories of the outcome variable by using the formula above. Figure 22 represents the predicted probability of thermal comfort concerns for each category, based on the final model. The sum of each category's probability of the thermal comfort concern outcome variable is 1.

Personal, Attitudinal, and Social Correlates of Parental Thermal Comfort Concerns

The associations of the personal, attitudinal and social factors with the parental thermal comfort concern outcome variable were the same across the regression models. Therefore, the results here are focused on Model 3 which incorporates Model 1 and Model 2.

The coefficient of the 'free or reduced lunch' variable was 0.493, which means that the odds ratio for being 'strongly agree' versus 'strongly disagree' about having thermal concerns was 1.64 estimated as exp[($1_{\text{(the scaling factor of strongly disagree)}} - 0_{\text{(the scaling factor of strongly agree)}}$)*0.493]. This means that other things being equal, the odds of 'strongly agree' to parental thermal comfort concerns (outcome variable: *my child gets too hot and sweaty when walking in my neighborhood*), compared to 'strongly disagree,' increased by 64% if children received free or reduced lunch service at school. It is also possible to compute the odds ratio of 'somewhat disagree' versus 'somewhat agree' by using the formula with the scaling factors for each category. The odds for this comparison is exp[($0.747_{\text{(the scaling factor of somewhat disagree)}} - 0.549_{\text{(the scaling factor of somewhat agree)}}$)*0.493] or 1.10, which means that the odds of 'somewhat agree' to parental thermal comfort concerns versus 'somewhat disagree' increased by 10% for parents whose children were qualified for free or reduced-price meals, compared to parents whose children did not qualify. From these two comparisons, it was found that the distance between the categories of the outcome variable reflects the magnitude of the associations with the predictor (64% increase in the odds of 'strongly agree' versus 'strongly disagree, 10% increase in the odds of 'somewhat agree' versus 'somewhat disagree'). In terms of the associations of the children's ethnicity variable with parental thermal comfort concerns, the odds of 'strongly agree' to parental thermal comfort concerns versus 'strongly disagree' increased by 205% for parents whose children were Hispanic (OR: $\exp[(1 - 0)*1.114] = 3.05$, $p < .001$) and by 74% for parents whose children were from other ethnicities (OR: $\exp[(1 - 0)*0.556] = 1.74$, $p = 0.021$), compared to parents whose children were White.

The following two attitudinal variables, 'walking is a good way to exercise' and 'I walk quite often in my daily routine' were associated with increased thermal comfort concerns. If parents perceived that walking is a good way to exercise and walked quite often in their daily routine, the odds of 'strongly agree' to parental thermal comfort concerns versus 'strongly disagree' increased by 71% (OR: $\exp[(1 - 0)*0.536] = 1.71$, $p < .001$) and 15% (OR: $\exp[(1 - 0)*0.143] = 1.15$, $p = 0.008$), respectively. In contrast, the social factor, 'I (would) enjoy walking with my child to/from school,' showed a negative association with parental thermal comfort concerns. If parents positively responded to the survey item, 'I (would) enjoy walking with their child to/from school,' the odds of 'strongly agree' to parental thermal comfort concerns versus 'strongly disagree' decreased by 25% (OR: $\exp[(1 - 0)*-0.293] = 0.75$, $p < .001$).

Environmental Correlates of Parental Thermal Comfort Concerns

In the one-by-one models that examined the associations between each environmental variable and the outcome variable, controlling for the covariates, two built environmental variables and six natural environmental variables were significantly associated with parental thermal comfort concerns. The presence of playgrounds led to a

50% decrease (OR: $\exp[(1 - 0)*-0.702] = 0.50$, p = < .001), and every additional intersection per acre resulted in a 99% decrease (OR: $\exp[(1 - 0)*-4.528] = 0.01$, p = < .001) in the odds of 'strongly agree' to parental thermal comfort concerns versus 'strongly disagree.' In terms of the natural environmental variables, the presence of parks decreased the odds of 'strongly agree' to parental thermal comfort concerns versus 'strongly disagree' by 19% (OR: $\exp[(1 - 0)*-0.210] = 0.81$, p = 0.072). Every additional percentage of tree canopy and of grass cover led to a 2% decrease (OR: $\exp[(1 - 0)*-0.025] = 0.98$, p = 0.005) and a 4% decrease (OR: $\exp[(1 - 0)*-0.045] = 0.96$, p = 0.002) in the odds of 'strongly agree' to parental thermal comfort concerns versus 'strongly disagree,' respectively. Furthermore, a one-unit increase in NDVI and a 1 foot increase in tree heights also decreased the odds of 'strongly agree' to parental thermal comfort concerns versus 'strongly disagree' by 85% (OR: $\exp[(1 - 0)*-1.914] = 0.15$, p = 0.006) and 5% (OR: $\exp[(1 - 0)*-0.051] = 0.95$, p = < .001), respectively. In contrast, every additional percentage of urbanized area led to a 1% increase in the odds of 'strongly agree' to parental thermal comfort concerns versus 'strongly disagree' (OR: $\exp[(1 - 0)*0.013] = 1.01$, p = 0.005). However, the urbanized area, the tree canopy, and the NDVI variables measured by the half mile home buffer were only significant at the 0.10 level, but were not significant at the 0.05 level (Appendix B-2).

Model 1 indicates the SLM regression model focusing on the built environmental variables associated with parental thermal comfort concerns, controlling for socio-demographic, attitudinal and social factors (Pseudo $R^2 = 0.0189$). The results showed that the levels of parental thermal comfort concerns decreased if parents lived within a neighborhood that had parks and a higher number of intersections per acre (OR: exp[(1 – 0)*-0.558] = 0.57 for the presence of parks, OR: exp[(1 – 0)*-3.969] = 0.02 for intersection density).

Model 2 shows the results from the SLM regression model focusing on the natural variables associated with parental thermal comfort concerns, controlling for the covariates (Pseudo R^2 = 0.0177). In contrast to the one-by-one models in which many of the natural environmental variables were significantly associated with parental thermal comfort concerns, Model 2 included only two significant natural environmental variables (tree canopy and grass cover). The reason for many variables to drop their significance was the multicollinearity problem, as many natural environmental variables are correlated with each other (Table 10). For example, three variables including urbanized area, tree canopy, and grass cover were highly correlated, showing correlation coefficients whose magnitudes were between 0.7 and 0.9. These three variables were only used one at a time for the one-by-one models.

Model 3 presents an SLM regression model that combined Model 1 with Model 2 (Pseudo R^2 = 0.0193). Two built environmental variables and one natural environmental variable remained their significance in Model 3, but the grass cover variable which was significant in Model 2 was no longer significant in this combined model. After controlling for the socio-demographic, attitudinal and social factors, the presence of playgrounds, higher number of intersections per acre, and higher percentage of tree canopy were correlated with reduced parental thermal comfort concerns. However, the presence of parks was only significantly associated with reduced thermal concerns when measured within the half mile home buffer (Appendix B-2).

Table 10
Pearson Correlation Matrix among Natural Environmental Variables

	(1)	(2)	(3)†	(4)	(5)	(6)	(7)†	(8)†
(1) Parks	1							
(2) Steep slopes	0.054	1						
	0.000							
(3) Urbanized	-0.270	-0.180	1					
area†	0.000	0.000						
(4) Tree canopy	0.285	0.147	**-0.768**	1				
	0.000	0.000	0.000					
(5) Grass cover	0.150	-0.010	-0.410	0.178	1			
	0.000	0.537	0.000	0.000				
(6) Temperature	-0.214	-0.084	**0.709**	-0.454	-0.247	1		
	0.000	0.000	0.000	0.000	0.000			
(7) NDVI†	0.236	0.134	**-0.925**	**0.843**	0.402	-0.578	1	
	0.000	0.000	0.000	0.000	0.000	0.000		
(8) Tree heights†	0.213	0.236	**-0.771**	**0.906**	0.266	-0.516	**0.851**	1
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Note: the numbers at the first row are the Pearson correlation values, and the numbers at the second row are the p-values. Pearson r values between 0.7 and 1 were marked in bold.
†: these variables were not used for Model 2 and Model 3 due to a multicollinearity problem.

Table 11
Thermal Comfort Concerns Regression Models

Stereotype logistic regressions	One-by-one models[a]		Model 1		Model 2		Model 3	
	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|
Built environmental variables								
Bike lanes (presence)	-0.217	0.384	-	-			-	-
Sidewalks (ratio)	0.049	0.876	-	-			-	-
Playgrounds (presence)	-0.702	0.000	-0.558	0.002			-0.514	0.006
Intersections (density, num./acre)	-4.528	0.000	-3.969	0.000			-3.776	0.000
Highways (presence)	-0.074	0.601	-	-			-	-
Railroads (presence)	-0.330	0.123	-	-			-	-
High speed streets (>30mph) (%)	0.001	0.718	-	-			-	-
Crime – hotspot	0.069	0.359	-	-			-	-
Crash – hotspot	-0.021	0.247	-	-			-	-
Natural environmental variables								
Parks (presence)	-0.691	0.002			-	-	-	-
Steep slopes >5% (%)	0.001	0.734			-	-	-	-
Steep slopes >8.33% (%)	0.000	0.906			-	-	-	-
Urbanized area (%)	0.013	0.005			-	-	-	-
Tree canopy (%)	-0.025	0.005			-0.019	0.031	-0.021	0.030
Grass cover (%)	-0.045	0.002			-0.037	0.014	-	-
Surface temperature (%)	0.048	0.161			-	-	-	-
NDVI (values ranging from -1 to 1)	-1.914	0.006			-	-	-	-
Tree heights (feet)	-0.051	0.000			-	-	-	-
Covariates								
Socio-demographic variables								
Student gender (male vs. ref. female)			-0.060	0.605	-0.051	0.627	-0.051	0.660
Student grade (ref. PK-K)								
1st – 3rd			-0.117	0.402	-0.140	0.264	-0.137	0.330
4th – 6th			0.195	0.230	0.082	0.571	0.180	0.269
Free or reduced lunch (yes vs. ref. no)			0.656	0.000	0.335	0.040	0.493	0.008
Student ethnicity (ref. White)								
Hispanic			1.214	0.000	0.947	0.000	1.114	0.000
Others			0.580	0.014	0.460	0.033	0.556	0.021
Attitudinal/social variables‡								
Walking is a good way to exercise.			0.493	0.000	0.499	0.000	0.536	0.000
I walk quit often in my daily routine.			0.141	0.008	0.142	0.004	0.143	0.008
I (would) enjoy walking with my child to/from school.			-0.286	0.000	-0.247	0.000	-0.293	0.000
Scaling factors								
Φ Strongly disagree			1 (constrained)		1 (constrained)		1 (constrained)	
Φ Somewhat disagree			0.745	0.000	0.740	0.000	0.747	0.000
Φ Neither disagree nor agree			0.641	0.000	0.669	0.000	0.655	0.000
Φ Somewhat agree			0.524	0.000	0.563	0.000	0.549	0.000
Φ Strongly agree			0 (base outcome)		0 (base outcome)		0 (base outcome)	
Total N				**3,374**		**3,334**		**3,334**
Pseudo R^2				**0.0189**		**0.0177**		**0.0193**

Note: [a]The one-by-one model indicates a model estimated by which an environmental variable was entered one at a time into the model including all the covariates. Values of all the covariates and scaling factors generated from each one-by-one model were not included in the table due to space considerations. The Pseudo R^2 represents the level of model improvements offered by the full model compared to the null model that has no predictors.

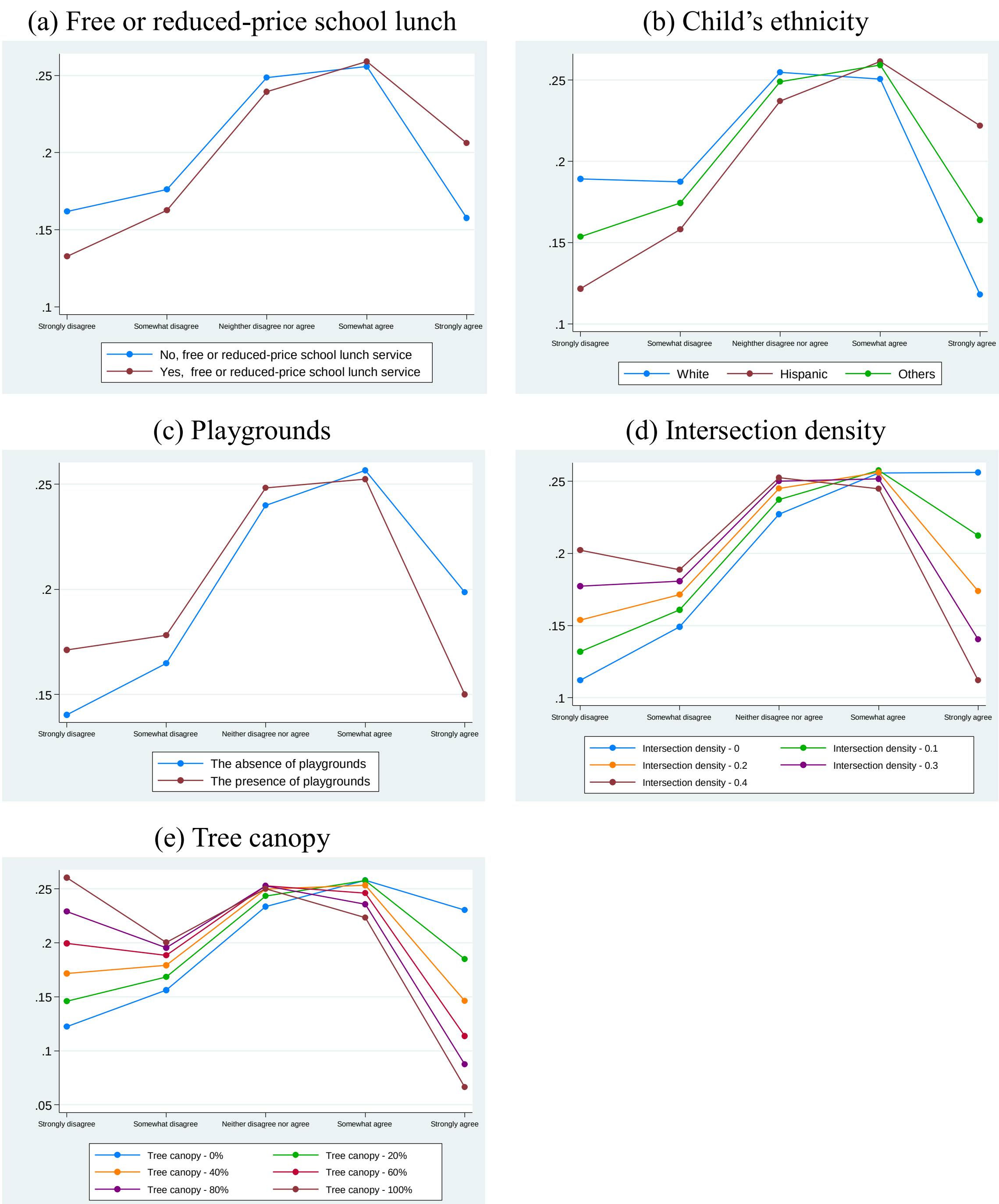


Figure 22
Predicted Probability of Thermal Comfort Concerns

4.4 CONCLUSIONS AND DISCUSSION

Parental safety and thermal comfort concerns have been considered as the main barriers to children's ATS after the long distance barrier, but how the parental perceptions are associated with the actual neighborhood environments have been rarely examined. This study examined how the objectively measured characteristics of built and natural environments are associated with parental safety and thermal comfort concerns for children's ATS, controlling for the socio-demographic, attitudinal and social factors. The following summarizes the findings from this study and the potential implications of the findings.

In terms of the environmental correlates of parental safety concerns, this study showed that more bike lanes, the presence of highways and of railroads, the presence of sex-offender home locations, the presence of water features, and more areas with steep slope around home (1/4 buffer area) were associated with increased parental safety concerns while higher street connectivity and more tree canopy were associated with decreased parental safety concerns. Further, the results from Model 1 utilizing the built environmental variables only showed that more sidewalks in the home buffer reduced parental safety concerns while greater crime hotspot areas increased the safety concerns. Among the significantly associated environmental correlates, the bike lane ratio variable seemed to be counterintuitively associated with the safety concern outcome. However, while bike lanes are encouraged as a means to promote active transportation activity among adults (Hoehner, Brennan Ramirez, Elliott, Handy, & Brownson, 2005), they may act as a barrier to ATS among school-aged children because parents seem to feel that bike lanes are not safe for their children. Most bike lanes in Austin and many other cities in the US are located along vehicular roadways designated with simple painted/striped lines without any buffer space, and thus increasing parental safety concerns especially for the young children. Further, this study supports the findings of several studies related to children's ATS. Ewing et al. (2004 and 2005) and Dalton et al. (2011) showed that more sidewalk coverage increased the odds of ATS. This study found that increase in sidewalk coverage led to a significant decrease in parental safety concerns. Related to the findings of several studies identifying that children were more likely to walk or bike to school in a neighborhood where street connectivity was high (Kerr et al., 2006; Mota et al., 2007), this study also showed that higher street connectivity reduced parental safety concerns. Scholossberg et al. (2006) and Zhu and Lee (2009) study showed that the presence of railroad tracks and of highways were negative correlates of children's walking to school, which was further supported in this study which showed increased parental safety concerns related to the presence of railroads and the presence of highways along the HTS route. Regarding the natural environmental variables, this study showed that parental safety concerns decreased if greater tree canopy area was present along the HTS route, but increased if the slope along the HTS route was steeper. Similarly, children were more likely to engage in ATS within a neighborhood where there were more trees (Larsen et al., 2009) and the terrain was gentle/flat (Anna Timperio et al., 2006).

Regarding the socio-demographic, attitudinal and social factors used as the covariates in this study, parents whose children were from higher grades had less safety concerns for their children's ATS while parents whose children were Hispanic had greater safety concerns than parents whose children were White. Further, parents whose children received free or reduced-price meals at school (low-income group) had higher safety concerns than parents whose children did not receive meals (high-income group). As noted in the descriptive statistics and in a series of GIS maps, the low-income group was faced with more hostile environmental conditions (e.g. greater urbanized coverages, less tree canopies, higher temperature, and higher crime and crash incidents, etc.) than the high-income group. This finding may indicate one of the reasons why low-income parents had greater safety concerns for their children's ATS. This study also showed that the two attitudinal factors, including 'walking is a good way to exercise' and 'I walk quite often in my daily routine' increased parental safety concerns. This finding can be explained by the fact that parents who walk more often in their daily routine and those who have positive attitudes toward walking may have more concerns about safety because they actually walk and therefore notice more problems/conditions in the environment that can be potentially harmful to their children. This point is associated with a causality issue, but since this study was a cross-sectional design, the causal relationship cannot be established. Future studies need to consider the causal relationships between study variables and to explore detailed mechanisms underlying these relationships. In contrast to the associations between the attitudinal factors and parental safety concerns, this study showed that parental safety concerns decreased if parents had more positive perceptions of social environments (e.g. their family/friends/other kids' walking to school) and felt stronger social connection with people in their neighborhood.

This study also examined the correlates of parental thermal comfort concerns through the SLM regression models. Among the built environmental variables, the presence of playgrounds reduced the levels of parental thermal comfort concerns. This finding is somewhat consistent with another study that showed that playgrounds are thermally comfortable in the afternoon (Conceição, Lúcio, & Lopes, 2008). However, why the playgrounds reduced thermal comfort level is not clear, and therefore future studies need to identify the environmental features or characteristics around the playgrounds. Further, this dissertation study also showed that the higher the street connectivity (higher number of intersections per acre) the lower the levels of parental thermal comfort concerns. This finding may be associated with the openness to the sky of street canyons, the places enclosed by buildings on both street sides. Ali-Toudert and Mayer found that larger openness to the sky of the street canyons increased the thermal heat stress because of the lack of shadiness in those streets (Ali-Toudert & Mayer, 2007). Since the street canyons in a higher street connectivity are generally shallow and provide smaller openness to the sky, the streets will have more shading that helps mitigate heat stress outdoors. This finding may show the potential of built environments that can be used as design strategies for reducing thermal comfort concerns or heat stress levels. Regarding the natural environmental correlates of parental thermal comfort concerns, the findings from this study suggest that more green environmental elements must be embedded within the neighborhood to mitigate parental thermal comfort concerns for their children's walking in the neighborhoods. In the one-by-one tests, the following natural environmental variables, greater tree canopy and grass cover, higher NDVI, higher tree heights, and the presence of parks, reduced the levels of parental thermal comfort concerns. In contrast, the greater the urbanized area along the HTS routes the higher the levels of parental thermal comfort concerns. Henry and Dick (1987) found that urban area's surfaces consisting of asphalt or asphaltic roofing are highly associated with increased temperatures.

From the results on the associations between socio-demographics and parental thermal comfort concerns, this study suggests that providing naturally healthy and thermally comfortable environments for low-income and minority families is necessary. This study found that parents whose children were from lower income households (qualified for free or reduced-price meals at school) and parents whose children were Hispanic or other non-White ethnicities had more thermal comfort concerns than the counterpart groups. Based on the results of the descriptive statistics and a series of GIS maps about the spatial distribution of the natural environment, low-income populations were exposed to thermally unpleasant environmental conditions (less parks, more urbanized area, less tree and grass coverage, higher surface temperatures, lower NDVI, and lower tree heights), compared to the high-income group. In terms of the attitudinal and social correlates of parental thermal comfort concerns, which were used as the covariates in the SLM regression models, this study also showed that parents' positive attitudes toward walking ironically increased their thermal comfort concerns for their children's walking in the neighborhood. As explained, similar to the discussion of the safety concern analysis, parents having positive attitudes toward walking might have more concerns about thermal comfort because they actually walk and might be more aware of environmental problems such as lack of street trees that are relevant to thermal comfort. To further the understanding of this issue, the causal relationship between parental attitudes and concerns about thermal comfort and walking should be examined.

To measure the environmental characteristics, this study considered two different spatial units for each outcome variable (100 feet and 200 feet HTS route buffer measures for the parental safety concern outcome, 0.25 mile and 0.5 mile home buffer measures for the parental thermal comfort concern outcome). The reason for utilizing the two spatial units for each outcome variable was because there is no consensus as to which buffer size is most appropriate for studies like this as it depends on the target outcome, populations, settings, etc. Also, results from the analyses based on different buffer measures may produce inconsistent results. Mitra and Buliung's study (2012) revealed the presence of scale or zoning effects in the statistical analyses between objectively measured built environments and ATS, indicating that the statistical significance of the environmental variables' coefficients could be changed by using different geographical units. In this study, the 100 feet and 200 feet HTS route buffer measures used for the analysis of parental safety concerns showed similar results, except for the presence of highways variable that was only significant in the 200 feet HTS route buffer measure. However, the quarter mile and the half mile home buffer measures used for the analysis of parental thermal comfort concerns showed slightly different results. In the one-by-one models, most of the natural environmental variables were statistically significant at the

0.01 level in the quarter mile home buffer measure while they were marginally significant at the 0.10 level in the half mile home buffer measure. One of the potential reasons for showing less significant results in the half mile home buffer measure might be because the larger size of airline home buffers creates greater overlapped areas between the buffers so that the ability to discriminate the environmental characteristics across different buffers can be reduced. Thus, this study suggests carefully assessing appropriate buffer sizes when measuring the impact of neighborhood environmental features on walking, considering both conceptual/theoretical and methodological issues.

This study has several strengths and limitations. It is based on the data collected from one city, Austin, Texas, and therefore the findings from this study are not applicable to other cities. However, findings should still offer relevant insights to the cities with similar demographic and environmental characteristics, and to those interested in addressing parental safety and thermal comfort concerns to help increase children's ATS. This is a cross-sectional study, thus causality between the objectively measured environment variables and the subjectively measured parental concerns cannot be assessed. Further, although many natural environmental variables were used for the final models, only a few variables including the presence of parks and tree canopy and grass coverage variables remained statistically significant in the final model. As explained earlier, this is primarily due to the serious multicollinearity problem for many natural environmental variables which forced the model to select only a few variables that were mostly independent of each other, not because other natural environmental variables were not significant. Especially, NDVI, air temperature factors, and tree height variables, individually, appeared significant in reducing parental thermal comfort concerns, but could not be included in the final model due to the multicollinearity.

Despite these limitations, this study makes an important contribution to the existing literature by employing quantitative methods to understanding how parental perceived barriers to ATS were associated with the objectively measured built and natural environment conditions, which has been rarely examined so far. These environmental characteristics are relatively easily modifiable, compared to changes in zoning and street networks to help reduce home-to-school travel distances. This study brought attention to the need to address safety and thermal comfort as two of the most significant barriers to WTS, and especially the issues of thermal comfort and the roles of natural environmental features which have not been studied sufficiently in WTS literature and in WTS promotion efforts. Future research will be necessary for assessing both the direct and the indirect associations of the environmental conditions with ATS, and for examining whether the parental safety and thermal comfort concerns play a mediating role in the environment-ATS relationship.

5. STUDY TWO:

DISTANCE VARIATION IN BUILT AND NATURAL ENVIRONMENTAL CORRELATES OF CHILDREN'S ACTIVE TRAVEL TO SCHOOL

5.1 INTRODUCTION

Given the rapid rise in obesity among-school aged children (Cynthia L Ogden et al., 2006) and their insufficient daily physical activity levels, identifying ways to help increase children's physical activity is necessary. Active travel to school (ATS) such as walking and bicycling to school has been considered as one of the ways to improve children's health as it helps increase daily physical activity (Saksvig et al., 2007; Sirard, Riner, et al., 2005; Tudor-Locke, Neff, Ainsworth, Addy, & Popkin, 2002). Although the findings are not consistent as to whether or not ATS reduces children's risk of obesity (Heelan et al., 2005; M. C. Lee, Orenstein, & Richardson, 2008; Rosenberg et al., 2006), promoting ATS still has many benefits in that it is conducive to children's development and helps them achieve a healthy adult lifestyle. Therefore, how to effectively promote children's ATS has been a main issue in the planning and public health fields.

A recent review highlighted that putting the focus on environmental factors in empirical research is helpful for developing effective or feasible actions to promote children's ATS, such as zoning regulations, integration of walking patterns into engineering standards, school siting, etc. (Davison et al., 2008). That is why, in recent years, environmental factors have been increasingly studied to identify their effects on children's ATS while considering personal factors such as gender, age, and socio-economic status as confounders (Babey et al., 2009; Dalton et al., 2011; Larsen et al., 2009; Panter et al., 2010b). Furthermore, a national-level program, 'Safe Routes to School,' showed the efficiency of environmental improvement to promote children's ATS. In a study utilizing pre-post surveys of 1,244 parents living in California, the improvement of built environmental infrastructure such as sidewalks, crossings, and traffic control, encouraged more children to walk to school (Boarnet et al., 2005). Current research dealing with the environmental aspects associated with children's ATS utilizes both self-reported surveys and the Geographic Information System (GIS) to measure the environmental conditions.

There are two main limitations of the previous studies published to date, which examined the relationships between environmental factors and children's ATS. First, a number of studies have identified the long distance between home and school as the most significant barrier to ATS, yet there is a lack of studies examining how the effect of the distance on ATS varies by different distance ranges. Regardless of whether the distance was subjectively measured by surveys (Salmon et al., 2007; Yeung et al., 2008; Zhu & Lee, 2009) or objectively measured by GIS (Larsen et al., 2009; R. Mitra et al., 2010; Yarlagadda & Srinivasan, 2008), most previous ATS studies utilized the continuous variable of home-to-school (HTS) distance as one of the predictors in the multivariate models and reported the odds of ATS by one unit change of HTS distance. Therefore, it was difficult to know at which distance threshold(s) the odds of ATS dramatically or smoothly changed, which can offer insights to effectively control the distance barrier to ATS. Several studies, including McDonald et al. (2011) and

Schlossberg et al. (2006), considered distance ranges utilizing one categorical variable in a multivariate analysis, with distance ranges of 0.25 miles, 0.25-0.5 miles, and 0.5-1.0 miles and <1 mile, 1 to <1.5 miles, 1.5 to <2.5 miles, and 2.5+ miles, respectively. However, because their studies just compared the longer distance ranges with the shortest distance ranges in the regression models, the variation of the impact of distance on ATS across distance ranges was still unknown. Second, past studies identifying environmental correlates of ATS have mainly focused on the 'built' elements such as land use mix (Larsen et al., 2009), population density (N. C. McDonald, 2008a; Nelson et al., 2008), street connectivity (Mota et al., 2007), road density or intersection density (Dalton et al., 2011; Panter et al., 2010b), sidewalk availability (Ahlport et al., 2008), and traffic volume (Giles-Corti et al., 2011), but little attention has been focused on the 'natural' elements such as greeneries, trees, landscaped buffers, etc. Instead, the natural correlates have been examined with respect to children's physical activity and weight status. Several studies, including Almanza et al.(2012), Cohen et al.(2006), Epstein et al.(2006) Pate et al.(2008), have found that children who were exposed to higher amount of greener spaces or parks were more likely to engage in more physical activity in their daily lives. Furthermore, a few studies have shown a negative relationship between being exposed to a natural environment and children's body mass index (Bell et al., 2008; Liu et al., 2007; Wolch et al., 2011). Regarding natural correlates of ATS, one study utilizing survey data of 614 students aged 11-13 years and GIS objectively-measured environmental data based on a quarter mile home buffer showed significant and positive associations between street trees in home neighborhood and children's active travel to school, but not from school to home (Larsen et al., 2009). More empirical studies on the associations between "natural" environmental factors and children's ATS may suggest insightful ideas or practical ways that help facilitate children's ATS.

Given the noted two main limitations in previous studies on environmental correlates of ATS, this study quantifies the varying roles of distance to school in predicting the odds of ATS across different distance ranges[3] and examines what built and natural environmental factors are associated with children's ATS after adjusting for individual characteristics and socio-economic status. Furthermore, this study also examines whether the relationships between built/natural environmental factors and ATS vary by HTS distance ranges.

[3] The idea of identifying the varying roles of distance to school in predicting children's ATS across different distance ranges came from an analysis topic from a research project, Small Town Walkability (PI for Texas region: Dr. Chanam Lee), which was funded by the National Institutes of Health, and in which the author of this dissertation worked as a research assistant. The objective of the research project was to identify built environmental elements that promote adults' walking in small towns in Washington, Texas, and New England areas. One of the studies in the STW project examined the associations between the built environment and walking to parks, identifying the varying roles of distance to park ranges (0≤400m, 400.1m≤800m, >800m) (Lee et al., 2015 (in preparation)). A manuscript of this analysis is currently in preparation .

5.2 METHODS

5.2.1 Conceptual Framework

A conceptual framework responding to the second objective of this dissertation was proposed (Figure 23). This conceptual framework shows the direct relationships between objectively-measured built/natural environments and children's ATS after controlling for personal factors and HTS distance ranges. Two sets of independent variables include built environmental and natural environmental variables. Built environmental variables include pedestrian infrastructure, transportation infrastructure, and crime and crash safety, while natural environmental variables include the presence of parks and water features, steep slopes, land cover types (such as urbanized area, tree canopy, and grass cover), greenness (normalized difference vegetation index, NDVI), and tree heights. For control variables, personal and household characteristics (such as the child's gender, grade, language; parental education levels; household car ownership) were used. Detailed information about the significance of the selected variables and the coding scheme of the variables are provided in *5.2.3 Variables* section.

The conceptual framework describes three exploratory hypotheses:

- Hypothesis 1: Unsafe and thermally uncomfortable built/natural environments will be associated with lower levels of ATS.
- Hypothesis 2: Each HTS distance range variables will have different impacts on ATS (shorter distance ranges will have stronger impact on ATS).
- Hypothesis 3: The relationship between built/natural environments and ATS will vary by the distance ranges.

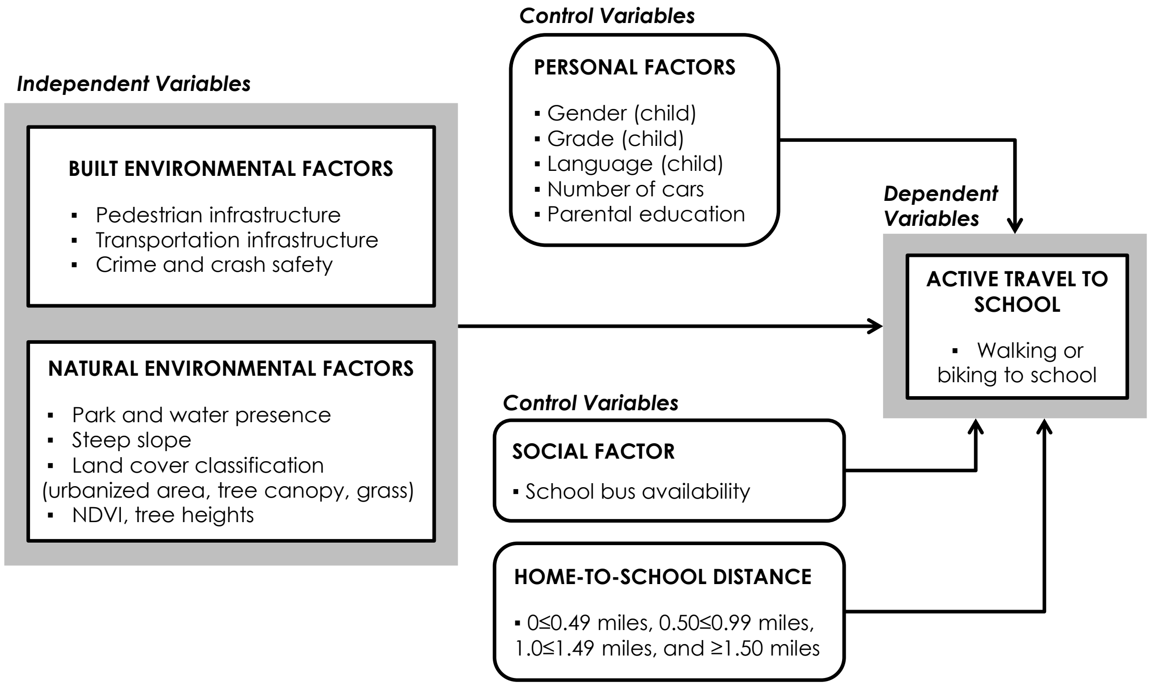


Figure 23
Conceptual Framework for Study 2

5.2.2 Study Design

This cross-sectional study was carried out in the Austin Independent School District (AISD) in Austin, Texas. Twenty schools out of the 81 elementary schools in the AISD were selected based on the following criteria: (a) spatial dispersion across AISD, (b) a wide range of income levels and Hispanic ratios, and (c) research approval from both the AISD and the study schools. The New Urban-Centric Locale Codes of the National Center for Education Statistics (National Center for Education Statistics) defined the study schools in AISD as being in a "large city" setting which indicates that the schools are close to an urbanized area or a densely settled urban core (National Center for Education Statistics, 2006).

A subset of data obtained from the "Why" and "Why Nots" of Active Living project (ALR project) funded by the Robert Wood Johnson Foundation's Active Living Program were used for this study. The ALR project, led by Dr. Chanam Lee from 2008 to 2012, aimed to examine multi-level barriers to walking to school among high-risk groups of children. This study utilized children's and parents' personal factors related to individual characteristics and GIS-measured built environmental factors obtained from the ALR project. Natural environmental factors separately generated by GIS and Environment Visualizing Images (ENVI) were also used for this study.

The surveys were completed by parents whose children were enrolled in the study schools. A total of 4,602 parental surveys (response rate: 34.0%) out of 13,573 surveys were returned in May–June 2010. Several demographic profiles of the samples, including each child's gender, ethnicity, grade, and the percentage of students receiving school bus service were utilized to examine the potential sample bias, and no serious bias was found. This study focused on 4,270 parental surveys out of 4,602, which were successfully geocoded from GIS, and linked the survey data to the environmental data to examine the environmental correlates of ATS.

Data sources for objectively-measured built and natural environmental data included the Austin Police Department for crash data; the Texas Department of Public Safety for crime data; the Texas Department of Transportation for raw street data including highways, sidewalks, bike lanes, and speed limits; the Capital Area Council of Governments for light detection and ranging (LiDAR) data; and the United States Geographical Survey for Landsat 5TM satellite images.

5.2.3 Study Variables

Personal and Social Variables

ATS was measured by asking parents whether or not their children traveled to or from school by walking alone, walking with friends, walking with a parent/adult, or biking to or from school on a normal day. If parents answered that their children walked or biked for trips to or from school, their children were classified as active travelers. The grades used in this study included pre-kindergarten, kindergarten, and 1st to 6th grades. Due to the large number of missing values in the parental income reports from the survey, the number of cars in a household and the highest level of education completed by adults in each household were used as proxies for family income as a few studies used it as a household income variable (Ewing et al., 2004; Tudor-Locke et al., 2003; Yelavich et al., 2008). Furthermore, languages that the children used most often at home, consisting of three answer options: English, Spanish, and Other, were assessed through the parental surveys (Carlin et al., 1997; Merom, Tudor-Locke, Bauman, & Rissel, 2006). A social variable, school bus availability, indicating whether the school provided bus service for children, was also used as a covariate.

Home-to-School Distance Range Variables

The shortest home-to-school distance was calculated through a network analysis based on geocoded home and school locations in ArcGIS version 10.0. Then, four distance range variables, 0≤0.49 miles, 0.50≤0.99 miles, 1.0≤1.49 miles, and ≥1.50 miles, were generated. As many researchers considered 1 mile as easy walking or biking distance to or from school for school-aged children (N. C. McDonald, 2007; N. C. McDonald et al., 2011), this study set 1 mile as a middle point for distance ranges and considered plus or minus half mile points from the mid-spot for identifying more detailed relationships of HTS distance ranges with ATS. While McDonald et al. (2011) focused on walking distance ranges of 0-0.25 miles, 0.25-0.5 miles, and 0.5-1 miles in their multivariate analysis, this study included easy and uneasy walking or biking distance ranges to identify more details of the variation of the odds of ATS by distance ranges. The unit of each HTS distance range variable was 100 meters because 1 mile unit change or 1 meter unit change resulted in a too high or too small odd ratio. For statistical analysis using these four distance range variables in the multivariate models, each distance range variable should subtract the values of the preceding distance range and assign 0 for lower distance values (Greene, 2003), as explained below.

$X_{0 \leq 0.49 \text{ miles}}$ = distance

$X_{0.5 \leq 0.99 \text{ miles}}$ = distance – 0.5 miles (800 meters) if distance ≥ 0.5 miles and 0 otherwise

$X_{1.0 \leq 1.49 \text{ miles}}$ = distance – 1.0 miles (1,600 meters) if distance ≥ 1 miles and 0 otherwise

$X_{\geq 1.5 \text{ miles}}$ = distance – 1.5 miles (2,400 meters) if distance ≥ 1.5 miles and 0 otherwise

This method was necessary to estimate the relationships between distance ranges and ATS as a piecewise linear function, which indicate the odds of ATS for each distance range.

Built Environmental Variables

Table 12 represents how built environment variables were generated and coded. The built environmental variables were measured within 100 feet of a home-to-school (HTS) route buffer in ArcGIS. The reason for using the 100 feet HTS route buffer as a measurement unit was because compared to larger buffer sizes such as 200 feet and 300 feet, the 100 feet HTS route buffer minimizes overlapped areas between the route buffers and is less likely to capture unexposed areas that are not easily seen from the routes (Won & Lee, 2013).

Table 12
Built Environment Measures and Variable Types

Built Environment Characteristics	Measures	Variable Type
Sidewalks	Length of sidewalks divided by total street length within HTS route buffer after multiplying by 100	Continuous
Bike lanes	Whether the percentage of bike lanes within HTS route buffer is greater than the mean of total bike lane percentage (zero percentage excluded for the mean calculation)	Binary
Playgrounds	Presence of playgrounds within HTS route buffer	Binary
Intersections	Number of intersections per acre within HTS route buffer	Continuous
Highways	Whether the HTS route was intersected by highways	Binary
Railroads	Whether the HTS route was intersected by railroads	Binary
High speed street	Length of high speed streets (>30 mph) divided by total street length within HTS route buffer after multiplying by 100	Continuous
Crime hotspots	Mean of crime hotspot z-scores within HTS route buffer	Continuous
Crash hotspots	Mean of all crash hotspot z-scores within HTS route buffer	Continuous
	Mean of pedestrian- and biker-related crash hotspot values	Continuous
Sex-offenders	Presence of sex-offender home locations within HTS route buffer	Binary

Note: all buffer measures are based on 100 feet.

Regarding roadway- or transportation-related characteristics, several variables including sidewalks, bike lanes, intersections, highways, and high speed limits were generated for this study. Sidewalks were measured by dividing the length of sidewalks by the total street length after multiplying by 100. Bike lanes were measured in the same way as sidewalks, but were recoded into a binary scheme that indicated whether the percentage of bike lanes was greater than the mean of the percentage of bike lanes from the total sample. Intersection density was measured by the number of intersections per acre. The playground variable was captured as a binary variable indicating whether playgrounds were present within the HTS route buffer. Further, whether or not the HTS route was intersected by highways or railroads were also measured. High speed street conditions were measured by dividing the length of high speed streets in which the speed limit was greater than 30 miles per hour by the total street.

For crime- or crash-related characteristics, crime and crash variables were generated utilizing hotspot analysis. In contrast with a simple method that quantifies the number of crime and crash incidents within a certain area, the hotspot analysis method makes it possible to capture the spatial distribution of the crime and crash incidents, which indicates whether or not the spatial patterns are clustered (Environmental Systems Research Institute, 2013). That is to say, it is possible to identify the phenomena of crime and crash occurrences with an understanding of the geographical process. This is the main merit of using the hotspot analysis method over the simple count measure. Crime and crash hotspot analyses were based on crime and crash point data and produced z-scores indicating whether an area was either hot or cold (Environmental

Systems Research Institute, 2013). If crime or crash incidents were distributed close to each other, they would show high crime or crash hotspot z-scores. Child-, sexual-, and assault-related crime types were used to generate the crime hotspot variable. All types of crashes and pedestrian- or biker-related crashes were used separately for creating crash hotspot variables. Furthermore, for another indicator of safety, sex-offender home locations within the HTS route buffer were identified, and the variable was recoded into a binary scheme that indicated the presence or absence of sex-offenders.

Natural Environmental Variables

Parks and water features were measured for their presence or absence within the HTS route buffer. Street slopes were measured using a digital elevation modeling process in ArcGIS, creating the following two variables: the percentage of steep slope area within the buffer in which the slope was greater than 5% and 8.33%, respectively. The standard of 5% (1:20 slope, height-to-distance ratio) for the steep slope variables was the maximum running slope allowed for an accessible route without a ramp, and the one of 8.33% (1:12 slope) was the maximum running slope allowed for a ramp (Americans with Disabilities Act, 2010). Similarly, a study considered 10% as the standard for a steep incline en route to school (Anna Timperio et al., 2006)

To differentiate land cover types, a four-category classification scheme was used: urbanized area, tree canopy, grass cover, and bare ground. The classification was processed using an iterative self-organizing data analysis technique (ISODATA), which was one of the unsupervised classification methods in ENVI 4.7 that is widely used to classify land cover types for various purposes. An aerial photograph taken on June 14, 2010, acquired from the national agricultural imagery program (NAIP), when the parental surveys were collected, was used in an ISODATA process in ENVI. Classification accuracy was assessed using 473 reference pixels for urbanized area, 495 for tree canopy, 347 for grass coverage, and 372 for bare ground, which were all greater than the minimum of number of samples, 50, for each class that is generally accepted for the accuracy test (Congalton, 1991). The overall classification accuracy of the four classes was 93.99% and the kappa coefficient was 0.91.

Surface temperature conditions within the HTS route buffer were measured using a Landsat 5 TM image taken on June 4, 2010, when the percentage of cloudiness was zero. Band 6 from Landsat 5 TM sensor acquires temperature data and stores this information as a digital number (DN) with a range of 0 to 255, which means that each pixel (120x120m) in an area has a DN value between 0 and 255. It is necessary to convert the DN values to degrees Celsius using the following three steps: the DN is converted to radiance; radiance is converted to Kelvin; and Kelvin is converted to Celsius (Yale Center for Earth Observation, 2010).

The normalized difference vegetation index (NDVI) was also generated using the band 3 (Boldemann et al.) and band 4 (near-infrared) from the Landsat 5 TM imagery and based on the following formula [(band 4 – band3) / (band 4 + band 3)]. The NDVI values indicate the amount of green vegetation in an area, ranging from -1 to 1 (low to high), and the NDVI variable is generated by taking the mean of NDVI within the HTS route buffer.

Tree canopy heights were measured using LiDAR data comprised of multiple points containing height information of an area. Only the point data within the tree canopy area (excluding the built-up areas) were selected to be classified by ISODATA to collect the tree height information. A canopy height model (CHM) was measured by subtracting a digital elevation model (DEM) representing the ground surface height from a digital surface model (DSM) representing the uppermost level surface (Means et al., 2000; Næsset, 1997). The CHM values represented tree canopy heights in a grid format since the DEM and DSM are grid-based models. The minimum cell size representing a grid was 15 feet (about 4.5 meters) which was three times larger than the ground sampling distance of the LiDAR data which was 1.4 meters. Cell values representing tree canopy heights which were lower than 3.5 feet (about 1 meter) were excluded because they were not tall enough to represent tree canopy/shade conditions important for this study focusing on ATS (Næsset, 1997). Measures and variable coding schemes for all the natural environmental variables mentioned above are presented in Table 13.

Table 13
Natural Environment Measures and Variable Types

Natural Environment Characteristics	Measures	Variable Type
Parks	Presence of parks within HTS route buffer	Binary
Water features	Presence of water features within HTS route buffer	Binary
Steep slopes (%)	Steep slope area (>5% or >8.33%) divided by total area of HTS route buffer area after multiplying by 100	Continuous
Urbanized area (%)	Urbanized area divided by total area of HTS route buffer area after multiplying by 100	Continuous
Tree canopies (%)	Tree canopy area divided by total area of HTS route buffer area after multiplying by 100	Continuous
Grass cover (%)	Grass cover area divided by total area of HTS route buffer area after multiplying by 100	Continuous
Temperature (°C)	Mean of temperature measured within HTS route buffer	Continuous
Normalized Difference Vegetation Index (NDVI)	Mean of NDVI measured within HTS route buffer (ranging from -1 to 1)	Continuous
Tree heights (feet)	Mean of tree heights measured within HTS route buffer	Continuous

Note: all buffer measures are based on 100 feet

5.2.4 Statistical Analysis

Built and natural environmental characteristics were compared among four different distance thresholds: 0≤0.49 miles, 0.50≤0.99 miles, 1.0≤1.49 miles, and ≥1.5 miles through a chi-squared test for categorical variables and an analysis of variance (ANOVA) test for continuous variables. Differences in average distance by gender, grade, and language were examined using a T test or ANOVA. Furthermore, the chi-squared statistic was used to determine the relationships between ATS and gender, ATS and grade, and ATS and language.

Mixed-effect spline regression modeling was utilized to examine whether or not the odds of ATS changed dramatically at certain distance thresholds, considering school ID as second level data. The spline regression model assumes a nonlinearity of the variable, breaking a regression line into a number of line segments separated by special joint points known as spline knots (Marsh & Cormier, 2001). In this study, the spline regression model examined whether or not the probability of ATS changed at the following distance thresholds: 0≤0.49 miles, 0.5≤0.99 miles, 1.0≤1.49 miles, and ≥1.5 miles, controlling for child's gender, grade, car ownership, parental education level, child's language, and school bus availability. Furthermore, mixed-effect regression modeling (based on non-spline regressions) was also utilized to examine the relationships between the study variables and ATS by the HTS distance ranges. Statistical analyses were undertaken using STATA version 12.0.

5.3 RESULTS

5.3.1 Sample Characteristics

Boys and girls were evenly represented in this study (boys: 48.7%, girls: 51.3%). Twenty-six percent of the samples were pre-kindergarten and kindergarten students, half (49.6%) were $1^{st} – 3^{rd}$ grade students, and twenty-four percent were $4^{th} – 6^{th}$ grade students. The mean of the number of cars from the total sample was 1.58 (N=316, 7.9% for carless households from the sample). Forty-three percent of the parents attained at least some college or an associate degree or above such as a bachelor's degree or graduate degree. The majority (57.6%) of the students used English most often at home, followed by Spanish at 40.7% and others at 1.6%. The mean of the shortest HTS distance from the total sample was 1.29 miles. The percentage of the students at each distance threshold was 26.7% (n=1,130) for 0≤0.49 miles, 34.7% (n=1,470) for 0.50≤0.99 miles, 18.5% (n=785) for 1≤1.49 miles, and 20.1% (n=854) for ≥1.5 miles.

5.3.2 Environmental Characteristics

Table 14 shows the results of bivariate tests examining the relationships of built and natural environmental characteristics across the distance thresholds and the difference in the mean of assessed variables by distance thresholds. The results represent significant differences in the frequencies or the means of all the variables among the four different distance thresholds. A higher proportion of sidewalks, intersection density, and more playgrounds were captured in the shorter distance ranges, while more highways and railroads, a higher number of sex-offender homes, and higher speed streets were observed in the longer distance ranges. In terms of natural environmental characteristics, more parks and water features, somewhat more tree canopies, steeper slopes, and more urbanized area were identified in the longer distance ranges, while slightly greater grass cover, higher tree heights and NDVI, and slightly higher temperatures were observed in the shorter distance ranges.

5.3.3 Distance and Active Travel to School

Figure 24 shows the reverse relationships between distance travelled to school and ATS. The majority (72.6%, n=809) of students living within 0.49 miles of their school were active travelers. In the 0.5–0.9 miles distance range, sixty percent of the students (n=881) inactively travelled to school, while forty percent of the students (n = 575) walked or biked to school. Beyond one mile, the number of students engaging in ATS dramatically decreased (14.9% in 1–1.49 miles, 11.1% in 1.5–1.9 miles). Among active travelers (n=1,568), half of the students (51.6%, n=809) lived within 0.49 miles, followed by students living within 0.5 – 0.9 miles at 36.7% (n=575) and students living within 1.0–1.49 miles at 7.4% (n=116).

Table 14
Descriptive Statistics of Built and Natural Environmental Variables

Variables	Total (N=4239)		≤0.49 miles (N=1130)		0.5 – 0.9 miles (N=1470)		1 – 1.49 miles (N=785)		≥1.5 miles (N=854)		Bivariate Test†	
	Freq. Mean	% (SD)	Freq. Mean	% (SD)	Freq. Mean	% (SD)	Freq. Mean	% (SD)	Freq. Mean	% (SD)	Test	Sig.
Built Environment Characteristics												
Sidewalks (%)	0.71 (0.19)		0.73 (0.16)		0.74 (0.16)		0.67 (0.22)		0.65 (0.20)		ANOVA	<0.001
Bike lanes (0: < mean, 1: > mean)	1420	33.5	344	30.4	381	25.9	335	42.7	360	42.2	χ^2	<0.001
Playgrounds (presence)	438	10.3	121	10.7	147	10.0	90	11.5	80	9.4	χ^2	<0.001
Intersections (density)	0.47 (0.14)		0.51 (0.17)		0.50 (0.13)		0.46 (0.10)		0.39 (0.13)		ANOVA	0.003
Highways (presence)	664	15.7	0	0.0	89	6.1	211	26.9	364	42.6	χ^2	<0.001
Railroads (presence)	401	9.5	16	1.4	69	4.7	63	8.0	253	29.6	χ^2	<0.001
High speed streets (>30mph) (%)	66.5 (25.6)		59.7 (31.0)		66.3 (23.3)		66.9 (25.0)		75.4 (18.0)		ANOVA	<0.001
Crime – hotspots	0.03 (0.79)		- 0.12 (0.55)		0.14 (0.81)		0.05 (0.89)		-0.13 (0.87)		ANOVA	<0.001
Crash – hotspots	1.11 (3.91)		1.71 (3.75)		1.00 (3.73)		0.63 (4.03)		0.95 (4.22)		ANOVA	<0.001
Crash – ped./bi. hotspots	0.69 (3.84)		1.19 (4.09)		0.39 (3.00)		0.00 (3.93)		1.19 (4.51)		ANOVA	<0.001
Sex-offenders (presence)	641	15.1	108	9.6	238	16.2	104	13.3	191	22.4	χ^2	<0.001
Natural Environment Characteristics												
Parks (presence)	2,688	63.4	458	40.5	830	56.5	618	78.7	782	91.6	χ^2	<0.001
Water features (presence)	973	23.0	17	1.5	244	16.6	229	29.2	483	56.6	χ^2	<0.001
Steep slopes > 5% (%)	24.13 (24.84)		16.54 (26.37)		22.56 (26.37)		28.63 (20.02)		32.75 (20.16)		ANOVA	<0.001
Steep slopes > 8.33% (%)	9.99 (15.73)		7.02 (16.42)		8.61 (15.36)		10.63 (13.12)		15.74 (16.13)		ANOVA	<0.001
Urbanized area (%)	42.70 (10.43)		40.49 (9.11)		42.06 (8.60)		43.50 (11.23)		46.01 (12.98)		ANOVA	<0.001
Tree canopy (%)	11.83 (5.50)		11.47 (5.50)		11.72 (5.56)		12.49 (6.89)		11.86 (5.50)		ANOVA	0.002
Grass cover (%)	10.87 (3.38)		11.04 (4.17)		11.02 (2.83)		10.65 (3.44)		10.60 (2.97)		ANOVA	0.002
Temperature (°C)	31.34 (1.35)		31.56 (1.34)		31.36 (1.57)		31.41 (1.15)		30.96 (1.02)		ANOVA	0.002
NDVI (min:-1, max: 1)	0.34 (0.07)		0.34 (0.06)		0.35 (0.06)		0.34 (0.08)		0.31 (0.08)		ANOVA	<0.001
Tree heights (feet)	7.93 (3.55)		7.98 (3.29)		8.09 (3.36)		8.18 (4.18)		7.34 (3.53)		F	<0.001

Freq.: frequency, ANOVA: analysis of variance, χ^2: chi-squared test, ped./bi: pedestrians/bikers
†: bivariate tests examined the unequal variance of the built and natural environmental variables among the four different distance ranges.

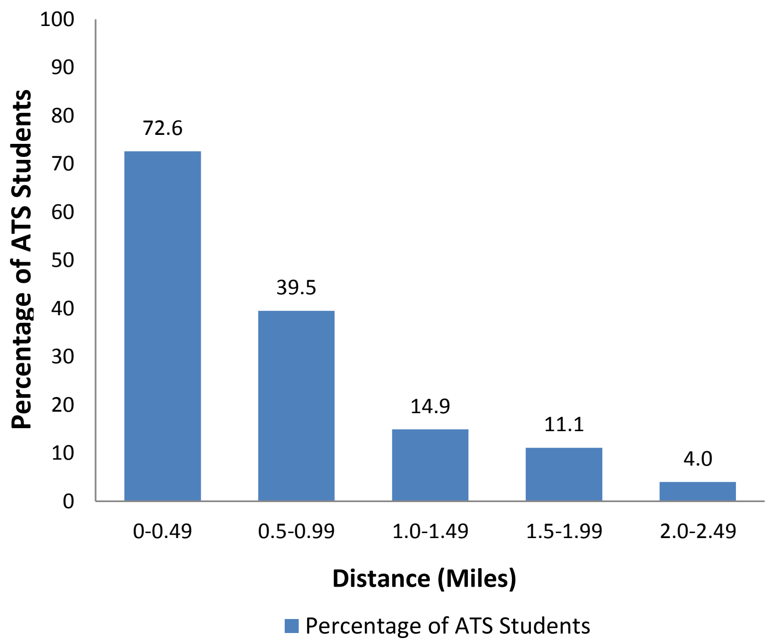


Figure 24
Active versus Inactive Travel to School by Distance

Table 15 displays the average distance travelled to school by individual characteristics (estimated as the shortest distance from home to school using GIS). There was no significant difference in the home-to-school distance between boys and girls. Higher grade students travelled longer distances than lower grade students ($4^{th} - 6^{th}$ grade: 1.3 miles, $1^{st} - 3^{rd}$: 1.2 miles, and PK – K: 1.1 miles). Distance to school was also longer if more cars were available in the household. Further, students travelled a longer distance if their parents possessed a higher education. A significant difference was found by language spoken at home. Students who spoke English most of the time at home travelled further (1.4 miles) than students who spoke Spanish (0.9 miles).

Table 16 shows the results from the χ^2 test examining the relationships between individual student characteristics and ATS. No gender and grade dependencies were observed for ATS. The ratios of ATS were lower if the number of cars in a household and parental education levels were higher. Further, the ratio of ATS was higher for students who spoke Spanish at home than for students who spoke English.

Table 15
Average of the Shortest Home-to-School Distance by Individual Characteristics

Variables		N (%)	Mean ± S.D.	ANOVA	p-value
Child gender	Female	2,138 (51%)	1.21 ± 1.36	0.24***	0.813
	Male	2,033 (49%)	1.20 ± 1.33		
	All	4,171 (100%)	1.20 ± 1.34		
Child grade	PK – K	1,090 (26%)	1.10 ± 1.17	4.87***	0.008
	$1^{st} – 3^{rd}$	2,050 (49%)	1.22 ± 1.38		
	$4^{th} – 6^{th}$	1,003 (24%)	1.27 ± 1.43		
	All	4,143 (100%)	1.20 ± 1.34		
Number of cars in the household	0	317 (8%)	1.14 ± 1.39	8.09***	<0.001
	1	1,456 (36%)	1.17 ± 1.49		
	2	1,873 (46%)	1.39 ± 1.82		
	3+	396 (10%)	1.56 ± 2.56		
	All	4,042 (100%)	1.31 ± 1.77		
Parental education level	Elementary or less	484 (12%)	0.98 ± 1.30	27.53***	<0.001
	Middle school	746 (18%)	0.97 ± 1.07		
	High school or GED	1,111 (27%)	1.12 ± 1.45		
	Some college/Associate degree	442 (11%)	1.56 ± 2.13		
	College graduate/Bachelor's degree	624 (15%)	1.84 ± 2.54		
	Graduate/professional degree	748 (18%)	1.48 ± 1.71		
	All	4,155 (100%)	1.30 ± 1.74		
Language spoken at home	English	2,279 (58%)	1.41 ± 1.58	64.46***	<0.001
	Spanish	1,612 (41%)	0.92 ± 0.85		
	Others	64 (2%)	1.09 ± 0.93		
	All	3,955 (100%)	1.20 ± 1.34		

*p<0.05, **p<0.01, ***p<0.001

Table 16
Active versus Inactive Travel to School by Individual Characteristics

Variables		Inactive Travel to School (% (n))	Active Travel to School (% (n))	χ^2 test	p-value
Child gender	Female	62.7% (1329)	37.3% (791)	0.031***	0.861
	Male	62.9% (1271)	37.1% (748)		
	All	62.8% (2600)	37.2% (1539)		
Child grade	PK – K	61.7% (669)	38.3% (416)	1.637***	0.441
	1^{st} – 3^{rd}	63.5% (1290)	36.5% (741)		
	4^{th} – 6^{th}	61.5% (612)	38.5% (383)		
	All	62.5% (2571)	37.5% (1540)		
Number of cars in the household	0	50.3% (158)	49.7% (156)	60.27***	<0.001
	1	58.7% (845)	41.3% (594)		
	2	68.1% (1254)	31.9% (587)		
	3+	69.3% (267)	30.7% (118)		
	All	63.4% (2524)	36.6% (1455)		
Parental education level	Elementary or less	48.9% (232)	51.1% (242)	173.10***	<0.001
	Middle school	47.9% (353)	52.1% (384)		
	High school or GED	64.9% (710)	35.1% (384)		
	Some college/Associate degree	71.8% (310)	28.2% (122)		
	College graduate/Bachelor's degree	73.4% (449)	26.6% (163)		
	Graduate/professional degree	70.3% (522)	29.7% (221)		
	All	62.9% (2576)	37.1% (1516)		
Language spoken at home	English	69.3% (1570)	30.7% (697)	107.13***	<0.001
	Spanish	53.1% (846)	46.9% (748)		
	Others	71.9% (46)	28.1% (18)		
	All	62.7% (2462)	37.3% (1463)		

*p<0.05, **p<0.01, ***p<0.001

5.3.4 Multivariate Analysis 1: Spline Logistic Regressions

Table 17 represents the results from partially adjusted models in which each environmental variable was added to the base model including all the personal and social variables and HTS distance range variables, and the results from the fully adjusted model. The following description of the results in this section is based on the fully adjusted model. Except for the student gender variable, all other variables selected to capture individual characteristics were significantly associated with the odds of ATS. Compared with the PK – K grade students, the odds of ATS were 1.41 times higher for the 4^{th} – 6^{th} grade students (OR = 1.41, p = 0.007). An increase in the number of cars in a household was associated with decreased odds of ATS by 40% (OR = 0.60, p < 0.001). An increase in parental education levels also showed a negative relationship with children's ATS (OR = 0.88, p = 0.004). Students who spoke Spanish most of the time at home were 73% more likely to engage in ATS than students who spoke English (OR = 1.73, p < 0.001). If the school bus service were available for children, they were 62% less likely to engage in ATS (OR=0.38, p<0.001).

Out of the four HTS distance range variables, three shorter distance ranges showed a statistical significance. A 100-meter increase in distance from school decreased the odds of ATS by 32% (OR = 0.68, p < 0.001), 19% (OR = 0.81, p < 0.001), and 6% (OR = 0.94, p = 0.031) for those living 0–0.49 miles, 0.5–0.9 miles, and 1–1.49 miles, respectively. Further, the probability of ATS also decreased when the HTS distance ranges increased (Figure 25).

For the built environmental variables, students were more likely to actively travel to school if they lived in a neighborhood that had more bike lanes (OR = 1.42, p = 0.002) and had playgrounds (OR = 2.01, p = 0.018). On the other hand, students were less likely to actively travel to school if HTS routes were intersected by highways (OR = 0.69, p = 0.083) and if pedestrian- and biker-related crash hotspots were present within the HTS route buffer (OR = 0.94, p = 0.001). For the natural environmental variables, students were more likely to engage in ATS if they lived in a neighborhood with parks (OR = 1.38, p = 0.017) and taller trees (OR = 1.04, p = 0.056), while students living in neighborhoods with steep slopes (>8.33%) were less likely to engage in ATS (OR = 0.99, p = 0.005). Figure 26 shows the predicted probability of ATS by the significant environmental variables.

Table 17
Spline Regression Models Estimating the Odds of Active Travel to School

Environmental variables	Partially adjusted models†			Fully adjusted model† (N = 3,438 , Pseudo R^2 = 0.2254)		
	OR	P>|z|	95% CI	OR	P>|z|	95% CI
Personal variables						
Child's gender (1: male)				1.05	0.585	(0.88, 1.25)
Child's grade (Ref. PK-K)						
$1^{st} – 3^{rd}$				1.15	0.205	(0.93, 1.43)
$4^{th} – 6^{th}$				1.41**	0.007	(1.10, 1.81)
Child's language (Ref.English)						
Spanish				1.73***	0.000	(1.37, 2.18)
Others				0.67	0.259	(0.33, 1.35)
Number of cars (range: 0–3)				0.60***	0.000	(0.52, 0.68)
Parents' education level[c]				0.88**	0.004	(0.80, 0.96)
Social variable						
School bus availability (1: yes)				0.38***	0.000	(0.30, 0.48)
HTS distance (unit: 100m)						
HTS distance: 0 ≤ 0.49 mi.				0.68***	0.000	(0.63, 0.74)
HTS distance: 0.5 to ≤0.99 mi.				0.81***	0.000	(0.78, 0.84)
HTS distance: 1 to ≤1.49 mi.				0.94*	0.031	(0.89, 0.99)
HTS distance: ≥1.5 mi.				1.00	0.680	(0.99, 1.01)
Built environmental variables						
Sidewalks (%)	1.00	0.343	(0.99, 1.00)			
Bike lanes (1: ≥ mean)	1.37**	0.006	(1.10, 1.71)	1.42**	0.002	(1.14, 1.77)
Playgrounds (presence)	1.62‡	0.097	(0.92, 2.85)	2.01*	0.018	(1.13, 3.58)
Intersections (no. of intersections per acre)	1.24	0.571	(0.59, 2.60)			
Highways (1 = intersected)	0.60*	0.014	(0.40, 0.90)	0.69‡	0.083	(0.36, 0.81)
Railroads (1 = intersected)	1.06	0.780	(0.70, 1.61)			
High speed streets (>30mph) (%)	1.00	0.438	(1.00, 1.01)			
Crime hotspot	0.84	0.212	(0.64, 1.10)			
Crash hotspot[a]	0.94**	0.008	(0.90, 0.98)			
Crash hotspot[b]	0.93**	0.001	(0.89, 0.97)	0.94**	0.001	(0.90, 0.97)
Sex-offenders (presence)	1.27	0.133	(0.93, 1.73)			
Natural environmental variables						
Park (presence)	1.30‡	0.056	(0.99, 1.69)	1.38*	0.017	(1.06, 1.79)
Water feature (presence)	1.13	0.443	(0.83, 1.54)			
Steep slope > 5% (%)	1.00	0.205	(0.99, 1.00)			
Steep slope > 8.33% (%)	0.99‡	0.099	(0.98, 1.00)	0.99**	0.005	(0.98, 1.00)
Urbanized area (%)	0.99	0.289	(0.98, 1.01)			
Tree canopy (%)	1.01	0.388	(0.99, 1.02)			
Grass (%)	1.00	0.933	(0.97, 1.04)			
Temperature (°C)	1.04	0.497	(0.93, 1.15)			
NDVI (min: -1, max: 1)	1.00	0.728	(0.99, 1.02)			
Tree height (feet)	1.02	0.327	(0.98, 1.06)	1.04‡	0.056	(1.00, 1.08)

†: All the associations were adjusted by the covariates including child's gender, grade, language, number of cars, parental education level, and HTS distance thresholds. *p<0.05, **p<0.01, ***p<0.001, ‡: Marginally significant at 0.10 level. [a]: Crash hotspot based on all crashes, [b]: Crash hotspot based on pedestrian- or biker-related crashes, [c]: Parents' education level was coded as 1 for elementary or less, 2 for middle school, 3 for high school or GED, 4 for some college/associate degree, 5 for college graduate/bachelor's degree, and 6 for graduate/professional degree. OR: odd ratios, CI: confidence interval

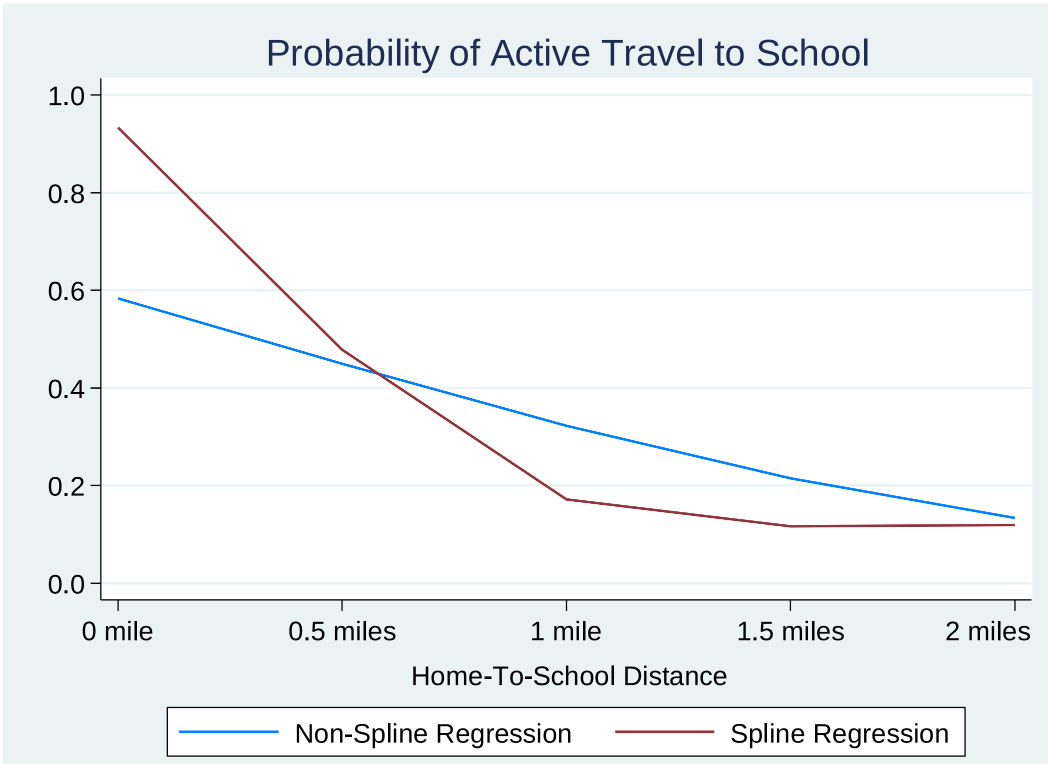


Figure 25
Probability of Active Travel to School by Distance

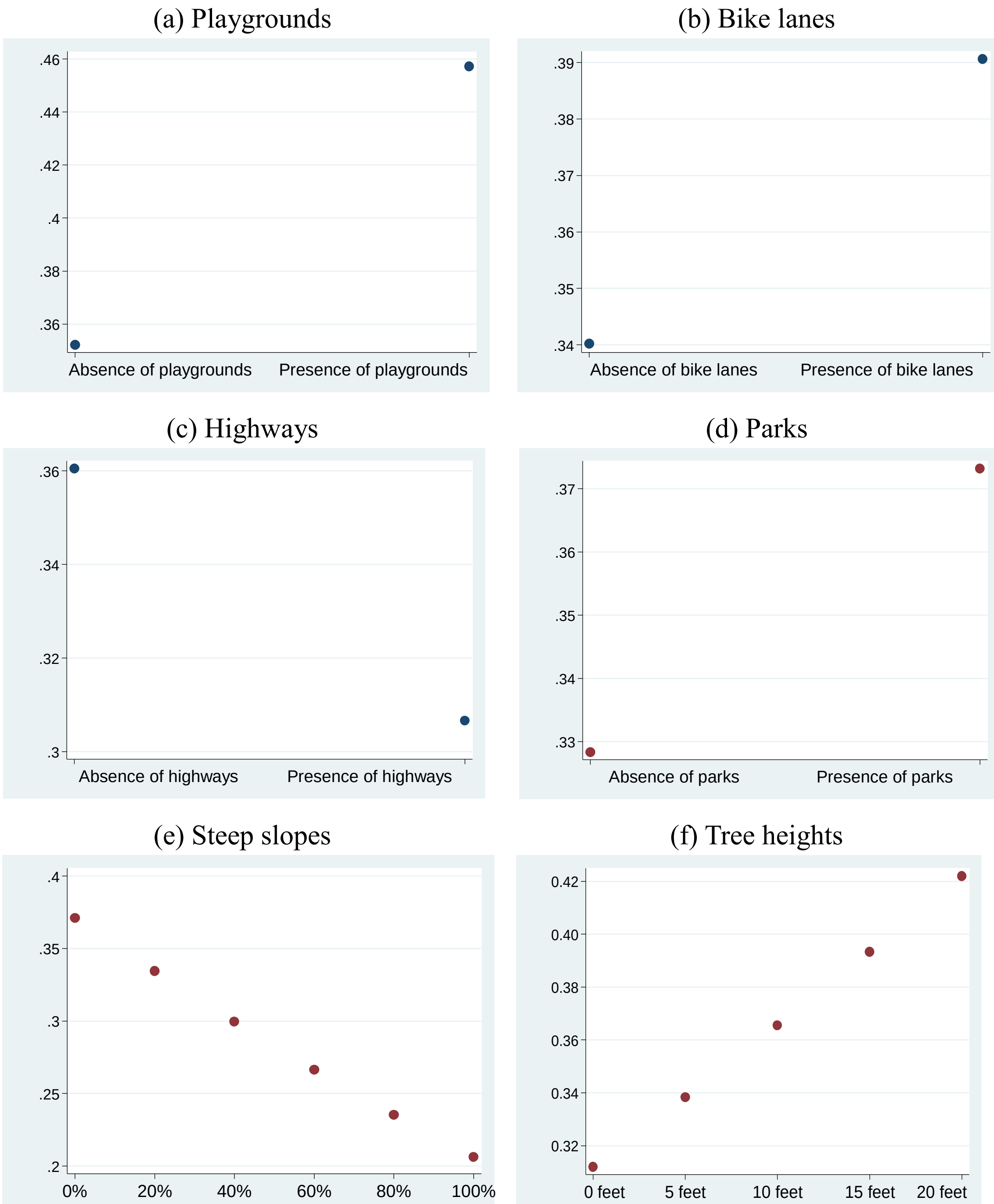


Figure 26
Probability of Active Travel to School by Environmental Correlates

5.3.5 Multivariate Analysis 2: Non-Spline Logistic Regressions

Table 18 shows the results of four separate mixed-effects logistic regression models (non-spline regressions) that examined relationships between environmental variables and ATS by four different HTS distance ranges, controlling for personal and the HTS distance variables.

Regarding the covariates (personal/social variables and HTS distance), a child's grade and language variables were only significant at ≤ 0.49 miles and 0.5 to ≤ 0.99 miles distance ranges. The 4^{th}-6^{th} grade's students (OR = 1.93, p = 0.007 for the ≤ 0.49 miles range, OR = 1.54, p = 0.023 for the 0.5 to ≤ 0.99 miles range) and students who spoke Spanish at their home (OR = 2.40, p < 0.001 for 0 ≤ 0.49 miles, OR = 1.63, p = 0.008 for 0.5 ≤ 0.99 miles) were more likely to engage in ATS than students in PK-K and students who spoke English. The car ownership was a negative correlate of children's ATS at the ≤ 0.49 miles range (OR = 0.68, p = 0.001), the 0.5 to ≤ 0.99 miles range (OR = 0.47, p < 0.001), and the 1 to ≤ 1.49 miles range (OR = 0.69, p = 0.041). An increase in parents' education levels was negatively associated with children's ATS, but it was only significant at the ≤0.49 miles range (OR=0.83, p=0.046). The school bus availability (a dummy variable) was strongly and negatively associated with children's ATS across the four HTS distance ranges (OR = 0.54, p = 0.009 for 0 ≤ 0.49 miles, OR = 0.31, p < 0.001 for 0.5 ≤ 0.99 miles, OR = 0.41, p = 0.004 for 1 ≤ 1.49 miles, OR = 0. 16, p < 0.001 for ≥ 1.5 miles). The negative relationship between HTS distance and ATS was only significant in the shorter distance ranges of ≤0.49 miles (OR = 0.62, p < 0.001) and 0.5 to ≤ 0.99 miles (OR = 0.79, p < 0.001).

Among the environmental variables, the presence of playgrounds (OR = 6.15, p = 0.010), the presence of parks (OR = 1.88, p = 0.002), and the percentage of sidewalks (OR = 1.04, p < 0.001) were positively associated with children's ATS at the ≤ 0.49 miles, 0.5 to ≤0.99 miles, and 1 to ≤1.49 miles ranges, respectively. While bike lanes were a positive correlate of ATS in the 0.5 to ≤0.99 miles range (OR = 1.43, p=0.035) and the 1 to ≤1.49 miles range (OR = 2.21, p = 0.002), pedestrian- and bike-related crash hotspots were a negative correlate of ATS in the shorter distance ranges, ≤ 0.49 miles (OR = 0.90, p = 0.005) and 0.5 to ≤ 0.99 miles (OR = 0.94, p = 0.046). The presence of highways variable was negatively associated with ATS at ≥ 1.5 miles (OR = 0.31, p = 0.006), while positively associated with at 1 to ≤ 1.49 miles (OR = 2.70, p = 0.024). Steep slopes greater than 8.33% was a negative correlate of ATS at 0.5 to ≤ 0.99 miles (OR = 0.97, p < 0.001). Lastly, a positive association between tree canopy and ATS was found at 0.5 to ≤ 0.99 miles (OR = 1.04, p=0.026), but a negative association between them was seen at ≥ 1.5 miles (OR = 0.90, p = 0.015).

Table 18
Built and Natural Environmental Correlates by Distance Ranges

	≤.49 miles		.5≤0.99 miles		1≤1.49 miles		≥1.5 miles	
	OR	P>|z|	OR	P>|z|	OR	P>|z|	OR	P>|z|
Personal variables†								
Child's gender (1 = male)	0.88	0.444	1.16	0.282	1.00	0.988	1.67	0.105
Child's grade (Ref. PK-K)								
1st – 3rd	1.47†	0.057	1.13	0.453	0.64	0.114	0.84	0.657
4th – 6th	1.93**	0.007	1.54*	0.023	0.91	0.767	0.73	0.483
Child's language (Ref. English)	-	-	-	-	-	-	-	-
Spanish	2.40***	0.000	1.63**	0.008	1.21	0.599	1.44	0.319
Others	1.22	0.751	0.43	0.221	0.52	0.537	0.00	0.991
Number of cars (range: 0–3)	0.68**	0.001	0.47***	0.000	0.69*	0.041	0.79	0.293
Parents' education level[c] (range: 1–7)	0.83*	0.046	0.92	0.194	0.86	0.139	0.85	0.231
Social variable†								
School bus availability (1 = yes)	0.54**	0.009	0.31***	0.000	0.41**	0.004	0.16***	0.000
HTS distance† (unit: 100m)	0.62***	0.000	0.79***	0.000	1.03	0.648	1.00	0.983
Built environmental variables								
Sidewalks (%)	-	-	-	-	1.04***	0.000	-	-
Bike lanes (0: ≤ mean, 1: > mean)	-	-	1.43*	0.035	2.21**	0.002	-	-
Playgrounds (1: presence)	6.15*	0.010	-	-	-	-	-	-
Intersections (no. of intersections per acre)	-	-	-	-	-	-	-	-
Highways (1 = intersected)	-	-	-	-	2.70*	0.024	0.31**	0.006
Railroads (1 = intersected)	-	-	-	-	-	-	-	-
High speed streets (mph>30) (%)	-	-	-	-	-	-	-	-
Crime hotspot	-	-	-	-	-	-	-	-
Crash hotspot[a]	-	-	-	-	-	-	-	-
Crash hotspot[b]	0.90**	0.005	0.94*	0.046	-	-	-	-
Sex-offenders (1 = presence)	-	-	-	-	-	-	-	-
Natural environmental variables								
Park (presence)	-	-	1.88**	0.002	-	-	-	-
Water feature (presence)	-	-	-	-	-	-	-	-
Steep slope > 5% (%)	-	-	-	-	-	-	-	-
Steep slope > 8.33% (%)	-	-	0.97***	0.000	-	-	-	-
Urbanized area (%)	-	-	-	-	-	-	-	-
Tree canopy (%)	-	-	1.04*	0.026	-	-	0.90*	0.015
Grass (%)	-	-	-	-	-	-	-	-
Temperature (°C)	-	-	-	-	-	-	-	-
NDVI (min: -1, max: 1)	-	-	-	-	-	-	-	-
Tree height (feet)	-	-	-	-	-	-	-	-
Total N		**875**		**1,203**		**655**		**734**
Pseudo R²		**0.1127**		**0.1281**		**0.0898**		**0.1223**

*p<0.05, **p<0.01, ***p<0.001, ‡: Marginally significant at 0.10 level
[a]: Crash hotspot based on all crashes, [b]: Crash hotspot based on pedestrian- or biker-related crashes, [c]: Parents' education level was coded as 1 for elementary or less, 2 for middle school, 3 for high school or GED, 4 for some college/associate degree, 5 for college graduate/bachelor's degree, and 6 for graduate/professional degree.
OR: odd ratios, CI: confidence interval

5.4 CONCLUSIONS AND DISCUSSION

This study is one of the first studies that address variations in HTS distance's effects on ATS by different distance ranges. The findings related to HTS distance suggest that the probability of ATS decreases with increased distance to school, and the magnitude of the distance-ATS relationship decreases dramatically after 1 mile and no significant relationship is found beyond 1.5 miles. Further, several studies identified that the prevalence of walking to school among children is high when the distance travelled to school is less than 1 mile (Noreen C McDonald, 2007; N. C. McDonald et al., 2011; Tracy E McMillan, 2007; Schlossberg et al., 2006). In terms of the modeling process, this study utilized a spline regression model to examine varying roles of distance ranges in affecting ATS. Since the spline regression model considers non-linear regression, it is possible to differentiate the probabilities of ATS by the distance ranges.

In addition to the uniqueness of examining the various magnitudes of distance range effects on ATS, several additional strengths of the current study contribute to suggesting feasible and practicable environmental solutions to promote ATS by focusing on the objectively-measured environmental variables. Further, this study was the first attempt to examine natural environmental correlates of ATS. Previously, natural environmental characteristics focused on children's physical activity (Almanza et al., 2012; I. Fjørtoft, 2004), paying less attention to children's ATS. This study considered various natural environmental variables including parks, water features, street slopes, tree canopy coverage, grass coverage, temperatures, NDVI, and tree heights.

In terms of the association between built environmental variables and ATS, this study confirmed the previously documented role of crime or crash safety in promoting ATS (Centers for Disease Control and Prevention, 2005; Greves et al., 2007; Panter et al., 2010a). Pedestrian- and biker-related crash incidents were importantly associated with ATS in the current study. Furthermore, mixed-effects non-spline regression models showed that the negative relationship between pedestrian-/biker-related crash hotspots and ATS was shown to be significant only in shorter distance ranges, ≤ 0.49 miles and 0.5 to ≤0.99 miles. As shown in this study, infrastructure to support safe ATS, including bike lanes and playgrounds showed a possibility for increasing the probability of ATS among children. Visibly marked bike lanes along the routes can create a much safer walking and cycling environment for young students. Playgrounds may also provide a safer walking environment by bringing children and family into the places as well as providing clear visual surveillance. On the other hand, the presence of highways functioned as a barrier to ATS in this study.

Regarding natural environmental correlates of ATS, the presence of parks and taller tree heights were positively associated with ATS, and steep slopes greater than 8.33% were negatively associated with ATS. The reason for only those three variables being statistically significant in the final model was because several variables were highly correlated with each other. Notably, larger tree canopy coverage was more likely to be associated with having a lower surface temperature and higher NDVI. Further, taller tree heights provided lower surface temperatures and were more likely to have a greater tree canopy. To avoid multicollinearity among those variables, the variance inflation factor was utilized for the modeling process, and thereby the final full model was generated which also showed the best model fit.

This study also has several limitations. This study is a cross sectional design so that the causal relationship between objectively-measured environmental variables and ATS could not be assessed. There was also a measurement issue for several natural environmental variables. NDVI and temperature had a 30x30 meter and 120x120 meter spatial resolution respectively. Therefore, those variables represent general environmental conditions along HTS routes and cannot capture more fine-grained details that may be further related to ATS. Furthermore, micro-environmental conditions such as sidewalk surface conditions (holes/cracks, bumps and uneven surfaces) and conditions of trees or vegetation are needed to be examined for the future studies.

In sum, the majority of active travelers lived within one mile of school, and the probability of ATS dramatically decreased after 1 mile and the negative effect of distance on ATS disappeared after 1.5 miles. This finding indicates not only the need for different intervention strategies to promote ATS across different distance ranges but also for reducing the school bus service eligibility from the current 2+ miles to 1–1.5 miles. Further, this study also confirms the significant role of built environmental features including bike lanes, playgrounds, and an absence of highways and reveals new findings related to the potential importance of parks and greenery in promoting ATS. Additional studies on how the objectively-measured environmental conditions are associated with parental perceptions of safety and weather concerns are necessary to further facilitate ATS among all children.

6. STUDY THREE:

SAFETY AND THERMAL COMFORT CONCERNS AS MEDIATORS IN THE ENVIRONMENT-ACTIVE TRAVEL TO SCHOOL RELATIONSHIP

6.1 INTRODUCTION

Active travel to school (ATS) has been promoted as a potential approach to increase children's physical activity in daily life (Saksvig et al., 2007; Sirard, Riner, et al., 2005; Tudor-Locke et al., 2002). However, the rate of ATS has decreased over the last few decades (N. C. McDonald et al., 2011). To promote ATS and encourage a healthy lifestyle among children, it is important to understand the mechanism of ATS. Since children's ATS is determined primarily by their parents, it is important to understand parents' decision making related to ATS. According to the Centers for Disease and Control and Prevention (Centers for Disease Control and Prevention, 2002), the most frequently reported barriers to ATS by parents included longer distances (55 %), traffic danger (40%), adverse weather conditions (24%), and crime danger (18%) in order of rank. In order to effectively promote ATS, more studies are needed to better understand the multi-level factors related to parental concerns and ATS.

A number of studies have revealed a negative association between the objectively-measured home-to-school (HTS) distance and ATS (Tracy E McMillan, 2007; Merom et al., 2006; Schlossberg et al., 2006; Anna Timperio et al., 2006; Yarlagadda & Srinivasan, 2008). Several studies also used the subjectively measured or perceived distance to school which also indicated a negative relationship with ATS

(Salmon et al., 2007; Yeung et al., 2008). In terms of the role of safety issues in relation to ATS, several studies have reported that higher parental safety concerns were negatively associated with children's walking to school behavior (Kerr et al., 2006; Zhu & Lee, 2009). Moreover, parental perceptions of stranger danger, road safety, and heavy traffic were also negatively related to their children's walking or cycling in their neighborhoods (Greves et al., 2007; Panter et al., 2010a; Anna Timperio et al., 2006; A. Timperio et al., 2004) and active free-play (Veitch, Bagley, Ball, & Salmon, 2006). In terms of weather issues, one study utilized a seasonal variable (spring, summer, fall, and winter) and showed an insignificant relationship with ATS among adolescents.

Modifying the distance factor is not an easy task and needs long-term changes in zoning, land uses, and street layouts. On the other hand, safety and weather concerns, which are the next most commonly reported barriers, can be adjusted by providing safer and more pleasant environmental conditions along HTS routes for the students living within a walkable distance. According to a national study conducted by McDonald in 2008, students living within a half mile from school are more likely to engage in ATS across all White, Black, and Hispanic race groups (N. C. McDonald, 2008b). McDonald's another study based on a national travel survey also showed that living in a quarter mile and a half mile from school would increase the probability of walking to school by 43% and 34% (N. C. McDonald, 2008a). Nonetheless, many students within a walkable distance from school are still driven to school. This group of students represents a significant proportion of those who can potentially benefit from improved safety and microclimatic conditions along their routes to school and can engage in ATS.

Studies that focus on built and natural environmental factors that affect parental concerns of safety and thermal comfort for children's ATS have rarely been conducted, despite their significant role as barriers to ATS. Therefore, studies examining the built and natural environmental correlates of not only parental concerns of safety and thermal comfort but also ATS at the same time can help develop strategies to lift some of the most significant barriers to ATS.

The purpose of this study is to examine whether or not parental concerns of safety and thermal comfort play a mediating role between the built/natural environment and ATS and to compare the built/natural environmental impacts on both mediators and ATS, focusing on a group of people living within a walkable distance from school.

6.2 METHODS

6.2.1 Study Design, Sample and Data Collection

This study used a sub-set of the Safe Routes to School (SRTS) parental survey data collected in 2010 as part of a larger project, the "Whys" and "Why Nots" of Active Living, funded by the Robert Wood Johnson Foundation's Active Living Research Program (PI: Dr. Chanam Lee, the academic advisor of this dissertation author). Parents whose children were enrolled in twenty elementary schools in the Austin Independent School District (AISD), in Austin, Texas, were asked to report their individual characteristics, social support, and environmental perceptions related to ATS. Out of 13,573 initial surveys, 4,609 parents' surveys were returned (response rate = 34.0%). Among the returned surveys, this study focused on the respondents (n = 1,130) who lived within a half mile of the schools because one of the main purposes of this study was to examine the exact role of built and natural environments in promoting ATS, while limiting the strong distance effect on ATS. As reported in Study 2 of this dissertation (Chapter 5), more than a half of active travelers (51.6%) from the sample lived within a half mile of school.

6.2.2 Study Variables

Personal Factors, Parental Concerns about Safety and Thermal Comfort, and ATS

Parental survey data used in this study included socio-demographic and -economic status, attitudes toward walking, social support (such as peer influence and social connectivity), parental concerns of safety and thermal comfort, and ATS. For socio-economic status factors, the number of cars in a household and whether or not children were qualified for a free or reduced lunch service at school were used as a proxy for the household income status. An annual household income variable was not used due to a high portion of missing data (45.2% out of the sample). Further, whether or not a child used Spanish most often at home was used instead of an ethnicity variable. For the ATS measure, parents were asked to report their child's travel mode for travel both ways "from home to school" and "from school to home," based on the following answer options: 'walk alone,' 'walk with friends,' 'walk with a parent/adult,' 'ride a school bus,' 'ride a public bus or light rail,' and 'ride in a private car, including carpooling.' If parents answered that their child used at least one walking or biking mode for home-to-school or school-to-home, their children were classified as active travelers.

Thus, ATS was measured by a binary variable indicating whether children walked or biked to or from school on a normal day.

The exact wording of survey questions on positive attitudes toward walking, social support, and parental concerns of safety and thermal comfort are presented in Table 20. Positive attitudes captured as a latent variable were assessed using six observed survey items regarding daily walking habits, enjoyment of walking and perceived benefits of walking. Factor analysis using the five survey items produced one factor that had a 2.44 Eigenvalue and showed that all the loadings were greater than 0.4, which means that the six survey items could be acceptably grouped together (Acock, 2008) (Appendix C-1). For a social support latent variable, four observed survey variables regarding the levels of social cohesion in neighborhoods were utilized. Factor analysis based on the four variables produced one factor and their factor loadings on the four social support related items were all greater than 0.4 (Appendix C-2). Parental safety concerns (latent variable) used as a mediator was measured using eight survey items: 'getting lost,' 'being taken or hurt by a stranger,' 'being bullied or harassed,' 'being attacked by stray dogs,' 'being hit by a car,' 'inhaling exhaust fumes,' 'no helpers in case of danger,' and 'getting injured by falling.' Factor analysis results of these variables also showed that the eight items could be reasonably grouped together under a single latent variable (Appendix C-3). For parental concerns about thermal comfort, a single survey item, 'my child gets too hot and sweaty,' was used. Further, several parental perception items that may affect parental concerns of safety or thermal comfort were also used in this study, including perceived tree shadiness and burden of carrying school bags. All the survey variables mentioned above were assessed using a 5-point Likert scale from 'strongly disagree' to 'strongly agree.'

HTS Route Environment

Objective measures of the built and natural environments were estimated using the Geographic Information Systems (GIS) and Environment and Visualizing Images (ENVI). The shortest HTS route was captured by a network analysis in GIS and showed an 89% matching rate with the actual HTS route, which was measured by a GPS unit for 112 respondents. All the built and natural environmental variables were measured within 100 feet of an HTS route buffer. Crime data between 2004 and 2010 provided by the Austin Police Department was utilized to generate the crime variable indicating the number of crimes within 100 feet of the HTS route buffer. The time period for the crime variable was based on the survey time which was 2010, and this study assumed that 7 years crime information can sufficiently represent the crime safety conditions in the neighborhoods. From a street GIS layer provided by the City of Austin, the percentages of streets with bike lanes within 100 feet of an HTS buffer was measured and recoded into a binary variable indicating the presence or absence of bike lanes. Further, the number of intersections was also measured utilizing a spatial analysis tool in ArcGIS. For the tree canopy coverage variable, a remotely-sensed image taken in June, 2010 when the surveys were distributed to parents, was used. The satellite image was separated into four classes: urban, tree, grass, and ground coverage through an unsupervised image classification method in ENVI. Finally, the percentage of tree canopy coverage was measured within 100 feet of an HTS route buffer.

6.2.3 Conceptual Framework

Based on the objectives of this study, a conceptual framework was generated representing the hypothetical associations among positive attitudes toward walking in neighborhoods, social support, objectively-measured environment, parental concerns of safety and thermal comfort (mediators), and ATS (outcome) (Figure 27). The conceptual framework describes three primary hypotheses, including:

- Hypothesis 1: Objectively-measured built and natural environments will be directly associated with parental safety and thermal comfort concerns and indirectly associated with ATS.
- Hypothesis 2: Longer HTS distances will be associated with increased parental safety and thermal comfort concerns for ATS.
- Hypothesis 3: Positive attitudes toward walking and positive social support will decrease safety and thermal comfort concerns, and promote children's ATS.

For the respondents who lived within a walkable distance, safer or greener amenities may help reduce parents' perceived concerns of safety and thermal comfort and thereby increase the possibility of their children's walking or biking to school. Thus, objectively measured built and natural environmental variables were hypothesized to directly influence ATS and indirectly influence it through parental safety or thermal comfort concerns. The conceptual framework also identifies whether positive attitudes and social support directly influence the relationship with ATS or indirectly through parental safety concerns. Socio-demographic and -economic status variables were controlled to better explain the hypothesized associations. Further, although this study focused on the respondents living within a half mile from school, the HTS distance variable was also used as a confounder for both parental concerns and ATS to examine whether the HTS distance still influences parental concerns and ATS.

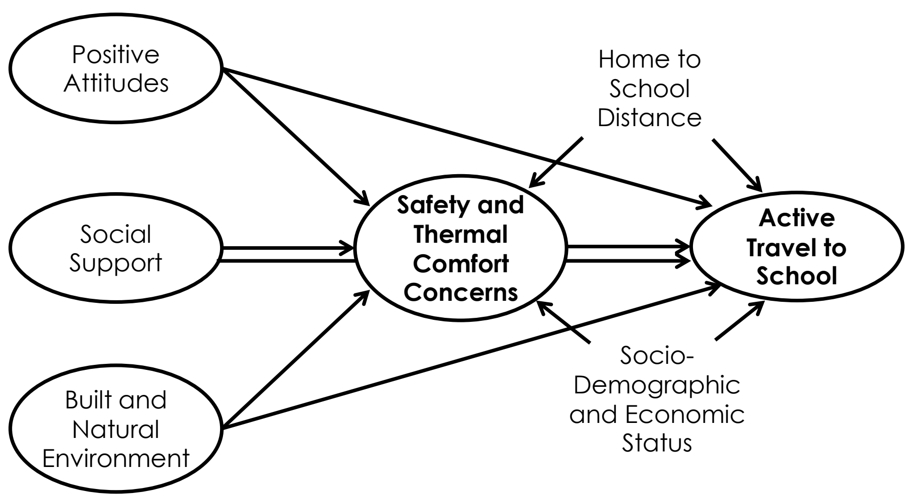


Figure 27
Conceptual Framework for Study 3

6.2.4 Statistical Analysis

This study utilized a structural equation model (SEM) for a comprehensive investigation of the relationships among personal factors, parental concerns, and ATS. Several latent variables regarding positive attitudes, social support, and parental safety concerns verified by factor analysis were used to estimate the measurement models with the multiple observed variables (Appendix C). The objectively-measured built and natural environmental variables were independently used as observed variables without a latent variable because of the statistical insignificances of the measurement models. The parental thermal comfort concern variable was also used as an observed variable because there was only one survey item related to parental thermal comfort perception. In terms of missing data, this study followed the listwise deletion because the observed variables did not follow a joint normal distribution and it is appropriate when running SEM models with binary outcome variable in STATA (StataCorp, 2013). To assess the overall model fit of SEM models, three fit indices were utilized: a comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardized root mean residual (SRMR) (Brown, 2012). Statistical analyses were undertaken using STATA, version 12. All the path associations in SEM were expressed by standardized coefficients and a p-value of 0.05 was used to determine the statistical significance of the associations.

6.3 RESULTS

6.3.1 Sample Characteristics

Table 19 shows the sample characteristics including socio-economic status, distances, and ATS. The study participants included in the analysis had 1.6 vehicles in the household on average and 3,695 (92.1%) had at least one vehicle. About 78% of the students received free or reduced lunch service at school. Almost half of the students (47.9%) used Spanish most of the time at home, and the remainders spoke English (50.3%) or other languages (1.7%). On average, the students traveled 0.32 miles from home to school, and most students (72.6%) were active travelers. Figure 28 shows home locations of walkers and non-walkers living within or beyond a half mile school buffer.

Table 19
Sample Characteristics for Study 3

Characteristics	% (n) or mean (±SD)
Free or reduced lunch service	
No	21.9% (225)
Yes	78.1% (801)
Number of cars in household	1.58 (±0.80)
Language	
Spanish	47.9% (501)
Non-Spanish	52.1% (544)
HTS distance (unit: mile)	0.32 (±0.11)
Active travel to school	
Active (i.e., walk or bike)	72.6% (809)
Non-active	27.4% (305)

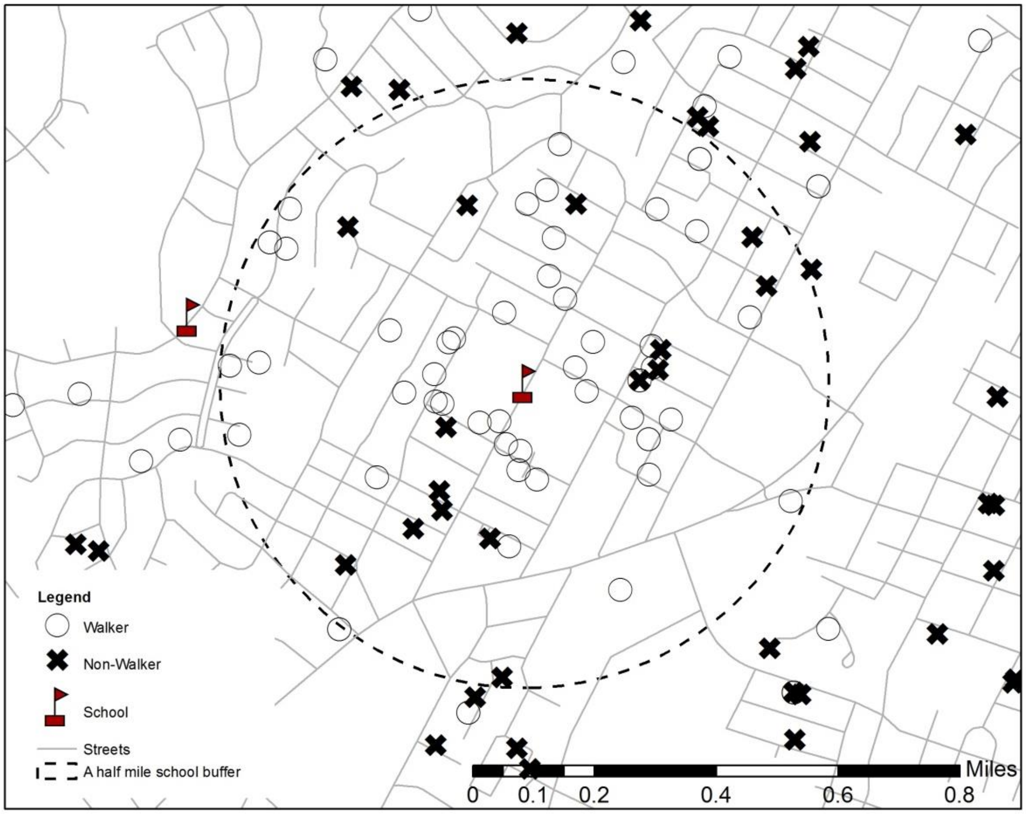


Figure 28
Home Locations of Walkers and Non-Walkers within or beyond a Half Mile School Buffer

6.3.2 Descriptive Statistics for Latent and Observed Variables

Table 20 shows the coding scheme and descriptive statistics for the latent and observed variables used in SEM. *Positive attitudes* used as a latent variable consisted of five observed variables. Most parents had a very positive attitude on walking behavior and its benefits. Further, over 70% of the parents somewhat or strongly agreed with the four specific survey items related to social support. On average, about 43% of the parents somewhat or strongly agreed on the eight survey questions related to safety concerns, while thirty-eight percent of the parents somewhat or strongly disagreed. Over one-third (41.3%) of the parents were concerned about their children's hot and sweaty condition resulting from walking in the neighborhood. Most parents (56.6%) perceived that the overall walking environment around their neighborhood, including sidewalks, roads, and houses, was well shaded by trees. About twenty-six percent of the parents worried about their children carrying a burden.

Table 20
Coding Scheme and Descriptive Statistics for Latent and Observed Variables

Latent and observed variables	Coding scheme and descriptive statistics	N
Positive attitude (5 items)		
How do you feel about walking and your neighbourhood:	1: Strongly disagree, 2: Somewhat disagree, 3: Neither disagree nor agree, 4: Somewhat agree, 5: Strongly agree	
My child walks quite often in his/her daily routine.	1: 8.5%, 2: 6.8%, 3: 12.3%, 4: 28.0%, 5: 44.5%	1077
Walking is a good way to exercise.	1: 2.0%, 2: 0.4%, 3: 1.3%, 4: 9.5%, 5: 86.8%	1103
Walking is a good way to interact with other people.	1: 3.9%, 2: 2.6%, 3: 9.8%, 4: 20.8%, 5: 63.0%	1083
I walk quite often in my daily routine.	1: 5.5%, 2: 4.4%, 3: 13.4%, 4: 26.3%, 5: 50.4%	1079
I (would) enjoy walking with my child to/from school.	1: 3.0%, 2: 2.5%, 3: 7.3%, 4: 19.1%, 5: 68.0%	1076
Social support (4 items)		
My family and friends like the idea of walking to school.	1: 4.3%, 2: 3.7%, 3: 18.5%, 4: 21.1%, 5: 52.3%	1074
Other kids walk to/from school in my neighborhood.	1: 3.2%, 2: 6.1%, 3: 6.3%, 4: 19.8%, 5: 67.6%	1079
Other kids and parents walk quite often in their daily routines.	1: 3.0%, 2: 3.5%, 3: 13.8%, 4: 24.9%, 5: 54.8%	1085
I feel connected to people in my neighborhood.	1: 6.7%, 2: 5.7%, 3: 18.3%, 4: 24.9%, 5: 44.5%	1074
Safety concerns (8 items)		
How about safety concerns about walking to school:		
My child may get lost.	1: 38.4%, 2: 15.2%, 3: 17.4%, 4: 16.6%, 5: 12.5%	1055
My child may be taken or hurt by a stranger.	1: 15.6%, 2: 12.1%, 3: 16.8%, 4: 28.3%, 5: 27.3%	1060
My child may get bullied, teased, or harassed.	1: 21.0%, 2: 15.6%, 3: 21.7%, 4: 22.7%, 5: 20.0%	1051
My child may be attacked by stray dogs.	1: 20.7%, 2: 15.0%, 3: 16.9%, 4: 23.0%, 5: 24.4%	1066
My child may be hit by a car.	1: 15.8%, 2: 10.3%, 3: 12.9%, 4: 28.5%, 5: 32.5%	1066
Exhaust fumes may harm my child's health.	1: 27.3%, 2: 14.5%, 3: 25.9%, 4: 18.4%, 5: 13.8%	1041
No one will be able to see and help my child in case of danger.	1: 21.8%, 2: 17.3%, 3: 20.3%, 4: 24.7%, 5: 15.9%	1059
My child may get injured by falling.	1: 28.0%, 2: 16.6%, 3: 21.7%, 4: 18.8%, 5: 15.0%	1055

Table 20
Coding Scheme and Descriptive Statistics for Latent and Observed Variables (continued)

Latent and observed variables	Coding scheme and descriptive statistics	N
Weather concern (1 item)		
My child gets too hot and sweaty.	1: 25.4%, 2: 14.5%, 3: 18.8%, 4: 25.4%, 5: 15.9%	1056
Perceived tree shadiness (1 item)		
It is well shaded by trees.	1: 14.3%, 2: 13.4%, 3: 15.6%, 4: 33.7%, 5: 22.9%	1074
Burden of carrying bags(1 item)		
My child has too much to carry.	1: 34.5%, 2: 19.5%, 3: 20.2%, 4: 18.1%, 5: 7.6%	1054
Crime		
No. of crimes within 100 feet of an HTS route buffer per acre	Mean: 1.38, SD: 2.61	1130
Intersection		
No. of intersections within 100 feet of an HTS route buffer	Mean: 3.91, SD: 1.70	1130
Bike lanes		
Presence of bike lanes within 100 feet of an HTS route buffer	0: Absence (50.4%), 1: Presence (49.6%)	1130
Tree canopy		
Percentage of tree canopy within 100 feet of an HTS route buffer	Mean: 11.47, SD: 5.50	1130
Free or reduced lunch service	0: No, 1: Yes, reduced price or free lunch	
Does your child qualify for special school lunch programs?	0: 21.9%, 1: 78.1%	1026
Car	No. of cars in household	
	Mean: 1.58, SD: 0.80	1051
Language (Spanish)	0: No (English or others), 1: Yes, Spanish	
What language do you use most often at home?	0: 52.1%, 1: 47.9%	1045
Distance	Network distance (meter)	
	Mean: 514.95 (0.32 miles), SD: 181.19 (0.11 miles)	1130
ATS (Active travel to school)	0: Non-ATS (27.4%) 1: ATS (72.6%)	1114

6.3.3 SEM 1: Safety Concerns

Figure 29 shows the results from the safety concern SEM model (n = 814) in which three latent variables were utilized: positive attitudes, social support, and parental safety concerns. The model fit indices demonstrated that this safety concern SEM model successfully accounted for the relationships among the study variables (CFI = 0.931, RMSEA = 0.048, SRMR = 0.049) (L. T. Hu & Bentler, 1995; Kenny, 2011).

Table 21 only shows the structural paths linked to the parental safety concerns (mediator) and ATS (outcome). In terms of the measurement paths, five observed variables regarding positive attitudes about walking were successfully and positively loaded to the "*positive attitudes*" latent factor. Further, four observed and eight observed variables were also positively loaded to the "*social support*" and "*parental safety concerns*" latent factors respectively.

In terms of the structural paths, the *parental safety concerns* latent factor utilized as a mediator was negatively associated with ATS (Coef. = − 0.17, $p<0.001$). Therefore, the coefficient of any structural paths linked through the *parental safety concerns* latent factor should be multiplied by the coefficient of this latent factor to accurately estimate the magnitude of association with ATS (StataCorp, 2013). The *social support* latent factor was associated with decreased parental safety concerns (Coef. = − 0.19, $p < 0.001$) and was indirectly associated with an increased likelihood of ATS (− 0.19 * − 0.17 = 0.03). The four objectively measured environmental variables used individually as observed variables were only associated with parental safety concerns, not with ATS. A higher number of intersections and number of crimes had direct associations with increased parental safety concerns and thereby indirectly decreasing the probability of ATS, while the presence of bike lanes and greater tree canopy coverage had a direct association with decreased parental safety concerns and indirectly increased the probability of ATS.

The distance variable was associated with decreased ATS only, with no significant relationship with parental safety concerns. The Spanish and number of cars observed variables were also directly associated with ATS, showing positive and negative directions to ATS respectively (Coef. = 0.11, $p = 0.001$ for Spanish language, Coef. = − 0.12, $p < 0.001$ for cars).

Table 21
Structural Equation Model for Safety Concerns Mediator

Structural paths	Standardized Coef.	SE	P>|z|	95% CI Lower	95% CI Upper
Active travel to school ←					
Safety concerns	− 0.17	0.03	0.000	− 0.23	− 0.10
Positive attitudes	0.41	0.04	0.000	0.34	0.48
Spanish language	0.11	0.03	0.001	0.05	0.17
Number of cars	− 0.12	0.03	0.000	− 0.18	− 0.06
Distance	− 0.17	0.03	0.000	− 0.23	− 0.11
Safety concerns ←					
Social support	− 0.19	0.04	0.000	− 0.27	0.11
Intersections (no. of intersections)	0.11	0.04	0.003	0.04	0.18
Crime (no. of crimes related to sexual assault and kidnapping)	0.07	0.04	0.056	0.00	0.14
Bike lanes (presence)	− 0.07	0.04	0.076	− 0.14	0.01
Tree canopy (percentage)	− 0.19	0.03	0.000	− 0.26	− 0.12

N = 814, CFI = 0.931, RMSEA = 0.048, SRMR = 0.049
CI: confidence interval, Coef.: coefficients, SE = standard error

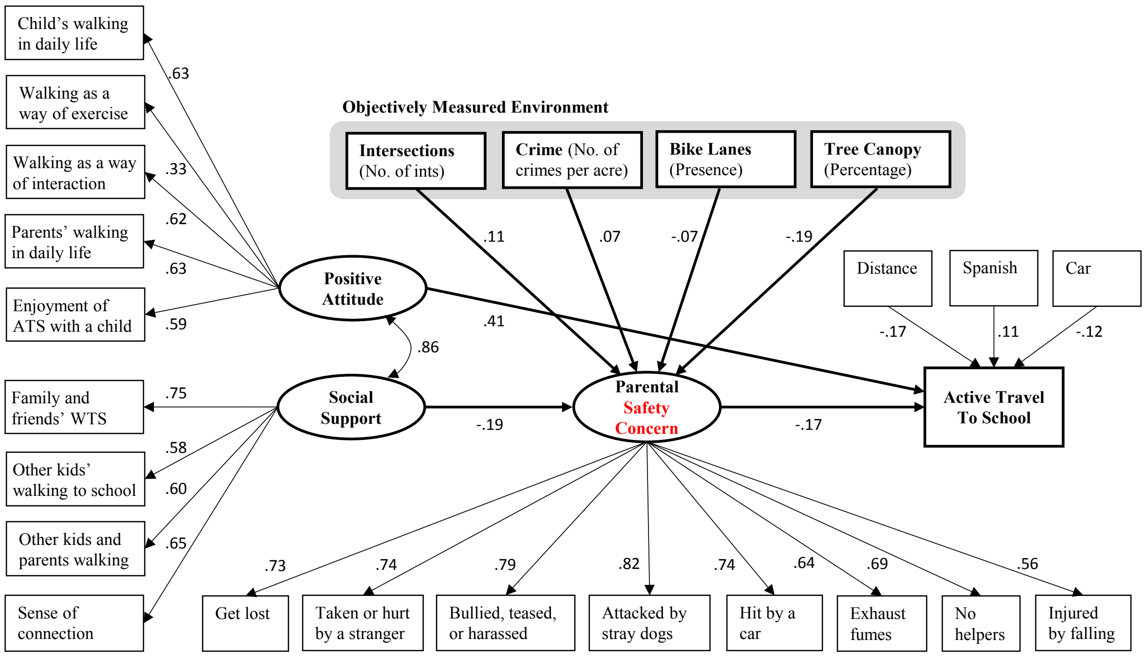


Figure 29
Structural Equation Model with Safety Concerns Mediator

6.3.4 SEM 2: Thermal Comfort Concerns

Table 22 and Figure 30 show the results from the thermal comfort concern SEM model (n = 872) in which one latent factor related to positive attitudes and twelve observed variables were utilized. The CFI, RMSEA, and SRMR from this weather concerns SEM model were 0.931, 0.048, and 0.049 respectively, which indicates a reasonable model fit.

The *positive attitudes* latent factor which consisted of the five observed variables was directly associated with increased ATS. Since the *parental thermal comfort concerns* latent factor was also negatively associated with ATS (Coef. = − 0.08, p=0.013), all the paths linked to the parental concern variable should be multiplied by the coefficient to account for the associations with ATS.

Among the objectively measured built or natural environment variables, only the tree canopy coverage variable was associated with a decreased level of parental thermal comfort concerns, and thereby increasing the probability of ATS (− 0.08 * − 0.08 = 0.01). Further, the objectively measured tree canopy variable was significantly correlated with parental perceptions of tree shade in their neighborhoods (Coef. = 0.15, p<0.001). The perceived shade variable was also negatively associated with the *parental thermal comfort concerns* latent factor (Coef. = − 0.12, p<0.001), leading to increase in the probability of ATS (− 0.12 * − 0.08 = 0.01). Among parental perceived behavior variables, a survey item related to children having too much to carry while commuting to/from school was positively associated with parental thermal comfort concerns (Coef. = 0.50), and thereby decreased the likelihood of ATS (0.50 * − 0.08 = 0.04).

The objectively measured distance variable was directly associated with parental thermal comfort concerns and ATS, showing a positive and negative relationship respectively (mediator: 0.09, $p = 0.001$; ATS: − 0.19, $p < 0.001$). Further, lower income parents whose children received free or reduced lunch service at school had a greater concern for weather than higher income parents (Coef. = 0.15, $p < 0.001$), and their children were less likely to engage in ATS (direct coef. = − 0.07, $p = 0.026$, indirect coef. = 0.15 * − 0.08 = − 0.01). A higher number of cars was associated with decreased ATS.

Table 22
Structural Equation Model for Thermal Comfort Concerns Mediator

Structural paths	Standardized Coef.	SE	P>z	95% CI	
				Lower	Upper
Active travel to school ←					
Thermal comfort concerns	− 0.08	0.03	0.013	− 0.14	− 0.02
Positive attitudes toward walking	0.36	0.04	0.000	0.28	0.44
Free or reduced lunch	− 0.07	0.03	0.026	− 0.13	− 0.01
Number of cars	− 0.14	0.03	0.000	− 0.20	− 0.08
Distance	− 0.19	0.03	0.000	− 0.25	− 0.14
Thermal comfort concerns ←					
Tree canopy (percentage)	− 0.08	0.03	0.012	− 0.14	− 0.02
Perceived tree shadiness	− 0.12	0.03	0.000	− 0.17	− 0.06
Perceived burden of carrying bags	0.50	0.02	0.000	0.46	0.55
Free or reduced lunch	0.15	0.03	0.000	0.10	0.21
Distance	0.09	0.03	0.001	0.04	0.14
Perceived tree shadiness ←					
Tree canopy (percentage)	0.15	0.03	0.000	0.09	0.22

N = 872, CFI = 0.950, RMSEA = 0.046, SRMR = 0.044
Coef.: coefficients, SE = standard error

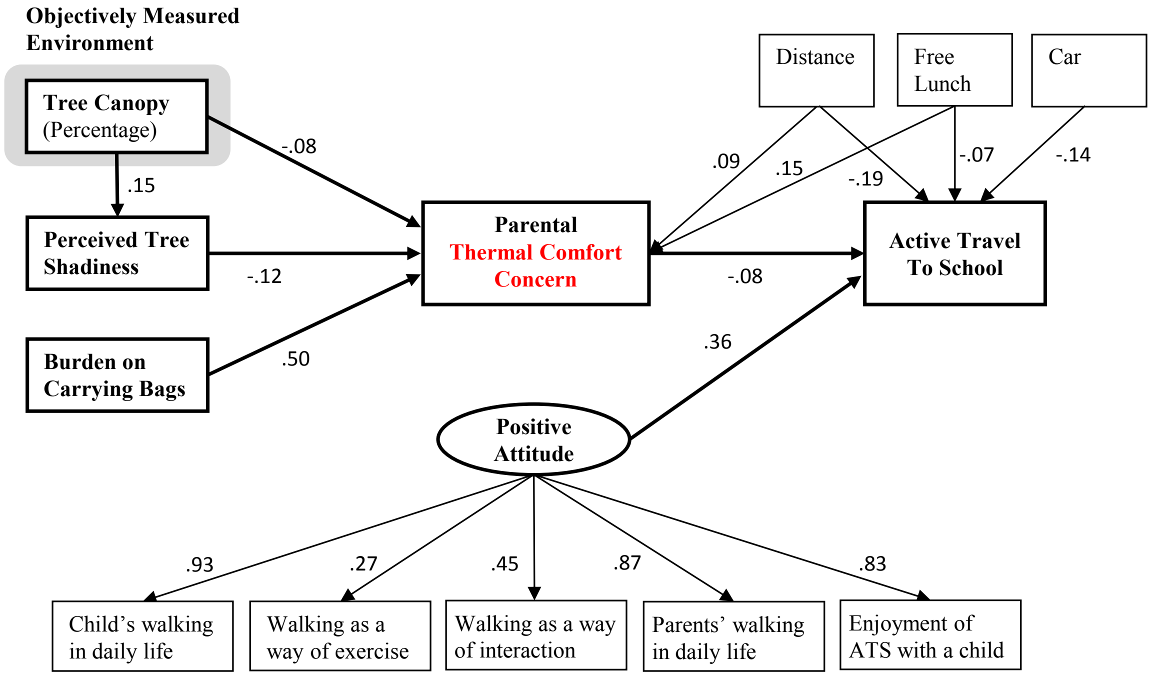


Figure 30
Structural Equation Model with Thermal Comfort Concerns Mediator

6.4 CONCLUSIONS AND DISCUSSION

This study examined the mediating roles of parental safety and thermal comfort concerns which were the most significant perceived barriers to children's ATS after the home-to-school distance factor, and utilized the objectively measured built and natural environmental variables that might affect both parental concerns and ATS, controlling for personal attitudes, social support, socio-economic status, and HTS distance. The SEM models were estimated separately for parental safety concerns and thermal comfort concerns used as a mediator between the built/natural environment-ATS relationship in each model. Based on the findings from this study, several personal, social, and environmental interventions related to parental safety and thermal comfort concerns and

ATS are discussed in the following sections. Table 23 shows the similarities and differences in the latent and observed variables related to the two mediators and the main outcome which is ATS.

Table 23
Similarities and Differences in the Latent and Observed Variables Used for the Safety and Thermal Comfort Concerns SEM Models

Significant in both ***safety and thermal concerns***	Significant for ***safety concerns*** only	Significant for ***thermal comfort concerns*** only
▪ Positive attitudes → ATS (+)	▪ Social support → safety concerns (−)	▪ Perceived tree shadiness → thermal comfort concerns (−)
▪ Tree canopy → safety and thermal comfort concerns (−)	▪ Intersections → safety concerns (+)	▪ Perceived burden of carrying heavily loaded back packs → thermal comfort concerns (+)
▪ Car → ATS (−)	▪ Crime → safety concerns (+)	▪ Distance → thermal comfort concerns (+)
▪ Distance → ATS (−)	▪ Bike lanes → safety concerns (−)	▪ Free or reduced lunch → thermal comfort concerns (+) & ATS (−)
	▪ Spanish → ATS (+)	

Findings from the SEM models suggest the importance of parental perceived safety and thermal comfort concerns as important mediators between the environment-ATS relationship. Improving safety conditions by providing more bike lanes and improving crime safety appear important in order to decrease parental safety concerns which appear necessary as a prerequisite for ATS promotion. In this study, a higher number of intersections, which show a higher street connectivity in an area increased parental safety concerns. One possible reason may be because the area with a higher street connectivity features higher traffic volumes and more crossings. A higher connectivity helps increase adults' walking as many previous studies found (Badland & Schofield, 2005; Saelens & Handy, 2008), but it may create an impediment to children's walking or biking due to a high traffic volume and multiple crossings that increase chances for children to cross over car roads. Further, multiple stop signs generally seen in an area with a higher street connectivity may also prevent children's walking and biking. Tree canopy had a significant impact on both safety and thermal comfort concerns, and therefore planting trees especially those with significant canopy coverage and keeping them healthy can help reduce parental perceptual barriers to ATS and lead to increased ATS. This study also found that parental concerns about their children having to carrying heavy items for school hindered ATS indirectly through its influence on thermal comfort concerns. Therefore, strategies to reduce the need for the children to carry heavy items may be important in influencing parental decisions on school commute mode.

In this study, positive walking attitudes and perceived benefits from walking showed a direct relationship with ATS in both the safety and thermal comfort SEM models, and they were not subject to the meditating effects of parental safety and thermal comfort concerns. Therefore, interventions focusing on promotional/training events related to pedestrian safety skills and education programs on benefits of ATS appear important. Further, based on the result of the positive role of social support, providing parents with chances to serve in a community will create a social cohesion that makes them feel connected to people in their neighborhood and safe enough for pleasant walking as well. A volunteer program such as "Walking School Bus" which requires one or more adults to escort small groups of children by walking with them to or from school can be an example of how parents can serve in a community.

In both parental safety and thermal comfort concerns models, the long home to school distance was a strong barrier to ATS even though this study focused on respondents who lived within a half mile of school.. In terms of the associations of longer distance with parental concerns of safety and thermal comfort, this study revealed that longer distance was only associated with increased parental thermal comfort concerns, but was not associated with safety concerns. Therefore, planting more trees or landscaped buffers in neighborhoods within a walkable distance from school will be effective in decreasing parental weather concerns. Among the socio-economic status variables, the number of cars variable was negatively associated with ATS in both parental safety and thermal comfort concerns SEM models, while Spanish language was positively associated with ATS in the safety concerns model only. Further, this study also identified that parents whose children were qualified for free or reduced school lunch service had greater thermal comfort concerns and their children were less likely to engage in ATS. It may be associated with the current natural environmental risks that were more focused on low-income people (tree canopy within HTS route buffer: 10.3% for low-income vs. 15.8% for high-income). Therefore, natural environmental interventions targeting the neighborhood where minority or low income people live appear more promising.

This study also has several limitations. First, while parental safety concerns were measured by eight specific items and used as a latent variable, parental thermal comfort concerns were measured by only one survey item used as an observed variable. Thus, future studies need to consider various characteristics related to thermal comfort concerns. For example, perceived quantity or quality of grass or trees en route, perceived shadiness en route, and the status of the sidewalk surface's reflection can be used as subordinate survey items related to weather concerns. Second, this study was a cross-sectional study and thus the causality between objectively measured environment and ATS cannot be established. However, this study considered parental safety and thermal comfort concerns used as mediators between the environment-ATS relationship, and attempted to relieve this limitation by employing a SEM model because SEM has a capability of supporting causal inference among study variables (Bollen and Pearl 2013). Last, this study mainly focused on objective environmental measures, dealing less with subjective measures. One of the reasons was that environmental perception latent factors consisting of several observed survey items became endogenous when adding a path from objectively measured observed variables. That was because both subjective and objective measures cannot be linked to each other when they are connected to the same parental concerns. To solve this limitation, the objective measures should only be linked to the subjective measures. Thus, for a more specific investigation of parental concerns in the relationship between objective environmental measures and ATS, future studies need to consider the actual objective measures that only affect subjective measures, not linking directly to the mediators.

In sum, findings from this study confirmed that parental safety and thermal comfort concerns played a mediating role in the relationship between the built/natural environment and ATS. Providing safer and greener environmental conditions en route can lead to a decrease in parental safety and thermal comfort concerns and thereby contribute to promoting children's ATS. This research in return will help guide the development of intervention strategies to relieve parental safety and thermal comfort concerns, and encourage their children to have a more active means of transportation to and from school.

7. CONCLUSION AND DISCUSSION

This dissertation research is one of the first attempts to examine the correlates of parental safety and thermal comfort concerns, which have not been sufficiently examined in previous studies, despite their significant roles as barriers to children's active school travels. This study also probed into the varying roles of home-to-school (HTS) distance ranges and of the impacts of built versus natural environmental elements on children's active travel to school (ATS). Furthermore, by focusing on the sub-samples of students living within a walkable distance from school, this study examined the mediating effects of both parental safety and thermal comfort concerns in the environment-ATS relationship. Findings from this study shed new light on the existing body of literature and can guide the development of effective interventions from both policy and planning aspects to promote children's active travel to school behaviors.

7.1 CONCLUSION

Section 4 included with two main results, including the built and natural environmental correlates of parental safety concerns and of parental thermal comfort concerns. In terms of parental safety concerns based on the ordinary-least square regression models, the presence of highways, railroads, bike lanes, sex-offenders, water features, and steep slopes increased parental safety concerns, while higher intersection density and more tree canopy decreased parental safety concerns. Among them, bike lanes (+) and intersection density (−) seemed to be counter-intuitively related to the outcome. However, it might be associated with the unsafe conditions of bike lanes built within vehicular roadways and often along major arterials with high traffic volume and speed and with the notion that some bicyclists can be aggressive and perceived as threats to child pedestrians/bicyclists, both of which can lead to increasing parental safety concerns. Furthermore, areas with high street connectivity are often with high development density and previous studies indicated that people are more likely to walk in high residential density or urban area than in low density or rural areas (Mota et al., 2007; Panter et al., 2010b), which can increase natural surveillance contributing to reduce parental safety concerns. In terms of parental thermal comfort concerns based on the stereo-type logistic regression models, this study showed that the presence of playgrounds, higher intersection density, and more tree canopy appeared to be significantly associated with decreased parental concerns of thermal comfort. Because of the multicollinearity problem, several natural variables, including urbanized areas, NDVI, and tree heights, were not utilized in the final model. In one-by-one models testing one variable at a time controlling for other covariates, however, those variables were all significantly associated with the outcome: urbanized area (+, increased thermal comfort concerns), greenery captured as NDVI (−, decreased thermal comfort concerns) , and tree heights (−).

In Section 5, built and natural environmental correlates of ATS and varying roles of distance ranges in hindering ATS were identified using mixed-effects logistic regression models. Based on the results from the fully adjusted regression model, the presence of bike lanes and playgrounds among the built environmental variables and the presence of parks and higher tree heights among natural environmental variables were positive correlates of ATS while the presence of highways, higher crash hotspots, and higher percentage of steep slopes greater than 8.33% among the natural environmental variables were negative correlates of ATS. This study also showed interesting findings in terms of the varying roles of HTS distance ranges in promoting or hindering ATS. The probability of ATS decreased in accordance with the increase of HTS distance ranges, but the magnitude of its negative relationship disappeared at the ≥ 1.5 miles distance range.

Furthermore, regular regression models estimated separately for each of the four distance ranges examined the potentially different relationships of built/natural environment variables with ATS across four distance ranges. The presence of playgrounds (+), parks (+), crash hotspots (−), and steep slopes greater than 8.33% (−) were significant correlates of ATS in the shorter distance ranges (0≤0.49 miles or 0.5≤0.99 miles) while the presence of highways was significantly associated with ATS at 1≤1.49 miles (+) and ≥1.5 miles (−). Furthermore, tree canopy was significant at 0.5≤0.99 miles (+, increased odds of ATS) and ≥1.5 miles (−, decreased odds of ATS). One explanation for the inconsistent results of the tree canopy variable across different distance thresholds can be because of the likelihood that residential areas far from schools tend to be less dense, primarily single family and possibly subdivisions. Or, it can be explained with the income issue that children living far away from school and whose parents are higher income are less likely to engage in ATS even though their neighborhoods along the routes have taller trees that provide pleasant and cool walking environments. Sidewalks at 1≤1.49 miles and bike lanes at 0.5≤0.99 miles and 1≤1.49 miles acted as significant facilitators of ATS. Thus, this study revealed that the impacts of built and natural environmental variables on ATS vary depending on the different HTS distance ranges.

Section 6 included the results of two SEM models estimating the mediating effects of parental safety concerns and of thermal comfort concerns in built/natural environments-ATS relationships. In the safety concern SEM model, indirect paths relating to ATS but through its relationship with safety concerns included social support (+), intersections (−), crime (−), and bike lanes (+). In the thermal comfort concern SEM model, perceived tree shadiness (+) and the burden of carrying heavy bags (−) were indirectly associated with ATS through its relationship with thermal comfort concerns. In both SEM models, tree canopy appeared to directly lessen the safety and thermal comfort concerns and thereby indirectly promote ATS. Furthermore, positive attitudes increased the prevalence of ATS directly in both SEM models

7.2 IMPLICATIONS AND CONTRIBUTIONS

7.2.1 Contributions to Research

This dissertation research contributes to advancing the urban planning and public health in several aspects in that it adds new knowledge to previous studies and provides fundamental and novel thoughts for future studies and effective interventions for ATS.

First, with respect to parental perceived barriers to children's ATS, this study focused on safety and thermal comfort concerns which were the most significantly reported barriers to ATS, after the distance factor, among parents in national surveys conducted by the CDC in 2002 and 2005 (Centers for Disease Control and Prevention, 2002, 2005). Despite the important roles of affecting children's ATS, how they can be controlled or improved have not been explored because parental safety concerns were utilized as one of the predictors of ATS and the thermal comfort concept has never been dealt with in previous studies. This study examined these two understudied barriers as the main outcome variables and identified their environmental correlates as reported in Section 4 and in the summary of the conclusion mentioned above. More studies are needed to further consider these two perceived barriers in terms of their roles for other outcome variables such as outdoor play or physical activities and to further examine detailed built environmental characteristics across different community settings that can help reduce safety and thermal concerns.

Second, this research focused on modifiable built and natural environmental conditions that potentially affect parental safety and thermal comfort concerns, as well as children's ATS. Its focus on modifiable environmental variables can facilitate practical implications, ranging from policies, environmental interventions, and design and development practices. Such implications may hold true for a potentially large number of communities sharing similar characteristics to the communities in this study. Furthermore, the new information on the roles of the natural environment might shine a light on the larger relevant issues that have thus far been insufficiently considered. Such issues could include climate change, urban heat islands, heat-related health problems, and the restorative values of the natural environment.

Third, to address more details of the relationship between HTS distance and ATS, this study assumed a nonlinearity of the HTS distance variable by utilizing mixed-effects *spline* logistic regressions, which has never been dealt with in previous studies. That is, the regression line representing the relationships between HTS distance and ATS are broken into several linear segments by the HTS distance ranges: ≤0.49 miles, 0.5 to ≤0.99 miles, 1 to ≤1.49 miles, and ≥1.5 miles. It generates four different HTS distance variables representing each distance range, and therefore it is possible to detect the variations of the odds of ATS among the four HTS distance ranges. This study revealed that the probability of ATS decreased dramatically after 1 mile and no significant relationship was found beyond 1.5 miles (OR=0.68, $p<0.001$ for 0≤0.49 miles, OR=0.81, $p<0.001$ for 0.5≤0.99 miles, OR=0.94, $p=0.031$ for 1≤1.49 miles, and OR=1.00, $p=0.680$ for ≥1.5 miles). This finding raised an important need to re-assess the validity of the current school bus service eligibility that is available only for children living beyond 2 miles from their school in Texas.

Fourth, in addition to the varying role of HTS distance itself in different HTS distance ranges, this study compared the effects of the built and natural environments on children's ATS, considering varying distance ranges. By conducting mixed-effects logistic regression modeling (non-spline regressions) for each of the four distance ranges, four different regression models were generated. Findings from this study showed the different roles of the built and natural environments in affecting children's ATS behaviors by four distance ranges. Such key differences of the variables associated with ATS across the HTS distance ranges indicated that (1) highways (−) at ≥1.5 miles and steep slopes (-)at 0.5 to ≤0.99 miles, (2) inconsistent effects of tree canopy (+) at 0.5 to ≤0.99 miles, but (−) at ≥1.5 miles, (3) play grounds (+) at ≤0.49 miles only, (4) crash hotspots (-) at ≤0.49 miles and 0.5 to ≤0.99 miles, (5) bike lanes (+) at 0.5 to ≤0.99 miles and 1 to ≤1.49 miles, and (6) sidewalks at 1 to ≤1.49 miles only. This finding shows the need for different intervention strategies to promote ATS across different distance ranges.

Fifth, a structural equation model (SEM) was utilized to examine the direct and indirect relationships among study variables and the mediating effects of parental safety and thermal comfort concerns in the environments-ATS relationships. It provided a comprehensive assessment of target environmental factors with their direct and indirect roles associated with children's ATS. This adds to the previous research that has mainly focused on the direct relationships of the built environments with ATS. Furthermore, to accurately examine the effects of built and natural environments on ATS, this study focused on children living within a walkable distance (0.5 miles) from their schools and compared the relative importance of built environmental variables that are related to parental safety and thermal comfort concerns and ATS. This study showed an interesting finding in that all the built and natural environmental variables were indirectly associated with ATS through its relationship with parental safety and thermal comfort concerns, which was consistent with an earlier analysis that focused on safety concerns utilizing the same dataset (C. Lee & Kim, 2012). In both SEM models, objectively-measured tree canopy appeared to be directly associated with decreased parental safety and thermal comfort concerns first, and thereby promote ATS indirectly. While the following built environmental variables, including intersection density (+, safety concerns), crime density (+), and bike lanes (−) were directly associated with parental safety concerns, the following perceived tree canopy (−, thermal comfort concerns) and perceived burden of carrying heavy bags (+) were proven to be direct determinants of parental thermal comfort concerns. Furthermore, in both SEM models, positive attitudes toward walking directly increased the prevalence of ATS. Findings from this study suggest that for those living within a walkable distance, addressing parental safety and thermal comfort concerns is the necessary prerequisite for achieving increased ATS.

Six, this study contributed to understanding the disproportionately distributed environmental risks that were focused on low-income people. From comparison tests conducted by chi-squared and analysis of variance tests among the built and natural environmental variables between low- and high-income households, lower income children were more likely to face unsafe built environmental conditions (such as less sidewalks and bike lanes, more crime and crash hotspots, more highways and railroads, and higher speed limits) and thermally unpleasant/hot environmental conditions (such as a small number of parks, more urbanized areas, less tree canopy, higher air temperatures, lower NDVI/greenery, and shorter trees).

7.2.2 Implications for Environmental and Policy Interventions

This dissertation research brought important issues that need to be considered for promoting children's ATS, including major parental perceived concerns of safety and thermal comfort, as well as modifiable and feasible built and natural environmental elements. This study highlights eight key environmental and policy interventions. The following suggestions are drawn from the findings of this study, which can be helpful for policy makers, planners, school administrators, and engineers, who are interested in encouraging ATS and building a safe and healthy environment for families and children.

1. Bike lanes and sidewalks separated from car roads

This study showed an interesting finding in terms of bike lanes in that a higher proportion of bike lanes along the HTS routes increased parental safety concerns. It may be associated with the current conditions of bike lanes that are located directly along car roads without any buffer space. Children lack the ability to recognize dangerous situations that they might become involved in and often they have to bike to school along with moving vehicles. Thus, bike lanes need to be separated from vehicular traffic lanes with physical demarcations (e.g., landscaped buffers (trees or grass) or parked cars, etc.). Designing bikeways with this idea can increase children's confidence in walking or biking as a safe and comfortable travel mode. Regarding bike lanes associated with ATS, this study showed that bike lanes played a role as a facilitator of ATS (based on the spline regressions). Furthermore, the results based on the non-spline regression models (four different regression models by HTS distance ranges) indicated that increasing bike lanes works more efficiently at 0.5≤0.99 miles and 1≤1.49 miles to promote ATS.

Consistent with the finding from previous studies (Dalton et al., 2011; Ewing et al., 2005; Ewing et al., 2004; Fulton et al., 2005), this study confirmed the positive role of sidewalks in inducing more children to engage in ATS. Furthermore, this study revealed that more sidewalks within the HTS routes were associated with decreased parental safety concerns. This study also found that installation of sidewalks for the 1 to

≤1.49 miles distance range had a significant potential in maximizing its positive role in promoting ATS. More than just enlarging the amount of sidewalks itself, designing streets with sidewalks in accordance with a human scale, buffering pedestrian sidewalk areas from vehicle traffic, and expanding sidewalk width enables more children to participate in ATS safely and comfortably (Landis, Vattikuti, Ottenberg, McLeod, & Guttenplan, 2001).

2. Trees to reduce safety and thermal comfort concerns and promote children's ATS

Confirming the positive role of trees in promoting children's ATS as one previous study found (Larsen et al., 2009), this study also provided a new knowledge regarding its relationship with parental perceived concerns of safety and thermal comfort. Based on the results of Study 1 (Chapter 4) estimating predictors of those concerns, a higher proportion of tree canopy along the HTS routes were significantly associated with both decreased parental safety concerns and parental thermal comfort concerns. In another study of this dissertation research examining the mediating effects of those concerns in environment-ATS relationship, which focused on children living within a walkable distance, the tree canopy variable was directly associated with decreased safety and thermal comfort concerns, and indirectly associated with children's ATS. Regarding the direct impacts of tree canopy on ATS, the mixed-effects spline logistic regression model results showed positive associations between tree heights and children's ATS. In addition, the results from the distance-specific analyses suggested that having more trees in areas about 0.5 to 1 miles from school could help increase more students walk or bicycle to school, but is not expected to make any difference beyond 1.5 miles. Therefore, policy makers and planners may consider promoting safety and thermal comfort by planting more canopy trees especially in areas that are a bit further away from school but still walking is possible, to increase the likelihood of successfully increasing students who engage in ATS. It is important to consider trees and other green landscape materials as part of key street infrastructure elements, because they can contribute to providing shade, visual interest, and increasing safety serving as buffers protecting and separating pedestrians from moving vehicles.

3. Latent active travelers within a one mile radius buffer from school

Based on the samples of this study, the majority (72.6%, n=809 out of 1,114) of students living within 0.49 miles of their school were active travelers, and about 40% of students living at 0.5-0.99 miles walked and bicycled to school. The number of active travelers beyond one mile, however, dramatically decreased to 14.9% at 1-1.49miles and 8% at 1.5+ miles. Furthermore, among all active travelers (n=1,568), a substantial percentage of them (88.3%, n=1,384) lived within one mile (≤0.49 miles: 51.6%, n=809; 0.5 to ≤0.9 miles: 36.7%, n=575). This finding implies that there are many potential active travelers within 1 mile. This is supported by the results based on the mixed-effects non-spline logistic regression models (four different regressions by distance ranges) that the negative relationship of the HTS distance variable with ATS appeared to be insignificant beyond one mile. This finding was consistent with the results (insignificant relationship between HTS distance and ATS beyond one mile) of a previous study utilizing 614 students aged 5 to 18 living in Alameda County (N. C. McDonald, 2007). Thus, policies or state-level initiatives such as Safe Routes to School programs need to focus on those living within one mile from school. Furthermore, one can take advantage of the implications of school siting at the community level that allows people to be close enough to school to walk or bike.

4. School bus service policies responding to walkable distances

The results of the spline-regression analysis showed that the probability of ATS dramatically decreased in a uniform manner until one mile, slightly decreased at the 1 to ≤1.49 miles range, and then no longer significant relationship between HTS distance range and ATS was found beyond 1.5 miles. This indicates that beyond 1.5 miles, distance no longer has any significant impact on children's ATS behaviors and ATS is not a viable option, and therefore alternative modes like school buses and private cars are required. This finding suggests the need for reducing the school bus service eligible boundary from the current 2+ miles to 1.5 miles so that more children can use the school bus service instead of being driven in their parents' car.

5. Crash-safety by physical design measures near schools

Based on the results of Study 2 (Chapter 5) examining the direct relationships between built/natural environments and ATS, it was an interesting finding that among traffic and crime variables, pedestrian- and bike-related crash hotspots were more importantly associated with children's ATS. Therefore, tailored traffic management strategies are needed to reduce the actual pedestrian- or biker-related crash incidents for the safety of children walking or biking to school. Installing traffic calming devices, school crosswalks, medians, and pedestrian safety signs can help control traffic volume and speed near schools and thereby improve the overall pedestrian experience and safety. Furthermore, this study revealed that crash hotspots impeded the prevalence of ATS at the ≤0.49 mile and the 0.5 to ≤0.99 mile HTS distance ranges. Therefore, the crash safety-related interventions require high priorities especially in areas immediately around and near the schools.

6. Playgrounds and parks around schools

This study found a potential role of playgrounds and parks in promoting not only safety/thermal comfort perceptions but also children's ATS. In Study 4 (Chapter 4), the presence of playgrounds decreased thermal comfort concerns and the presence of parks decreased both safety and thermal comfort concerns. Playgrounds and parks are the places where children and families can play, engage in physical activity, and have social interaction with neighbors (I. Fjørtoft, 2004; Roemmich et al., 2006). Because of the nature of playgrounds and parks as places where people gather, the places have higher visual surveillance and can improve safety of pedestrians walking on nearby streets. For more practical implications of utilizing playground and park resources, this study highlights the potentially higher effectiveness of building playgrounds near schools within a half mile area and parks at about a half to one mile distance from schools.

7. Educational/promotional events and social participation events

This study also highlights important issues related to personal attitude toward walking and social support, indicating the need for educational/promotional and social participation events to successfully promote ATS. Based on the results of the positive role of walking attitudes in promoting ATS in Study 3, educating parents and children about the mental and physical benefits from being physically active and about safety in walking or biking to school will be helpful in improving parents' and children's walking attitudes and increasing motivation for ATS. Furthermore, this study showed that social support (i.e., seeing many people walking around the neighborhood) and social connectivity in a neighborhood were associated with decreased parental safety concerns, and may promote children's ATS. In this vein, it will be a good strategy for joining parents or families in neighborhood community events or community organizations so that they can contribute to their community. The "Walking School Bus" program can be an example of doing so (Kearns, Collins, & Neuwelt, 2003; Kingham & Ussher, 2007). While parents or guardians form children into groups and escort them to school by walking together, neighbors will have opportunities to interact with their neighbors and other children and to feel it is safe enough to walk within neighborhoods and to let their child walk to school. Furthermore, grouping children and walking together to school will increase driver awareness and it helps drivers abide by crosswalk laws more completely (Kingham & Ussher, 2007).

8. Additional efforts needed for low-income children

The comparison analysis of built and natural environmental risks between low- and high-income children generated an important issue that environmental risks hindering health-related behaviors were more concentrated in areas where low-income children lived. Furthermore, this study indicated that low-income parents had higher safety and thermal comfort concerns for their children's ATS. Given the common finding that low-income people are more likely to walk to school due to less available car-ownership (Larsen et al., 2009; Martin et al., 2007; N. C. McDonald, 2007, 2008b), the findings from this study imply that more through and careful attention and efforts toward reducing the disproportionate distributions of resources and features supporting rather than hindering healthy lifestyles must be provided to low-income people.

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APPENDIX A

A-1) Descriptive Statistics (based on 100feet home-to-school route buffer)

Descriptive Statistics and Bivariate Tests of Built and Natural Environmental Variables by Income Status (based on 100feet home-to-school route buffer)

Built environmental variables	Description (Neighborhood area within a child's home buffer)	Total Freq. Mean	Total % (SD)	Low income Freq. Mean	Low income % (SD)	High income Freq. Mean	High income % (SD)	Bivariate test: Test	Bivariate test: Sig.
Built Environmental Variables									
Bike lanes (ratio)	Length of bike lanes divided by total street length	0.28	(0.31)	0.30	(0.32)	0.24	(0.26)	T	<.001
Sidewalks (ratio)	Length of sidewalk lanes divided by total street length	0.71	(0.19)	0.69	(0.19)	0.74	(0.18)	T	<.001
Crime – hotspot	Average z-scores of crime hotspots	0.02	(0.78)	0.39	(0.62)	-0.67	(0.58)	T	<.001
Crash – hotspot	Average z-scores of crash hotspots with total crashes	1.08	(3.91)	2.63	(3.33)	-1.84	(3.20)	T	<.001
Crash – ped./bi. hotspot	Average z-scores of crash hotspots based on pedestrian- and biker-related crashes	0.69	(3.85)	1.89	(3.63)	-1.58	(3.16)	T	<.001
Playgrounds (presence)	Presence of playgrounds	104	2.7	92	3.6	12	0.9	χ^2	<.001
Intersections – density	Number of intersections per acre	0.47	(0.14)	0.49	(0.14)	0.44	(0.14)	T	<.001
Highways (presence)	Presence of highways	771	19.9	443	17.5	328	24.4	χ^2	<.001
Railroads (presence)	Presence of railroads	402	10.4	222	8.8	180	13.4	χ^2	<.001
% of high speed streets	Percentage of streets with speeds over 30 mph	66.59	(25.52)	70.17	(22.91)	59.85	(28.66)	T	<.001
Natural Environmental Variables									
Parks (%)	Total area of parks divided by neighborhood area*100	2.98	(4.38)	2.60	(4.42)	3.71	(4.21)	T	<.001
Parks (presence)	Presence of parks	2,490	64.1	1,407	55.4	1,083	80.4	χ^2	<.001
Water features	Presence of water features	918	23.6	673	26.5	245	18.2	χ^2	<.001
Mean slope	Average steep slope of neighborhood area	3.66	(2.37)	3.28	(2.15)	4.36	(2.58)	T	<.001
Steep slope > 5% (%)	Total area of slope greater than 5%, divided by neighborhood area*100	24.31	(24.87)	21.05	(25.06)	30.45	(23.32)	T	<.001
Steep slope > 8.33% (%)	Total area of slope greater than 8.33%, divided by neighborhood area*100	10.04	(15.76)	9.68	(14.63)	10.73	(17.67)	T	0.047
Urbanized coverage (%)	Total area of urbanized coverage divided by neighborhood area*100	42.63	(10.37)	44.92	(10.37)	38.33	(8.89)	T	<.001
Tree canopy (%)	Total area of tree canopy divided by neighborhood area*100	11.85	(5.83)	9.50	(4.47)	16.27	(5.51)	T	<.001
Grass coverage (%)	Total area of grass coverage divided by neighborhood area*100	10.89	(3.38)	10.70	(3.41)	11.25	(3.29)	T	<.001
Temperature (°C)	Average temperature in neighborhood area	31.34	(1.35)	31.38	(1.45)	31.24	(1.14)	T	0.002
NDVI (ranging from -1 to 1)	Average NDVI in neighborhood area	0.34	(0.07)	0.32	(0.07)	0.37	(0.06)	T	<.001
Tree heights (feet)	Average tree heights in neighborhood area	7.94	(3.56)	6.79	(2.87)	10.12	(3.72)	T	<.001

Note: Low and high income children were classified by a survey question of "free or reduced lunch service." If a child received the free or reduced school lunch service, the student was placed in the low income category.
Freq.: Frequency, SD: Standard deviation, T: T-test, χ^2: Chi-squared test

A-2) Descriptive Statistics (based on 1/2 mile home-to-school route buffer)

Descriptive Statistics and Bivariate Tests of Built and Natural Environmental Variables by Income Status (based on 1/2 mile home buffer)

Built environmental variables	**Description** (Neighborhood area within a child's home buffer)	Total		Low income		High income		Bivariate test	
		Freq. Mean	% (SD)	Freq. Mean	% (SD)	Freq. Mean	% (SD)	Test	Sig.
Built Environmental Variables									
Bike lanes (presence)	Presence of bike lanes	484	12.5	249	9.8	235	17.5	χ^2	<.001
Sidewalks (ratio)	Length of sidewalk lanes divided by total street length	0.82	(0.19)	0.80	(0.19)	0.86	(0.17)	T	<.001
Crime – hotspot	Average z-scores of crime hotspots	0.17	(0.99)	0.62	(0.84)	-0.66	(0.66)	T	<.001
Crash – hotspot	Average z-scores of crash hotspots with total crashes	1.07	(3.92)	2.51	(3.34)	-1.65	(3.46)	T	<.001
Crash – ped./bi. hotspot	Average z-scores of crash hotspots based on pedestrian- and biker-related crashes	0.50	(3.62)	1.49	(3.21)	-1.37	(3.60)	T	<.001
Playgrounds (presence)	Presence of playgrounds	514	13.2	363	14.3	151	11.2	χ^2	0.007
Intersections – density	Number of intersections per acre	0.15	(0.07)	0.15	(0.06)	0.16	(0.06)	T	0.003
Highways (presence)	Presence of highways	885	22.8	659	25.9	226	16.8	χ^2	<.001
Railroads (presence)	Presence of railroads	344	8.9	251	9.9	93	6.9	χ^2	<.001
% of high speed streets	Percentage of streets with speeds over 30 mph	48.79	(21.43)	54.50	(19.57)	38.04	(20.65)	T	<.001
Natural Environmental Variables									
Parks (%)	Total area of parks divided by neighborhood area*100	5.76	(9.03)	3.76	(6.26)	9.53	(11.82)	T	<.001
Parks (presence)	Presence of parks	2,785	71.7	1,613	63.50	1,172	87.01	χ^2	<.001
Water features	Presence of water features	1,161	29.9	816	32.1	345	25.6	χ^2	<.001
Mean slope	Average steep slope of neighborhood area	4.60	(3.27)	4.26	(2.76)	5.24	(3.99)	T	<.001
Steep slope > 5% (%)	Total area of slope greater than 5%, divided by neighborhood area*100	28.92	(25.38)	27.42	(25.37)	31.74	(25.17)	T	<.001
Steep slope > 8.33% (%)	Total area of slope greater than 8.33%, divided by neighborhood area*100	14.72	(19.88)	14.54	(18.01)	15.05	(22.98)	T	0.446
Urbanized area (%)	Total area of urbanized coverage divided by neighborhood area*100	33.77	(12.12)	37.59	(11.71)	26.60	(9.29)	T	<.001
Tree canopy (%)	Total area of tree canopy divided by neighborhood area*100	17.79	(7.98)	14.35	(6.02)	24.26	(7.16)	T	<.001
Grass cover (%)	Total area of grass coverage divided by neighborhood area*100	11.63	(3.61)	11.63	(3.68)	11.63	(3.49)	T	0.954
Temperature (°C)	Average temperature in neighborhood area	31.22	(1.55)	31.45	(1.58)	30.78	(1.39)	T	<.001
NDVI (ranging from -1 to 1)	Average NDVI in neighborhood area	0.37	(0.09)	0.34	(0.08)	0.43	(0.06)	T	<.001
Tree heights (feet)	Average tree heights in neighborhood area	10.91	(4.65)	9.29	(3.65)	13.94	(4.80)	T	<.001

Note: Low and high income children were classified by a survey question of "free or reduced lunch service." If a child received the free or reduced school lunch service, the student was placed in the low income category.
Freq.: Frequency, SD: Standard deviation, T: T-test, χ^2: Chi-squared test

APPENDIX B

B-1) Regression models (safety concerns)

Safety Concern Regression Models (based on 100 feet home-to-school route buffer)

Safety Concern (OLS regression)	One-by-one models[a]		Model 1		Model 2		Model 3	
	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|
Built environmental variables								
Bike lanes (ratio)	0.092	0.009	-0.279	0.007			0.107	0.058
Sidewalks (ratio)	-0.288	0.003	0.151	0.007			-	-
Playgrounds (presence)	-0.124	0.245	-	-			-	-
Intersections (density, num./acre)	-0.424	0.001	-0.343	0.005			-0.310	0.012
Highways (presence)	0.197	0.000	0.133	0.008			-	-
Railroads (presence)	0.209	0.000	0.102	0.094			0.108	0.074
High speed streets (>30mph) (%)	0.002	0.010	-	-			-	-
Crime – hotspot	0.135	0.000	0.141	0.000			-	-
Crash – hotspot	0.016	0.002	-	-			-	-
Sex offenders (presence)	0.194	0.000	0.135	0.008			0.147	0.004
Natural environmental variables								
Park (presence)	0.072	0.053			-	-	-	-
Water feature (presence)	0.242	0.000			0.198	0.000	0.132	0.004
Steep slope (degrees)	0.027	0.000			0.034	0.000	0.038	0.000
Urbanized area (%)	0.004	0.032			-	-	-	-
Tree canopy (%)	-0.020	0.000			-0.021	0.000	-0.021	0.000
Grass cover (%)	0.000	0.989			-	-	-	-
Surface temperature (%)	-0.025	0.051			-	-	-	-
Normalized Difference Vegetation Index (NDVI) (min: -1, max: 1)	-0.010	0.000			-	-	-	-
Tree heights (feet)	-0.023	0.000			-	-	-	-
Covariates								
Socio-demographic variables								
Student gender (male vs. ref. female)			-0.046	0.175	-0.047	0.162	-0.044	0.187
Student grade (ref. PK-K)								
1st – 3rd			-0.091	0.026	-0.085	0.037	-0.087	0.031
4th – 6th			-0.217	0.000	-0.218	0.000	-0.221	0.000
Free or reduced lunch (yes vs. ref. no)			0.083	0.131	0.077	0.132	0.080	0.121
Student ethnicity (ref. White)								
Hispanic			0.228	0.000	0.221	0.000	0.231	0.000
Others			0.031	0.630	0.019	0.775	0.019	0.771
Attitudinal/social variables‡								
Walking is a good way to exercise.			0.251	0.000	0.255	0.000	0.253	0.000
I walk quit often in my daily routine.			0.052	0.001	0.052	0.001	0.050	0.001
I (would) enjoy walking with my child to/from school.			-0.055	0.004	-0.056	0.003	-0.054	0.004
My family and friends like the idea of walking to school.			-0.045	0.015	-0.046	0.014	-0.044	0.017
Other kids walk to/from school in my neighborhood.			-0.059	0.000	-0.065	0.000	-0.062	0.000
I feel connected to people in my neighborhood.			-0.092	0.000	-0.093	0.000	-0.091	0.000
Total N				**3,291**		**3,291**		**3,291**
R^2				**0.1313**		**0.1318**		**0.1377**

Note: [a]The one-by-one model indicates a model estimated by which an environmental variable was entered one at a time into the model including all the covariates. Values of all the covariates, total N and R^2 generated from each one-by-one model were not included in the table due to space considerations.

B-2) Regression models (thermal comfort concerns)

Thermal Comfort Concerns Regression Models (based on a half mile home buffer)

Weather Concern (SLM regression)	One-by-one models[a]		Model 1		Model 2		Model 3	
	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|
Built environmental variables								
Bike lanes (presence)	-0.240	0.315	-	-			-	-
Sidewalks (ratio)	-0.772	0.037	-	-			-	-
Playgrounds (presence)	-0.578	0.000	-0.405	0.002			-0.363	0.005
Intersections (density, num./acre)	-6.700	0.000	-5.421	0.000			-5.395	0.000
Highways (presence)	0.142	0.231	-	-			-	-
Railroads (presence)	-0.544	0.001	-	-			-	-
High speed streets (>30mph) (%)	0.005	0.194	-	-			-	-
Crime – hotspot	0.069	0.359	-	-			-	-
Crash – hotspot	-0.022	0.234	-	-			-	-
Natural environmental variables								
Parks (presence)	-0.691	0.002			-0.564	0.039	-0.483	0.067
Steep slopes >5% (%)	0.001	0.835			-	-	-	-
Steep slopes >8.33% (%)	-0.001	0.638			-	-	-	-
Urbanized area (%)	0.011	0.086			-	-	-	-
Tree canopy (%)	-0.019	0.066			-	-	-	-
Grass cover (%)	-0.048	0.007			-0.053	0.008	-	-
Surface temperature (%)	0.034	0.374			-	-	-	-
NDVI (values ranging from -1 to 1)	-1.657	0.063			-	-	-	-
Tree heights (feet)	-0.054	0.002			-	-	-	-
Covariates								
Socio-demographic variables								
Student gender (male vs. ref. female)			-0.042	0.723	-0.046	0.697	-0.043	0.714
Student grade (ref. PK-K)								
1st – 3rd			-0.115	0.415	-0.126	0.373	-0.103	0.468
4th – 6th			0.201	0.220	0.155	0.343	0.210	0.201
Free or reduced lunch (yes vs. ref. no)			0.761	0.000	0.625	0.000	0.742	0.000
Student ethnicity (ref. White)								
Hispanic			1.278	0.000	1.215	0.000	1.282	0.000
Others			0.605	0.011	0.592	0.013	0.601	0.012
Attitudinal/social variables‡								
Walking is a good way to exercise.			0.495	0.000	0.526	0.000	0.493	0.000
I walk quit often in my daily routine.			0.133	0.014	0.135	0.012	0.134	0.013
I (would) enjoy walking with my child to/from school.			-0.285	0.000	-0.315	0.000	-0.286	0.000
Scaling factors								
Φ Strongly disagree			1 (constrained)		1 (constrained)		1 (constrained)	
Φ Somewhat disagree			0.721	0.000	0.734	0.000	0.720	0.000
Φ Neither disagree nor agree			0.627	0.000	0.628	0.000	0.617	0.000
Φ Somewhat agree			0.523	0.000	0.529	0.000	0.517	0.000
Φ Strongly agree			0 (base outcome)		0 (base outcome)		0 (base outcome)	
Total N				**3,374**		**3,332**		**3,374**
Pseudo R^2				**0.0198**		**0.0177**		**0.0201**

Note: [a]The one-by-one model indicates a model estimated by which an environmental variable was entered one at a time into the model including all the covariates. Values of all the covariates and scaling factors generated from each one-by-one model were not included in the table due to space considerations. The Pseudo R^2 represents the level of model improvements offered by the full model compared to the null model that has no predictors.

APPENDIX C

C-1) Factor analysis: Personal attitudes toward walking (5 items used)

Factor analysis/correlation	Number of obs = 1,046
Method: principal-component factors	Retained factors = 1
Rotation: (unrotated)	Number of params = 5

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	**2.659**	1.830	0.532	0.532
Factor 2	0.829	0.181	0.166	0.698
Factor 3	0.648	0.199	0.130	0.827
Factor 4	0.449	0.034	0.090	0.917
Factor 5	0.415	.	0.083	1.000

LR test: independent vs. saturated: chi2(10) = 1382.22   Prob>chi2 = 0.0000

Factor loadings (pattern matrix) and unique variances

Variables	Factor 1	Uniqueness
My child walks quite often in his/her daily routine.	0.6916	0.5217
Walking is a good way to exercise.	0.6886	0.5259
Walking is a good way to interact with other people.	0.7719	0.4042
I walk quite often in my daily routine.	0.7695	0.4079
I (would) enjoy walking with my child to/from school.	0.7203	0.4812

C-2) Factor analysis: Social support (4 items used)

Factor analysis/correlation	Number of obs = 1,034
Method: principal-component factors	Retained factors = 1
Rotation: (unrotated)	Number of params = 4

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	**2.477**	1.779	0.619	0.619
Factor 2	0.697	0.208	0.174	0.794
Factor 3	0.490	0.154	0.123	0.916
Factor 4	0.336	.	0.084	1.000

LR test: independent vs. saturated: chi2(6) = 1298.02   Prob>chi2 = 0.0000

Factor loadings (pattern matrix) and unique variances

Variables	Factor 1	Uniqueness
My family and friends like the idea of walking to school.	0.7677	0.4106
Other kids walk to/from school in my neighborhood.	0.8030	0.3552
Other kids and parents walk quite often in their daily routines.	0.8364	0.3005
I feel connected to people in my neighborhood.	0.7370	0.4569

C-3) Factor analysis: Parental safety concerns (8 items used)

Factor analysis/correlation
Method: principal-component factors
Rotation: (unrotated)

Number of obs = 978
Retained factors = 1
Number of params = 8

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	**4.651**	3.853	0.581	0.581
Factor 2	0.798	0.186	0.100	0.681
Factor 3	0.612	0.084	0.077	0.758
Factor 4	0.527	0.081	0.066	0.824
Factor 5	0.446	0.076	0.056	0.879
Factor 6	0.370	0.016	0.046	0.926
Factor 7	0.354	0.114	0.044	0.970
Factor 8	0.241	.	0.030	1.000

LR test: independent vs. saturated: chi2(28) = 3978.06 Prob>chi2 = 0.0000

Factor loadings (pattern matrix) and unique variances

Variables	Factor 1	Uniqueness
My child may get lost.	0.7316	0.4647
Other kids walk to/from school in my neighborhood.	0.8076	0.3478
My child may get bullied, teased, or harassed.	0.8331	0.3059
My child may be attacked by stray dogs.	0.7984	0.3626
My child may be hit by a car.	0.7863	0.3817
Exhaust fumes may harm my child’s health.	0.7244	0.4753
No one will be able to see and help my child in case of danger.	0.7218	0.4791
My child may get injured by falling.	0.6844	0.5316