ABSTRACT

Title of Document: CHILDREN'S ACTIVITIES AND SCHOOL TRAVEL: A TOUR BASED ANALYSIS OF THE INFLUENCE OF CHILDREN'S OUT-OF-HOME ACTIVITIES ON THE CHOICE OF SCHOOL TRAVEL PATTERNS

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Understanding children's travel patterns is important because children are often dependent on others for travel choices and their travel patterns can have significant implications on travel by parents or other members of the household.

Children's auto-dependence, particularly in school travel, has been a point of concern among researchers and policy makers. The rising levels of childhood obesity and the dramatic decline of children's active school travel in both the U.S. and abroad have turned researchers' attention to a better understanding of school travel behavior. Recent work in this field looks to understand what factors influence the travel decisions of school children in order to better inform current and future policies trying to decrease children's auto-dependence and promote active travel.

This study looks to analyze children's out-of-home activities and the impact these activities have on children's travel patterns. In particular, it explores the role of children's activities on the choice of tour patterns and travel mode to school.

Using both national and regional data derived from the National Household Travel Survey, this study performs descriptive analysis and estimates multinomial choice models testing the effect of children's participation in out-of-home activities on their joint decision of school tour type and mode choice to school.

This research examines the effects of children's out-of-home activities on a child's travel to school patterns, while controlling for important factors including children's, parental and household characteristics as well as trip attributes and built environment measures derived from children's travel literature. The focus is on school-age children from 5 to 17 years of age.

The findings of this study point to the importance of considering children's activities on travel behavior research. This research contributes to the understanding of the factors influencing children's travel decisions to school and informs policy makers of new factors to consider when making policy decisions. In addition, because children's travel is so interconnected with adult travel, the link between children's activities and travel choices may have implications to overall transportation policy.

CHILDREN'S ACTIVITIES AND SCHOOL TRAVEL: A TOUR BASED ANALYSIS OF THE INFLUENCE OF CHILDREN'S OUT-OF-HOME ACTIVITIES ON THE CHOICE OF SCHOOL TRAVEL PATTERNS

By

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Dedication

To John and Nora,

my wonderful children who have significantly impacted my travel behavior.

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The success of this study required the help of various individuals. I am eternally indebted to all those who believed in me throughout this process.

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Chapter 1: Introduction

1.1 Background and Research Question

In travel behavior research, children and teenagers are an understudied population (Paleti, Copperman, and Bhat 2011). Understanding children's travel patterns is important because children are often dependent on others for travel choices and their travel patterns can have significant implications on travel by parents or other members of the household. Researchers have proposed that a better understanding of children's activity patterns and the links between parents and children's travel is essential for better travel demand modeling (Paleti, Copperman, and Bhat 2011; Yarlagadda and Srinivasan 2008).

Recently, health advocates have been promoting an increase in physical activity to combat current rising levels of obesity and other chronic illnesses. To this end, travel behavior research has been focusing on proposing ways of promoting active transport and decreasing auto-dependence for both adults and children (Millward, Spinney, and Scott 2013; Guell et al. 2012; Goeverden and Boer 2013; McDonald 2008a; Simons et al. 2013)

In adult travel behavior research, importance has been given to looking at activities to understand why travelers are making particular decisions regarding engagement in more or less travel, destinations decisions, time of travel and travel modes. Studies of adult travel suggest that researchers agree that travel is derived from the demand to engage in activities and over the years travel decisions have become more complex.

This has led researchers to focus activity-based travel theory to study travel behavior (Bowman and Ben-Akiva 2001; Akar, Clifton, and Doherty 2012; Cirillo and Axhausen 2009; X. Chen 2012).

Researchers have now been turning their attention to the impact of activities on children's travel; however the focus of these studies (McDonald 2008b; He 2013; Vovsha and Petersen 2005; Yarlagadda and Srinivasan 2008; Deka 2013) remains on the activities of adults, in particular the work patterns of the parents.

As with adults, children's increased out-of-home activity demand creates increased travel demand. Data from the National Household Travel Surveys of 1990 and 2001 show that there have been significant changes in travel behavior of children. As recently as 1990, children traveled much less and engaged in fewer activities than in 2001. For example, middle school children took 35% more trips and spent 62% more time travelling in 2001 than in 1990. These numbers speak to a change in children's activities and travel patterns.

Participation in out-of-home activities may have significant implications on children's travel patterns in terms of number and duration of trips, trip chaining and mode choice. Based on children's activity participation rates, activity type and spatial distribution of trip destinations, children who engage in more out-of-home activities and have to travel further distances are likely to have different travel patterns than children who do not participate in out-of-home activities and who stay closer to home. In addition, children's schedules and travel territories may dictate their choice of travel modes. Understanding the variation in children's activity patterns will help

determine the influence of these out-of-home activities on their choices of travel patterns and mode to school. It is understood that choices of children's travel are not necessarily made by the child and are often made by the parents. However, this study will refer to these choices as the travel choice of the student.

This dissertation research focuses on the analysis of children's out-of-home activities and the impact these activities have on children's travel patterns. In particular, it explores the role of children's activities on the choice of tour patterns and travel mode to school. This research examines the effects of children's out-of-home activities on a child's travel to school patterns, while controlling for important factors (children's, parental, household and land use) derived from the children's travel literature. The focus is on school-age children from 5 to 17 years of age.

Specifically, this research will answer the following question:

How does children's participation in out-of-home activities affect their joint decision of school tour type and mode choice to school?

1.2 Importance of Research

Children's auto-dependence, particularly in school travel has been a point of concern among researchers and policy makers. In the last two decades, active school travel has significantly declined (McDonald 2007; He 2013; Killingsworth and Lamming 2001; Fyhri et al. 2011; Simons et al. 2013). The rising levels of childhood obesity and the constant decline of walking to school has turned researchers' attention to a better understanding of school travel (McDonald 2008a; McDonald 2007).

Understanding activity patterns for children, specifically their travel to school is important for several reasons. First, the school aged population has increased over the years and now encompasses one quarter of the total US population (Ewing, Schroeer, and Greene 2004; Yarlagadda and Srinivasan 2008; Shin 2005). Secondly, school trips are mandatory trips for children, and like work trips for adults, they present an opportunity for large scale changes in travel behavior, thus understanding travel behavior in their school tours is important. In addition, children are responsible for a large number of trips made by a household and their travel patterns during the after-school period have shown to have significant implications for travel patterns of adults (Paleti, Copperman, and Bhat 2011). Therefore, the children population represents a significant portion of travel and cannot be excluded from travel behavior research. For these reasons, research in children's travel patterns has received recent attention. The understanding of children's engagement in activities and how these activities affect their travel choices, particularly in their tours to school, is essential for an accurate picture of current and future travel behavior patterns. Although previous research has looked at children's individual school trips, this study will examine the school tour and incorporate children's activities in models of mode choice to school.

The findings of this research help bridge the gap in the travel behavior literature between children's out-of-home activities and travel patterns. A better understanding of the factors that influence children's travel behavior can help inform future transportation policies, including those encouraging a decrease in children's auto-dependency.

1.3 Research Framework

1.3.1 Defining Children's Activities

Studying children's participation in out-of-home activities is an important piece of understanding their travel behavior, especially in their travel to school tours. Children may engage in several out-of-home activities both before and after school. Before school, students may travel to a relative's home for before school care, a friend's house, or even some organized sports or other school activity. After school activities are even more varied. Often younger children will need after school care either in school or other locations, while older students may have after school jobs. Students may also engage in a variety of after school activities including social and recreation purposes, school-related activities, personal business, serve passenger (picking-up and dropping-off others), dining out, and shopping (Clifton 2003). In addition, parents often take their children on the parent's errands or other activities as they may not be able to leave their children at home. This study analyzes data from a travel survey that does not discern the motivation for participating on a particular activity. Therefore, in this study, all out-of-home activities that children participate in will be analyzed. This includes participation in activities for the purpose of the child such as participation in sports or going to a friend's house, as well as participation in household activities, such as accompanying a parent to the grocery store or bank.

Figure 1 shows a framework of the types of out-of-home activities children can participate in. The study will analyze children's spatially separated out-of-home activities, whether they are for the benefit of the child or whether the child is

accompanying other household members on their errands. Children's out-of-home activities are derived from a travel survey and grouped into categories based on the trip purpose information. Based on the literature, activities are often categorized into the following groupings: mandatory (school or work related), discretionary (leisure and social), maintenance (shopping, dining, personal services etc.), and passenger serve (pick up or drop off other household members). Therefore this study aggregates activities into discretionary, maintenance, passenger serve and work.

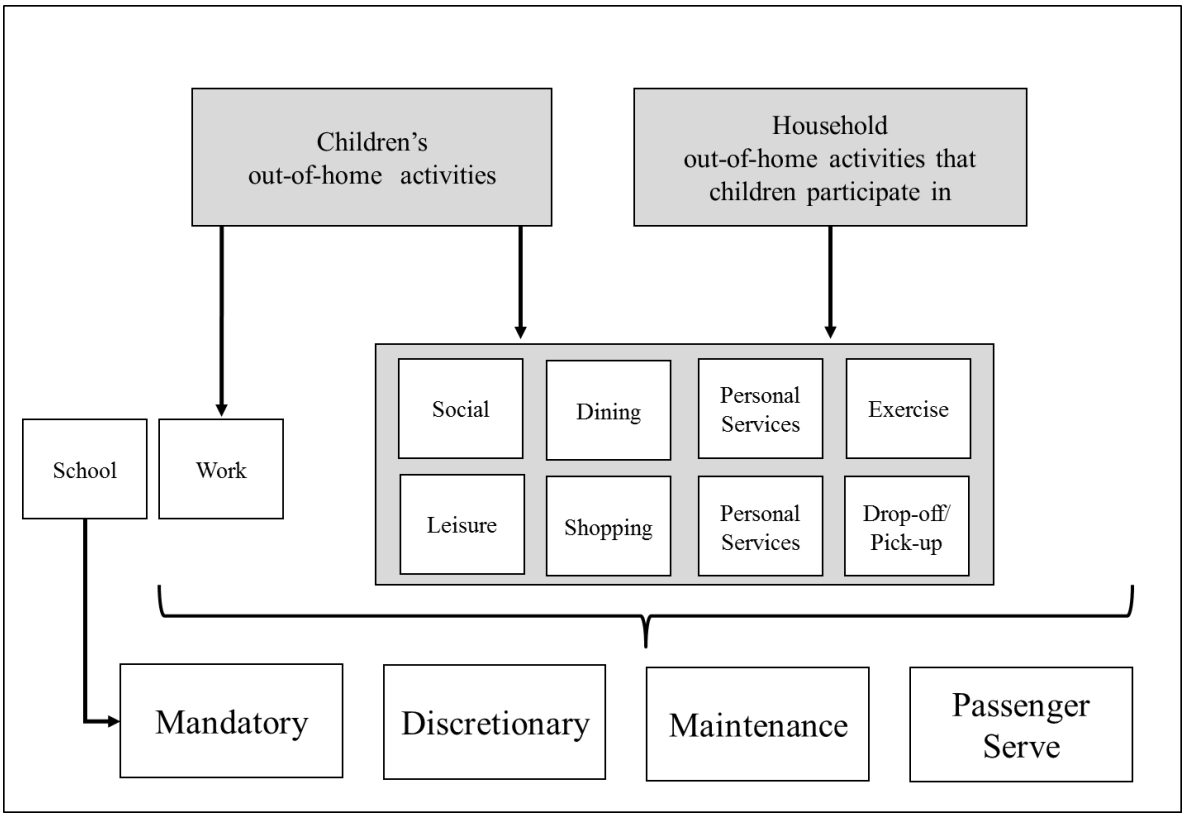

Figure 1: Framework of children's out-of-home activities

1.3.2 Activities and School Tours

Besides the more direct relationship between engagement in out-of-home activities and mode choice, this study also explores the relationship between engagement in

activities and the choice of school tours types. The school tour is defined as linked trips beginning at home that includes travel to school and potentially other activities before returning home. School tour types can vary from simple tours (from home to school and back home) to more complex tours where several activities occur during the school tour. Participation in more out-of-home activities may lead to more complex schools tours as the children make additional stops for various activities on their way home from school. However, it may also be the case that some children participate in out-of-home activities after returning home from school. Clifton (2003) found that 40% of children make an additional trip after returning home from school. In these cases, the tours to school may be rather simple and those children may have additional choices of travel, including using the school bus, or participating in carpools, or walking home with friends. Understanding how participation in out-of-home activities affects the school tour is an important part of this research.

1.3.3 Conceptual Framework

The main objective of this study is to investigate the "school tour" and examine the influence of travel to before- and after- school activities on their school tour type and mode choices. Specifically, this study is investigating whether children's participation in out-of-home activities affect the joint decision of the child's tour and mode choice to school. Figure 2 shows the conceptual framework of how activities affect the joint decision of the type of school tour and the mode to school. The framework shows that decisions regarding engagement in activities impact the choice of tours that children participate in and affect the mode choice of the tour to school.

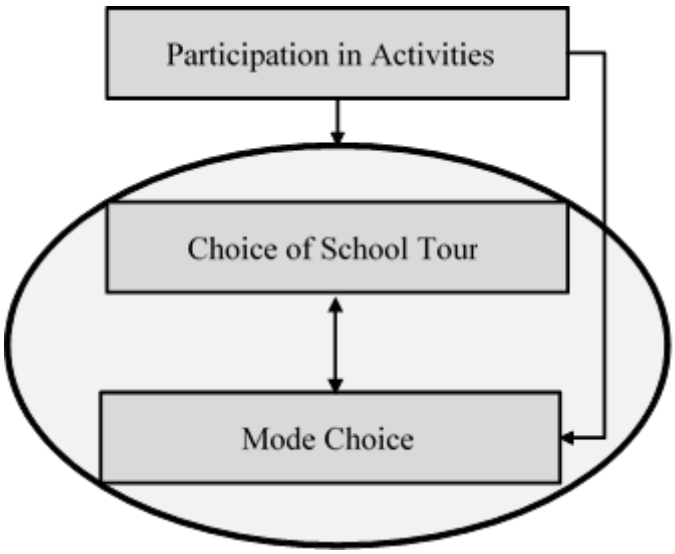

Figure 2: Conceptual Framework

1.3.4 Tour-based analysis

In the past children's mode choices to school have been studied and modeled as individual trips, however this research adds a new component to modeling mode choice for school trips by looking at the whole school tour. Tour-based analysis is used to determine how engagement in out-of-home activities at any time during the day influences the types of school tours and the mode choice to school.

Recent studies in travel behavior have recognized that adult travel often involve more than one destination and have confirmed the importance of modeling mode choice decisions as a tour instead of a single trip (C. Chen, Gong, and Paaswell 2007; Miller, Roorda, and Carrasco 2005; X. Chen 2012). As in adult travel, where the mandatory trip category encompasses work trips, for children, school trips are their main mandatory trips. Thus, the same principles of jointly modeling the mode and tour decisions for adult work travel are applied to children's school travel.

This study aims to shed light on the decision making behind the trip to school, based on the decision of types of tours and mode to school, and how engagement in activities may affect these decisions. The time and space constraints of before- and after-school activities may dictate the travel patterns of the student as well as the choice for using a personal automobile for the trip to school. A decision diagram for the tour to school is shown in Figure 3. As seen in the diagram, children have several options on their tours to school. They may engage in simple tours such as going from home to school and back home or much more complex ones where they start at home, travel to activities before school, go to school, and engage in one or more activities after school before returning home.

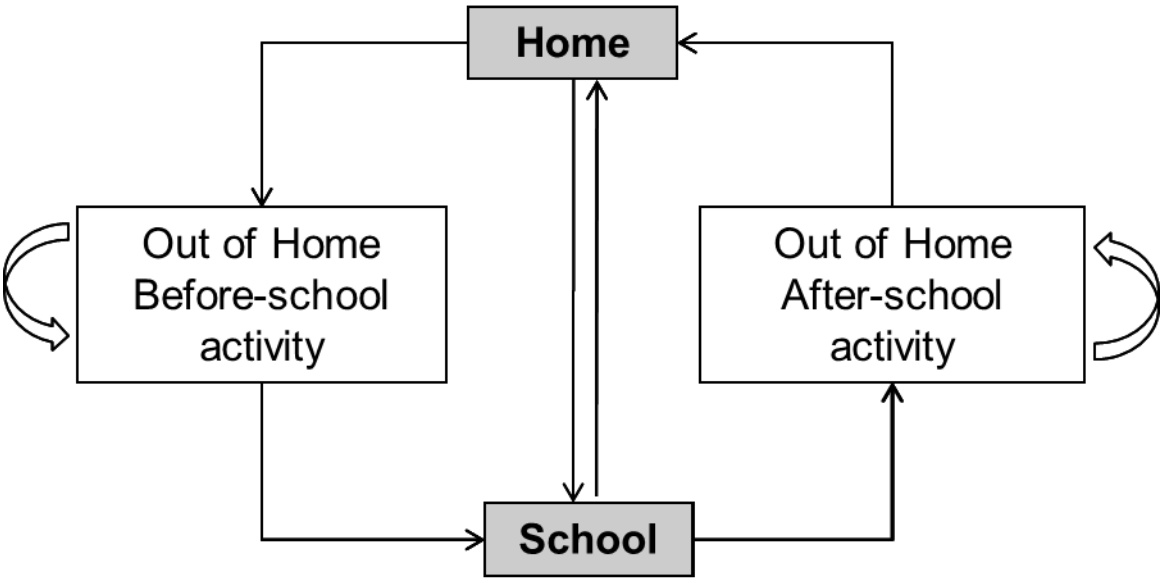

Figure 3: Tour to School

In this research, a school tour is defined as linked trips that begin at home and include travel to school as well as any other activities before returning home. The school tour may take several shapes depending on how many and what types of other stops are made on the way to and from school. The school tour consists of at least three parts: home (H), school (S) and back home (H). However it may also include other mandatory (work), maintenance, discretionary, and other stops along the way. There are many possibilities of school tours and one of the contributions of this research is providing insight into the travel tours of children and develop a classification scheme that can be used in a model.

1.4 Policy Implications

Currently, there are several policy programs, such as Safe Routes to School, that try to affect children's travel, without much understanding of children's travel behavior. These programs focus on walking to school and try to promote reduction in auto dependence, and increase safety and health benefits for children who engage in active travel. However, little has been done to find other ways to promote safer travel and decrease children's auto-dependence by targeting other travel purposes other than school. Children's increased participation in out-of-home activities and increased distances to schools may make it less feasible for many students to walk to school. Therefore, programs that promote walking to school may be less effective. The findings of this study help the understanding of children's travel patterns and shed some light on the direction for effective policies for children's travel.

The objective of this research is to have a better understanding of children's motivations for travel and using a personal automobile in order to affect future policy. The findings of this study point to the importance of considering children's activities on children's travel behavior research. Because children's travel is so interconnected with adult travel, the link between children's activity and travel choices may have implications to overall transportation policy.

1.5 Contributions

The results of this research contribute to the existing research in the following two ways. First, this study analyzes the school tour rather than the school trip for children's school travel patterns. As recent studies of adult travel have proven the importance of modeling trip chaining, as opposed to single trips to work, this research will show a novel approach to model of children's trips to school by modeling the school tour.

In addition the research assesses the impact of participating in out-of home activities on a child's joint decision of choice of school tour type and mode to school. This research identifies an effect of children's level of participation in out-of-home activities on the complexity of school tours and on children's auto dependence.

1.6 Dissertation Organization

The dissertation is organized as follows. This first chapter introduced the issue of children's activities and shows the importance of understanding the link between children's activities and children's travel patterns, particularly with regards to

children’s travel to school. This chapter also presents a conceptual framework for this study.

Chapter 2 comprises of the literature review which starts with a discussion of the existing literature on children's travel behavior and how this area of research has evolved. This section includes a discussion on current studies of travel to school, including research on active travel. Followed by a review of activity-based modeling for travel behavior research, including the impact it has on the research of children's travel to school.

Chapter 3 discusses the methodology of categorizing types of school tours, followed by a discussion on the specifications of the tour and mode choice models used for the analysis. Chapter 4 describes the datasets used for the empirical analysis and presents the approach used to convert individual trip data into an activity-based dataset used in the model specifications.

Chapter 5 discusses children's overall trip and activity patterns of children in both a national level and for a localized case study. Chapter 6 reports the results from the choice model analysis of the effects on children's activities on choice of school tours and mode of travel to school. This chapter concludes with a discussion of the contributions of this research to children's travel literature and future transportation policy.

Chapter 2: Literature Review

2.1 Introduction

Travel demand research has focused on the understanding of travel patterns by estimating the amount and distribution of travel in a region. Historically, researchers, planners and policy makers have been almost exclusive focused on motorized transportation (Desyllas et al. 2003). However, with the growing concern for automobile dependence and the increased attention to the health benefits of active travel (McDonald 2007; Millward, Spinney, and Scott 2013; Craig et al. 2002; Ewing et al. 2003; Guell et al. 2012), researchers have refined their methods of studying travel demand. In search of a better understanding of what influences travel behavior, and specifically choices about transportation mode, important questions arise about who, when, how, where, with whom and for what purpose trips are made.

Travel behavior research has mostly focused on adult travel, whereas children and teenagers are an understudied population (Paleti, Copperman, and Bhat 2011; McMillan 2005; Lawrence Frank and Company, Inc. 2008; Goeverden and Boer 2013). Understanding children's travel patterns is important because of several factors. First, children's travel patterns are often interrelated with parents travel. Children's travel is often dependent on the travel patterns of adults in the household. Conversely, children's travel needs can have significant implications on the travel patterns of parents and other adult household members that must chauffer or accompany the children to their destinations.

Secondly, the children population accounts for a significant percentage of trip makers. In particular, the school aged population in the US has increased over the years and now encompasses one quarter of the total population (Ewing, Schroeer, and Greene 2004; Yarlagadda and Srinivasan 2008; Shin 2005). In addition, children's travel behavior is different from that of adults (Mackett 2013; Lawrence Frank and Company, Inc. 2008). Not only are children's travel needs different than that of adults but they are often not allowed to travel unescorted and therefore are dependent on the travel of others.

Therefore, researchers proposed that a better understanding of children's activity patterns and the links between parents and children's travel is essential for better travel demand modeling (Yarlagadda and Srinivasan 2008; Paleti, Copperman, and Bhat 2011). Children's travel behavior studies are a growing body of literature. Researchers are now trying to understand children's travel needs and what factors influence their travel decisions.

2.2 Children's Auto-dependence

Children's dependence on the automobile has significantly increased over time and has become a point of concern to policy makers. In particular, children's auto-dependence on their travel to school is drawing the attention of researchers in several fields of study including transportation and health. Increases in traffic congestion, fuel emissions, children's obesity and other health impacts, and health care costs are just some of the issues concerning policy makers.

Over the last few decades, children's active transport to school (walking and bicycling) has significantly decreased (McDonald 2007; Killingsworth and Lamming 2001; He 2013; Fyhri et al. 2011; Simons et al. 2013; Mackett 2013), while use of an automobile on the trip to school nearly tripled (Gavin 2009). Research shows that there has been an alarming 40% reduction in walking to school in the last 20 years (Killingsworth and Lamming 2001). In 1969, more than 40% of children and 87% of those living within 1 mile of school walked or biked to school; but by 2001, fewer than 13% participated in active travel to school (McDonald 2007; Ewing, Schroeer, and Greene 2004; Martin and Carlson 2005; Gavin 2009). Meanwhile, the percentage of children using a car on the trip to school rose from 20 to 55 percent between 1969 and 2001(Gavin 2009).

This trend is not unique to the U.S. as researchers are also seeing a significant decrease in active transportation in school children and adolescents of all ages in several European countries over the past 15 years (Fyhri et al. 2011; Simons et al. 2013). A British study argues that as concern of road safety has risen, active transport to school has fallen steadily while car trips to school have significantly increased (Hillman 2006). Another British study of children's travel behavior and its health implications reports that Britain has seen a decline in children walking and cycling and a considerable increase in the number of trips made by car (Mackett 2013).

The decrease in children's active travel may be a contributing factor in the alarming obesity rates of children in the U.S. Studies shown that the rates of overweight children and adolescents have tripled between 1980 and 2002 (McDonald 2007;

Ogden et al. 2006; Kapell and Dill 2009) and now, almost one third of children and teenagers are overweight or obese (Gavin 2009; White House Task Force on Childhood Obesity 2010). These rising levels of childhood obesity and the constant decline of walking to school has turned researchers' attention to a better understanding of school travel (McDonald 2008a; McDonald 2007; McMillan 2007) as there has been little documentation on school travel trends and causes for the shift to the automobile in trips to school (McDonald 2007).

To help combat the trend of increased obesity among children, recent attention to children's health research has generated interest in finding ways to improve health and physical activity level in children through an increase in active transport to school (McDonald 2008a; McDonald 2007; Pont et al. 2011; Pont et al. 2013). In fact, the White House Task Force on Childhood Obesity has a mission to increase walking and biking trips to school by 50 percent by the year 2015 (White House Task Force on Childhood Obesity 2010). This increase would mean that by 2015, almost 20 percent of trips to school would be biking or walking (White House Task Force on Childhood Obesity 2010).

2.3 School travel

As previously discussed, the children population is responsible for a large number of trips made by a household and their travel patterns cannot be excluded from travel behavior research. In addition, researchers have found that children's travel patterns, particularly during the after-school period have shown to have significant implications for the travel patterns of adults (Paleti, Copperman, and Bhat 2011;

McMillan 2005). As with adult's work trips, school trips comprise the majority of mandatory trips for children, and present an opportunity for large scale changes in travel behavior. Therefore understanding travel behavior in the trip to school has become important as researchers and policy makers find ways to promote active travel and healthier lifestyles.

Mackett (2013) notes that children who walk more are generally more active than those who travel mostly by car. In addition, Pont et al. (2011) argues that supporting physical activity in everyday activities, such as active travel, is a sustainable approach to combat the decline in children's participation in physical activity. This study highlights the need to include physical activity on everyday events of children such as travel to school (Pont et al. 2011)

To promote the increase in physical activity through active travel and decrease in children's auto-dependence on their travel to school, policy makers are exploring new programs and policies to encourage children's non-motorized travel. Two such programs are the US Department of Transportation's National Safe Routes to School program (http://www.saferoutesinfo.org), launched in 2005 and the Walking School Bus Initiative (http://www.walkingschoolbus.org). However, these programs are being implemented without much understanding on how these programs would affect a shift from the automobile to walking or biking.

The National Safe Routes to School program was established to improve safety on walking and bicycling routes to school and to encourage children to use active modes of transportation in their travel to school. As of September 2012, the program has

apportioned almost $1.15 billion in funds for improvements benefiting more than 14,000 schools across the U.S.(National Center for Safe Routes to School 2013). These programs focus on built environment improvements, such as addition of pedestrian infrastructure (e.g. sidewalks), traffic control measures, and pedestrian warning systems. Seventy to ninety percent of funds are used for infrastructure improvements and the remaining funds are used for other projects such as education (McDonald, Barth, and Steiner 2013; Gavin 2009).

Since the inception of Safe Routes to School programs, researchers began studying the effects of these programs on the shift from the automobile to active modes of travel to school. McMillan (2007) notes that programs, such as Safe Routes to School, that try to address the increasing auto-dependence of children's trip to school through urban form improvements are put into place despite minimal research showing the influence of urban form on children's travel (McMillan 2007). Although some studies have found link between some aspects of the built environment and walking to school, overall results on the effect of these programs on children's active transport are mixed (Boarnet et al. 2005a; McDonald 2008a; McMillan 2005; McMillan 2007).

A walking school bus (WSB) is another initiative aimed that increasing walking to school. The concept of a walking school bus is a group of children walking together to school led by an adult that supervises the children for the entire trip to school. These programs seem to be effective at increasing walk rates by attracting children who were previously driven to school, but there have been relatively few evaluations of these types of programs (McDonald and Aalborg 2009). Although WSB programs

seem to show a benefit towards affecting modal shift away from the automobile, little is still known about the full effects of these programs.

Research on Walking School Bus (WSB) programs notes that liability or administrative burdens can adversely affect the success of these programs (McDonald and Aalborg 2009). The benefits of WSB includes convenience to the parents that do not need to accompany their kids to school but still are assured that their children are safely engaging in active travel to school. However, if the WSB programs are organized by parent, it can become cumbersome to administer and difficult to find volunteers to be the "drivers" of the walking school bus. A New Zealand study on WSB programs by Kingham and Ussher (2005) found that over 50% of WSB routes ended after one year, largely because of lack of volunteers to serve as "drivers" (Kingham and Ussher 2005; McDonald and Aalborg 2009). The same study recommends more institutional support by schools or local government to ensure longevity of the programs and lessen the burden on the parents (Kingham and Ussher 2005; McDonald and Aalborg 2009). However liability concerns is a major reason for the lack of institutional support for WSB programs in the U.S. (McDonald and Aalborg 2009).

Researchers agree that the decision-making process of the parent and child to engage in active travel is complex and many factors influence the choices of what modes of travel to take and whether to engage in active travel, particularly in their travel to school (Pont et al. 2011; Pont et al. 2009; McMillan 2005; Sidharthan et al. 2011).

There are several reasons that may account for the increase in auto-dependence to travel to school, including personal and socio-demographic characteristics of the child, parents and household, built environment factors, school sitting, safety, and the interaction between students' travel and that of other members of the household, and attitudes about active travel. Children's travel to school continues to be of interest to transportation researchers and policy makers. Over the last few years, researchers have looked at many factors to try to understand what influence travel behavior of children, in particular in their trips to school.

2.3.1 Personal Characteristics

In children's mode choice to school research, several studies evaluated the interaction between personal characteristics and mode choice to school. These studies have analyzed mode choice to school controlling for personal characteristics of the child such as gender, age and race and found significant results.

A study of factors associated with travel to school for children and teens between the ages of 5 through 18 years in Atlanta, Georgia found significant relationship between age and mode choice. This study specified a multinomial choice model using the Atlanta, Georgia household travel dataset (SMARTRAQ) and found that the probability of walking increases between the ages of 5 and 8, then holds constant until age 12, increases again between ages 12 and 16, then finally dips once students reach age 16. This study also concludes that the probability of riding a school bus remains constantly neutral across all ages, while the probability of driving alone increases rapidly at age 16 (Lawrence Frank and Company, Inc. 2008).

McDonald (2008b) studied the effect of household interactions on children's school travel. An odds ratio analysis showed that walking rates increase by 2 percentage points per year as children age, but the effect is only statistically significant for children aged 5 to 14 years of age. For older students, having a driver's license showed a 9 percent decrease in the probability of walking or biking to school. Regarding race, the study concluded that Hispanic students are more likely to walk to school than white students. Similar results were shown for other minorities but the results were not as significant (McDonald 2008b)

A study of children's travel to school in the San Francisco Bay area, used an econometric model to simultaneously determine the choice of mode and the escorting person for children's school travel. The study used the 2000 San Francisco Bay Area Travel Survey (BATS) data and found strong impacts between characteristics of the child such as age, gender, and ethnicity and mode choice decisions (Yarlagadda and Srinivasan 2008).

Yarlagadda and Srinivasan (2008) found that very young children are more likely to be walked to school by mothers compared to older children and more likely to be escorted to school by their parents by car than using transit or school bus. As the children become older, they are more likely to use the school bus or transit and children between 13 and 17 years of age are the most likely to walk or bike independently. This latter group is also the most likely to be driven by others (i.e. not a parent), such as friends.

The same study also found that Caucasian children are less likely to be walked to school by their mother and less likely to use transit for school travel compared to children of other ethnicities. Regarding gender, the study reports that boys are more likely to bike or drive alone to school and less likely to be walked by their mothers, suggesting that boys are more independent in their school travel compared to girls (Yarlagadda and Srinivasan 2008).

Another study using a multinomial logit model to understand mode choice for the trip to school, used the 2001 National Household Travel Survey (NHTS) data and found relationships with several individual characteristics (McDonald 2008a). The study found that being a girl is associated with a decrease in number of walking trips less and independent travel. Regarding age, the study found that as age increases, so does walking to school rates. In addition, the author reports modest effects of race and ethnicity on walking rates. The data shows that 10 percent of white children walk to school while 22 percent of African American children walk to school (McDonald 2008a).

More recent studies on children's mode choice to school, support the findings that children's age, gender and race are related to their school travel mode. Hsu and Saphores (2013) found that both girls and younger children (5 to 10 years old) are less likely to walk, bike or use transit to school. In addition, the study found that African-American and Hispanic students are more likely to travel by active modes to school (Hsu and Saphores 2013).

Sidharthan et al. (2011) presents a school mode choice model using travel survey data for children in Southern California aged 5-15 years. This study looks at the influence of spatial interaction effects on the household decision-making processes when choosing a mode of transportation for children's school trips. Regarding personal characteristics, the study finds that age and gender are statistically significantly associated with mode choice. They conclude that older children are more likely to use non-motorized modes of transportation. A gender effect is also apparent in this study as females are less likely to choose the bicycle than their male counterparts (Sidharthan et al. 2011).

2.3.2 Household Characteristics

Several household characteristics have also been found to have an impact in the mode choice of children to school, including household size, household composition (single parent versus a two-parent household), income, vehicle availability and parent's work status.

The Sidharthan et al. (2011) study found that both higher household income and vehicle ownership is associated with greater propensity to use the car on the trip to school and lower utility for alternative modes (school bus and walk). Both McDonald (2007) and Hsu and Saphores (2013) also found that children from lower income households are more likely to walk or bike to school. McDonald (2008a) also finds that increase in income by 10% leads to a 2.6% decline in walking and a 2% increase in being driven to school.

Hsu and Saphores (2013) and Yarlagadda and Srinivasan (2008) found that children from households with more vehicles, are less likely to use the school bus or transit on their travel to school. In addition, other household attributes such as non-availability of vehicles in the household, the license-holding of the parents, and the household structure (i.e., single-parent versus two parent family) also are shown to influence mode choice (Yarlagadda and Srinivasan 2008).

Several studies have found that children that have more siblings (larger households), are more likely to walk or bike to school and less likely to be driven (McDonald 2008a; Hsu and Saphores 2013). McDonald (2008b) also found that having siblings is associated with higher rates of walking and biking but only for high school students. When comparing driving and taking the school bus, Yarlagadda and Srinivasan (2008) found that when multiple school-going children are present in a household, they are less likely to ride the school bus and are more likely to be driven to school by the mother (Yarlagadda and Srinivasan 2008).

Parent's work status, particularly the presence of working mothers has a positive association with children taking the car to school, possibly because the non-working parents can accompany the children on the walk to school, whereas working parents drop off their children on the way to work. Several studies support this claim. McDonald (2008b) found that the mother's work status strongly influences whether children walks to school. The study found that elementary and middle school students with mothers who commute in the morning have the lowest probability of non-motorized travel. Similarly, Sidharthan et al. (2011) found that children in

households with nonworking adults are more likely to use the walk mode to school. The Bay Area study by Yarlagadda and Srinivasan (2008) also found that parent employment characteristics have strong impacts on the mode choice decisions to school. They found that mothers who are employed full-time are less likely to walk their children to school. In addition, mothers who go to work on the school day are also more likely to drive their children to school. Regarding the father's work status, the authors note that the fathers' decision to go to work and their work flexibility influence whether or not the father drives his children to school (Yarlagadda and Srinivasan 2008).

2.3.3 Distance from Home to School

Distance to school has increased over time, both in the U.S. McDonald (2007) and abroad (Mackett 2013). Several studies have found that one of the strongest effects on the decision to walk or bike to school is the distance between home and school (McDonald 2008a; Hsu and Saphores 2013; Yarlagadda and Srinivasan 2008; McDonald 2007; National Center for Safe Routes to School 2010; Kapell and Dill 2009; Goeverden and Boer 2013; Mackett 2013).

A longitudinal study on the trends of school children finds that distance from home to school has the strongest influence on walking or biking to school and that this increase in distance to school could account for half of the decline in active mode to school (McDonald 2007). Another study examining the mode of travel to school for children K through 12 in Gainesville, Florida also found that students with shorter walk or bike times to school proved significantly more likely to walk or bike. (Ewing,

Schroeer, and Greene 2004). McDonald (2008b) reports that each additional mile of distance between home and school decreases the probability of walking or biking to school by 14 to 21 percentage points depending on age group. Interestingly, Yarlagadda and Srinivasan (2008) find that the distance between home and school strongly and negatively impact the choice of walking to and from school, but the impact is stronger on the trip to school (Yarlagadda and Srinivasan 2008)

Studies evaluating Safe Routes to School Programs report similar findings. A National Center for Safe Routes to School report provides findings from surveys administered to parents and children of Safe Routes to School programs throughout the United States from April 2007 to May 2009, and includes the finding that distance between home and school is strongly and inversely related to walking and bicycling (National Center for Safe Routes to School 2010). Another study using surveys completed by parents of school children in the City of Portland as part of its Safe Routes to School program reports that students who live within a half-mile of school are more likely to bike or walk and that 60% of these students used active travel to school (Kapell and Dill 2009).

However, a study of middle school students walking and biking to and from school in four schools in Oregon found that distance to school was not a predictor of whether children took a car on the trip to school (Schlossberg et al. 2006).

2.3.4 Land use

Some studies of adult travel have found that urban form can have an impact on travel behavior (Cervero and Kockelman 1997; Ewing et al. 2003; Ewing and Cervero 2010). As an example, Ewing et al. (2003) measured urban sprawl at the county and metropolitan levels and related the degree of sprawl with levels of physical activity and health. The study reports that residents of sprawling counties (low density residential development, lack of land-use mix, and poor accessibility) were less likely to walk during leisure time, weigh more, and have greater prevalence of hypertension than residents of compact counties (Ewing et al. 2003). The authors note that urban form can be significantly associated with some forms of physical activity and health.

Because these studies found a relationship between the built environment and adult mode choice, programs and policies, such as Safe Routes to School programs (SRS), are trying to affect a shift of children to active modes of travel through mostly infrastructure improvements. A recent study assessing the distribution of funds for Safe Routes to School programs, report that most of funding was spent on infrastructure (62.8%) or combined infrastructure and non-infrastructure (23.5%) projects (McDonald, Barth, and Steiner 2013). These programs focus on built environment solutions, despite a lack of evidence to support the influence of urban form on children's travel (McMillan 2007; Lawrence Frank and Company, Inc. 2008).

A few localized studies assessing the effectiveness of these programs reported some changes in walking behavior due to Safe Routes to School programs (Boarnet et al.

2005b; Staunton, Hubsmith, and Kallins 2003), but the overall results on the effect of these programs to children's active transport are mixed (Boarnet et al. 2005a; McDonald 2008a; Yarlagadda and Srinivasan 2008) and do not address travel to purposes other than school.

A study evaluating the relationship between urban form, distance, and mode choice to school found that children whose routes to school had higher intersection densities and lower dead-end densities were more likely to walk (Schlossberg et al. 2006). However, Yarlagadda and Srinivasan (2008) evaluated the effect of several land-use and built-environment variables on mode choice to school but found that none were statistically significant predictors of children's mode choice.

Another study of children's mode choice for the school trip found that population density is positively associated with walking to school, even after accounting for trip distance. However, the study found that this relationship between mode choice and population density to be weak (McDonald 2008a). Ewing, Schroeer, and Greene (2004) also found mixed results in regards to the relationship of urban form and mode choice for school children. They found that students traveling through areas with sidewalks on main roads were more likely to walk to school, but other land use variables such as density and land use were not significant (Ewing, Schroeer, and Greene 2004).

Specific studies examining urban environment improvements of Safe Routes to school programs also found mixed results (Boarnet et al. 2005a; Boarnet et al. 2005b; McMillan 2007). An evaluation of several California Safe Routes to School programs

found that some infrastructure improvements showed to be successful in shifting children into active modes to school, however others showed limited or no benefit. Improvements such as sidewalks and traffic control measures around some of the schools were found to increase walking and bicycling to school, while other infrastructure additions such as crosswalks, restriping and pedestrian warning systems were not as effective (Boarnet et al. 2005a).

Researchers are now concluding that although some land use improvements can affect mode choice in children, they are neither the sole factor nor the most important in affecting mode choice decision for children's travel. Schlossberg et al. (2006) argue that although urban form helps predict school travel mode, it is only one of many factors that affect children's school travel decisions.

Similarly, a study of thirteen elementary schools in California examines the effect of urban form on travel behavior of children as well as the magnitude of influence that both urban form and non-urban form factors have on children's mode choice to school (McMillan 2007). This study also concludes that urban form is important but not the sole factor that influences school travel mode choice, and that other factors such as perceptions of safety, parents' attitudes, household transportation options, and social/cultural factors can have a significant impact in school travel choices. In fact, the analysis indicates that the influence of these other factors is greater than that of urban form (McMillan 2007). A study modeling mode choice to school based on parental attitudes found some relationships between land use and mode choice. For example, the study found that living in non-urban areas reduces the likelihood of

active commuting from school by children. However, the authors suggest that urban form improvements such as sidewalks may reduce mother's perception of risk and therefore could aid in the decision of allowing children to walk to school (Hsu and Saphores 2013).

Another recent study of children's school trip mode also discusses the fact that additional factors, other than urban form, are likely to have significant effects on travel patterns of children and warns proponents of Safe Routes to School programs that "improving walking and bicycling environments around schools cannot entirely determine whether children will walk or bicycle to school" (Deka 2013).

Lawrence Frank and Company, Inc. (2008) also agree that numerous factors influence children's travel to school. This study finds that consistent with adult travel behavior literature, several factors such as shorter distances and presence of pedestrian facilities encourage walking. However, the author notes that the relationship between neighborhood design and children's school travel are not as strong as that found in adult travel behavior studies. He argues that neighborhood designs that are compatible with walking behavior, such as compact residential neighborhoods and interconnected street networks, are necessary to promote walking. However, travel mode to school may be constrained by other factors, such as parental preferences, perceptions, and safety (Lawrence Frank and Company, Inc. 2008). This study also finds that other land use factors that have shown to influence on adult travel behavior, such as mixed use pattern, does not seem to have an effect on mode choice to school (Lawrence Frank and Company, Inc. 2008). Boarnet et al. (2005a) further discuss that

traffic improvements by themselves are not likely to be sufficient in changing children's school travel decisions, particularly in locations that already have low levels of active transportation. The authors argue that programs aimed at urban form improvements to encourage active travel modes would be more effective if coupled with other efforts.

The studies discussed in this section support the notion that urban form is important but not the sole factor nor the most important factor in children's choice of mode to school. Changes to the built environment are necessary to allow for a shift in children's travel behavior. However, current built environment solutions such as the Safe Routes to School programs do not affect the spatial distribution of origins and destinations and therefore are not sufficient for changing behavior (McDonald 2008a). With this in mind, studies in children's travel patterns and mode choice warrants further research to discern the reasons why children's active transport is continuously decreasing and auto-dependence is increasing at such alarming rates.

2.3.5 Other factors influencing mode choice to school

In search of a better understanding of children's travel decisions, researchers started considering other factors, other than urban form, to help explain mode choice to school (McMillan 2007; Hsu and Saphores 2013; Deka 2013; McDonald and Aalborg 2009; Lawrence Frank and Company, Inc. 2008; Kapell and Dill 2009; Sidharthan et al. 2011; Simons et al. 2013; Pont et al. 2013). As presented in the previous section, researchers studying mode choice to school are now arguing that there are likely to be other factors with stronger associations to mode choice than urban form. Two such

factors are parental attitudes and convenience. The notion is that even if distances to school are short and walking environments are conducive for active travel to school, parent's attitudes about children's safety or time constraints on the child's or parents schedules may keep children from walking to school.

A San Francisco Bay area study of travel patterns of school children between the ages of 10 and 14 found that 75% of parents that live close to school (under 2 miles) and drive their children to school, report that they do so for convenience and to save time. In addition, almost half of those parents reported that they do not allow their child to walk to school without adult supervision and accompanying their child on a walk to school greatly increases the time devoted to that particular trip (McDonald and Aalborg 2009). An Atlanta, Georgia household travel dataset study looking at children's travel patterns to school for children and teenagers between 5 and 18 years of age, found that parents perception of safety and walkability of the neighborhood influence mode choice for students (Lawrence Frank and Company, Inc. 2008).

Hsu and Saphores (2013) also report that parental attitudes are important in school mode choice. This study analyzed the impacts of parental gender and attitudes on children's school travel mode based on the California 2009 National Household Travel Survey. They found that parental attitudes are a significant predictor of children choosing active modes to school, particularly the mother's attitudes. Their results show that in general, when mothers have higher concerns about traffic and their children are less likely to walk or bike to school. (Hsu and Saphores 2013).

Another study using data from the California National Household Travel Survey Studies found that children's mode choice are also influenced by spatial and social interactions. The study suggests that parents may be influenced by the travel patterns of other children in the neighborhood. If other children walk or bike to school, then parents are more likely to allow their children to do the same (Sidharthan et al. 2011)

The studies discussed in this section show that it is important for researchers and policy makers to consider other factors that may influence children's school travel, including parental attitudes, convenience, and time constraints. McDonald and Aalborg (2009) adds that current policies to encourage children's mode choice such as Safe Routes to School do not effectively address issues of convenience and time constraints.

2.3.6 Activities and travel

As the discussion in the previous section shows, the notion of time constraints and convenience of the household is an emerging topic of discussion in school travel research. In adult travel behavior studies, researchers have started looking at household activities in order to understand why travelers are making particular decisions regarding engagement in more or less travel, destinations decisions, time of travel and travel modes.

Similarly in children's school travel, as researchers explore other factors that can be the barriers or facilitators of active travel, they have started considering the impacts of activities of the household in their studies. Recent research found that the addition of

parents' activity constraints to school travel literature has proven to be have significant effects (McDonald 2008b; Yarlagadda and Srinivasan 2008; Vovsha and Petersen 2005; Vovsha, Petersen, and Donnelly 2004; Deka 2013; He 2013).

McDonald (2008b) studies the influence of household interactions, including parent's commuting patterns, on the affecting of children's active transportation to school. The analysis of U.S. children between the ages of 5 and 14 years, shows that children whose mother commutes to work in the morning, are less likely to walk or bike to school. The author argues that policies to encourage children's active travel to school need to address parental time constraints (McDonald 2008b).

A recent study of school travel using the 2001 Southern California Regional Household Travel Survey looks at the effect of spatial and temporal constraints of parental employment. This study finds that parents work schedules and locations, particularly the mother's, is very important in the probability of parents escorting their children to school (He 2013). Similarly, Deka (2013) also looks at the relationship between adult's work trips and children's school travel patterns. The study concludes that children are less likely to take active modes to school when adults in the household drive to work (Deka 2013). Furthermore, another recent study of children's travel behavior found that 50% of the trips to school by car were part of a parent's work trip, and another 18% were part of other trips (Mackett 2013).

Although researchers are investigating the effect of parent's trips and activities on school travel, they are mainly focused on the parents commuting patterns (Yarlagadda

and Srinivasan 2008; McDonald 2008b), whereas other interactions and especially activities that children engage in are not well addressed in these studies.

2.3.7 Children's out-of-home activities and school travel

Just recently, children's travel studies have started to see the importance of examining children's activities. As with adult travel, children's travel also present constraints that need to be considered, such travel to school may be impacted by other activities that students participate in. Copperman and Bhat (2009) found that over 55 percent of children pursue at least one out-of home activity after school and confirm the importance of examining children's after school activity-travel patterns.

Fyhri et al. (2011) finds that organized leisure activities is a contributing factor to less active travel behavior for children. Another recent study finds that children who attend before or after school care are also less likely to walk, bike, or use transit to and from school (Hsu and Saphores 2013).

Furthermore, a survey of children's mode choice to school finds that over 21 percent of children report that the reason why they use the car to or from school is because they participate in before or after school activities, and another 18 percent report that they use a car because they need to transport musical instruments or projects to school (Schlossberg et al. 2006)

Although there are few studies looking at the impact of children's out-of-home activities on school travel patterns, they find evidence that incorporating children's

activities on children's travel behavior research is important. Furthermore, Paleti, Copperman, and Bhat (2011) note that travel demand modeling is limited by the lack of attention of activity patterns of children. They further argue that further research in children's activity patterns is important to inform both policies to promote active travel of children and travel behavior of adults (Paleti, Copperman, and Bhat 2011). The understanding of children's engagement in activities and how these activities affect their travel choices, particularly in their travel to school, is essential for an accurate picture of current and future travel behavior patterns.

This dissertation study hypothesizes that children's out-of-home activity patterns before and after school may have significant implications to children's auto-dependence. This research analyzes children's school tours and address the effects of before and after school out-of-home activities on a child's use of an automobile for the school trip, while controlling for important factors (parental commute patterns, household structure, and urban form) derived from the school travel literature.

2.4 Tour based modeling for travel behavior

This section discusses the tour based modeling approach that is used in this study to model school travel. It presents the activity-based model theory and why it is a superior method than trip based analysis.

In travel behavior literature, adult mode choice has been heavily researched; however, in the past mode choice has been mostly modeled as a single trip (Miller, Roorda, and Carrasco 2005; C. Chen, Gong, and Paaswell 2007). Studies of adult travel behavior agree that today's trips have become far more complex than years ago and conclude

that trip chaining, as opposed to single trips, has become increasingly more prominent specially in travel to work (C. Chen, Gong, and Paaswell 2007; Levinson and Kumar 1995).

In an effort to understand why travelers are making particular decisions regarding engagement in more or less travel, destinations decisions, time of travel and travel modes, researchers have focused on studying activity based theory. Activity based models encompass two main ideas: travel is derived from the demand to engage in activities; and the desires to travel are limited by temporal-spatial constraints (Bowman and Ben-Akiva 2001; Cirillo and Axhausen 2009).

As the demand for engaging in more activities has grown, recent studies in travel behavior recognize that adult travel often involve more than one destination and thus confirm the importance of modeling mode choice decisions as a tour instead of a single trip (C. Chen, Gong, and Paaswell 2007; Miller, Roorda, and Carrasco 2005; X. Chen 2012; Ho and Mulley 2013)

Tour-based models deconstruct a person's day into a set of tours, which are defined as round trips based at home or the travel from home to one or more activity locations and back home (Doherty and Mohammadian 2007; Bowman and Ben-Akiva 2001). The modeling of tour decisions is an improvement over trip-based models because it incorporates "an explicit representation of temporal spatial constraints among activity stops within a tour" (Bowman and Ben-Akiva 2001).

Ho and Mulley (2013) add that analyzing tours, rather than individual trips, provides "a better understanding of travel behavior and a more appropriate framework for examining responses to transport polices".

As in adult travel, the mandatory trip category encompasses work trips, for children, school trips are their main mandatory trips. In this study, the same principles of adult work travel are applied to children's school travel. Therefore rather than studying the individual school trip, the school tour is analyzed.

Although previous research has looked at children's individual school trips and what factors may influence mode to school, this study examines the school tour and incorporate children's activities in models of mode choice to school.

Chapter 3: Methodology

The goal of this study is to explore the role of children's participation in out-of-home activities on their school travel patterns. In particular, this study tries to determine if participation in out-of-home activities by students have an impact on their choices of mode to school and school tour types.

As discussed in the previous chapters, children's auto-dependence and significant decline in active travel has led researchers to focus on trying to understand the motivations behind children's travel choices, particularly in their travel to school. In addition, recent studies of travel behavior recognize that adult travel often involve more than one destination and have confirmed the importance of modeling mode choice decisions as a tour instead of a single trip. Although previous studies have looked at children's individual school trips in mode choice research, this study examines the school tour and incorporates children's activities in models of mode choice to school.

There are two main contributions that this research aims to make. First, just as recent studies of adult travel behavior have proven the importance of modeling trip chaining, this study uses a novel approach to model children's travel to school by modeling the school tour rather than the individual trip. Secondly, this study identifies an impact of participation in out-of home activities on a child's joint decision of choice of school tour type and mode to school.

To help answer the research question of "how does children's participation in out-of-home activities affect their school tour type and mode choice to school?", this study:

1) Categorizes children's out-of-home activities
2) Defines school tour types
3) Uses a choice model approach to determine if there is a relationship between participation in out-of home activities and choice to school tour type and mode to school

3.1 Out-of-home Activity Categories

School children can participate in a variety of activity types, these activities can occur at home, such as hobbies, in-home meals, watching television, practicing an instrument, or hosting friends. Students can also participate in a large number of out-of-home activities before or after school. Clifton (2003) reports that students engage in a variety of after school activities including social and recreation purposes, school-related activities, personal business, serve passenger, dining out, and shopping. Going to school and activities that occur within the school are also a part of the out-of-home activity grouping. However, the purpose of this study is to look at the influence of out-of-home activities other than school, on the travel-to-school patterns of school children in elementary, middle and high schools (defined as 5-17 years of age).

It is important to note that because of the interactions between children's and adult travel, both children and adults may participate in activities that are for the benefit of

other members of the household. For example, a parent may take their child to play a sport after school and remains at the field and watches the game. On the other hand, a parent with young children, will need to bring their children along to a grocery shopping trip. Therefore the child participates in a shopping trip that may be to the benefit of the parent. The scope of this study is to analyze school children's spatially separated out-of-home activities, whether they are for the benefit of the child or whether the child is accompanying other household members on their errands.

Based on the literature, activities are often categorized into the following groupings: mandatory (school or work related), discretionary (leisure and social), maintenance (shopping, dining, personal services etc.), and passenger serve (pick up or drop off other household members). Because the school tours are being analyzed, this study aggregates activities reported by the students into the following categories: discretionary, maintenance, passenger-serve and work (e.g. after-school jobs for high school students).

3.2 School Tours

Adult travel behavior research has proven the importance of modeling trip chaining as opposed to single trips to work. As school trips are the equivalent mandatory trips of students, this research will show a novel approach to model of children's trips to school by modeling the school tour.

There are many possibilities of school tours and part of this research will be to classify all types of school tours into a few categories to be used in the modeling

analysis. One of the contributions of this research is to provide insight into the travel tours of children and develop a classification scheme that can be used in a model.

As previously discussed, a school tour is defined as linked trips that begin at home and include travel to school as well as any other activities before returning home. There can be a large number of school tour types depending on how many and what types of other stops are made on the way to and from school. The school tour consists of at least two trips: the trip from home (H) to school (S) and the return trip from school back to home. This tour would be categorized as a home-school-home (H-S-H) tour. However, any number of other out-of-home activities can be introduced within the tour. For example, a student could have the following occurrences in a day:

1) Leaves home in the morning and goes to school
2) Leaves school and goes to a friend's house
3) Goes to soccer practice with his friend
4) After practice, his mother picks him up and he accompanies her to the grocery store
5) After shopping, they return home.

This tour type would take the shape of: H-S-O-O-O-H, where H=home, S=school, and O=other out-of-home activity. However, for this analysis, only four types of tours will be used in the analysis. Thus, all school tours types will be classified in the following four categories:

- **H**-**S**-**H**
- **H**-**S**-O-**H**

- **H**-O-**S**-**H**
- **H**-O-**S**-O-**H**

Where: H=home; S=school, O=non-school out-of-home activity and where O type activities may include more than one stop. Therefore, the example above of H-S-O-O-O-H, would be categorized as an H-S-O-H tour type.

To this end, trip data is used from a travel survey to construct the school tours as described above. The individual trips for each student were concatenated together to build the school tour. A series of scripts and manual clean-up was used to build the daily trip tours for each student and school tours were identified for each student. Then, each student's school tour was classified in one of the four categories described above.

3.3 Model Specifications

The main analysis of this study is modeling the impact of children's out-of-home before- and after-school activities on their choices of school tour types and mode of travel to school. To this end, travel survey data is used to construct individual students' school tours as described above. Descriptive statistics and multivariate analysis are performed in this study using PAWS Statistical package and Stata programs. Geographical Information Systems (GIS) is also used to calculate additional urban form metrics. The analysis is done with both a national travel dataset as well as a localized case study dataset, for the Baltimore Area that contains geocoded origin and destination information for each trip. Both datasets are described in Chapter 4.

To capture decisions in travel behavior, the discrete choice model methodology provides an appropriate framework. Discrete choice models are used to explain or predict choices between discrete alternatives by estimating the likelihood that a decision maker chooses a particular alternative.

There are three models specified for each data set for a total of six models. Using both the national and the Baltimore Area datasets, this study specifies a tour choice model (Model 1), a mode choice model (Model 2), and a model of the joint decision of tour type and mode to school (Model 3). First, the two preliminary individual models of choice of school tour type and mode choice are estimated. For the national dataset, a multinomial logit (MNL) choice model (Model 1) is specified to analyze the impact of participation in out-of-home activities on the likelihood of choosing different types of school tours controlling for socio-demographic variables, household characteristics, trip attributes, and urban form (shown in section 3.3.1). Then, a binomial logit model (Model 2) is used to study the influence of out-of-home activities on the student's choice of mode to school (shown in section 3.3.2).

For the Baltimore case study dataset, because of a much smaller sample size, only two alternatives are given for both the tour and mode choices. Therefore for the two preliminary models, binomial logit models are specified for both preliminary models of tour type and mode choice.

In adult travel behavior modeling, the interaction between transportation mode and activity decisions has become important, but the causality between these two choices is not clear (Krygsman et al. 2007; Ye et al. 2007). Although some studies for both

work and non-work trips suggest that for the most part the choice of activities (or trip chaining complexity) precedes the choice of travel mode (Krygsman et al. 2007; Ye et al. 2007), a recent study has determined that for work trips, trip chaining and mode choice decisions are simultaneous (Islam & Habib 2012). The same reasoning could be applied to children's travel, where the assumption that the choice of the complexity of the tour to school and the choice of mode is done simultaneously. Therefore, a joint model of choice of school tour type and mode to school is also evaluated (Model 3). A multinomial logit choice model for the joint decision of a school tour type and mode choice to school is specified to evaluate what factors impact the joint choice of school tour type and mode (as shown in section 3.3.3).

The model controls for socio-demographic variables (gender, age groups, race, household composition and household income), parents work status, household vehicle ownership, accompaniment in school trips (by parents, friends or siblings) and land use variables as shown in Figure 4.

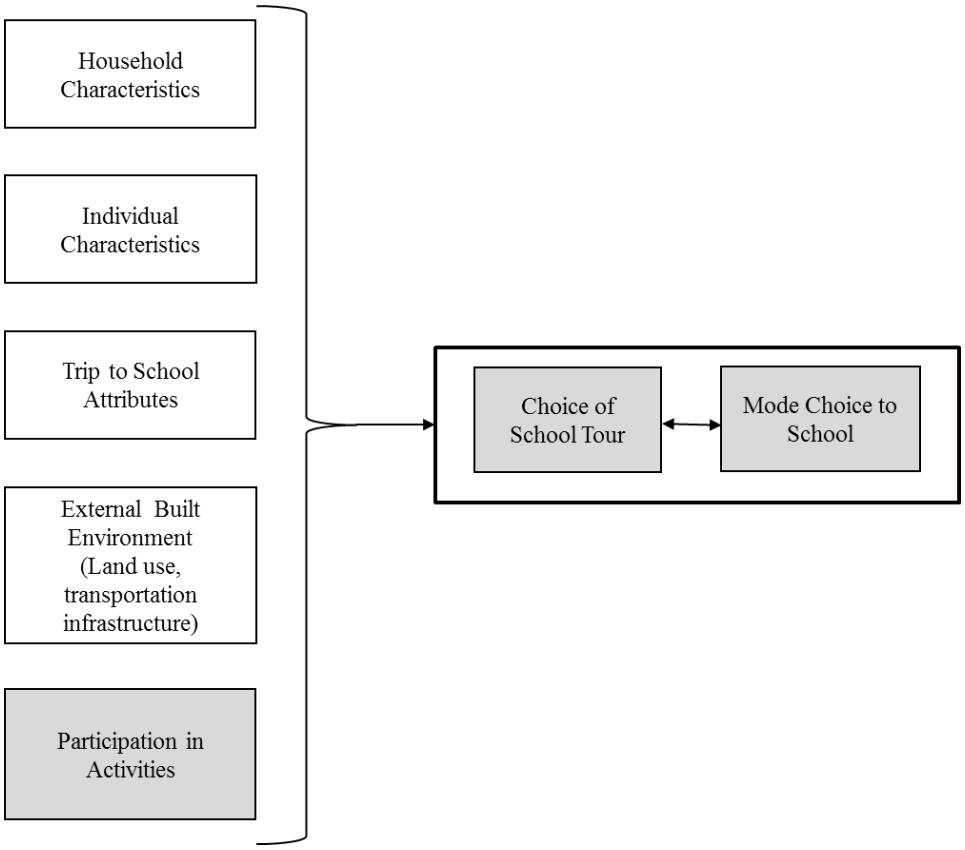

Figure 4: Joint Choice Model Framework

A summary of the models presented in this paper is shown on Table 1. As described above, there are three models specified for each dataset: two preliminary models and a joint model of tour type and mode choice. Specification of the choice models are shown in the sections below.

Table 1: Summary of Choice Models

	Model 1: Tour Type Choice	*Model 2: Mode Choice*	*Model 3: Joint Choice of Tour Type and Mode to School*
National Data	Multinomial Logit Model of School Tour Type	Binary Logit Model of Mode Choice	Multinomial Logit Model of School Tour Type
Baltimore Area Case Study Data	Binary Logit Model of School Tour Type	Binary Logit Model of Mode Choice	Multinomial Logit Model of Joint Decision of Tour Type and Mode to School

3.3.1 Model 1: School Tour Type Model

The multinomial logit (MNL) model structure is used to perform this analysis. The MNL is a type of a discrete choice model that can be used to predict a "decision maker's choice of one alternative from a finite set of mutually exclusive and collectively exhaustive alternatives" (Koppelman & Bhat 2006). Discrete choice models are based on the random utility theory, which assumes that the decision maker's preference for an alternative can be captured by the value of an index, called utility. It is assumed that the decision maker *n* chooses the alternative that yields the highest utility. The probability of any alternative *i* being selected by individual *n* from a choice set C_n is given by equation (1)

$$P_n(i) = \Pr(U_{in} \geq U_{jn}, \forall j \in C_n) \qquad \text{[Equation 1]}$$

Where, U is the utility of the given alternative and $J_n \leq J$ is the number of feasible choices.

Because the analyst has imperfect information about an individual's utility level, uncertainty is introduced into the utility equation (Ben-Akiva & Lerman 1985). Equation 2 represents the utility (U_{in}) of alternative *i* in the choice set C_n for decision-maker *n*.

$$U_{in} = V_{in} + \varepsilon_{in} \qquad \text{[Equation 2]}$$

Where:
Vin is the systematic (observed) component of the utility of alternative j, and

ε_{in} is the error term (not observed)

If $\beta = (\beta_1, \beta_2, ..., \beta_k)$ represents the vector of k unknown parameters and x_{jn} represents the vector of attributes of the alternative and the decision maker, then the systematic component of the utility, V_{jn}, is shown in equation (3):

$$V_{jn} = \beta_1 X_{jn1} + \beta_2 X_{jn2} + \beta_3 X_{jn3} + ... + \beta_k X_{jnk} \ . \qquad \text{[Equation 3]}$$

In the MNL model, as described by (Ben-Akiva & Lerman 1985), the probability that a decision maker n chooses alternative i in a set of all possibilities Cn is given by equation (4) and the MNL model can be expressed as shown in equation (5)

$$P_n(i) = \Pr(U_{in} \geq U_{jn}, \forall j \in C) \qquad \text{[Equation 4]}$$

$$P_n(i) = \frac{e^{V_{in}}}{\sum_{j \in C_n} e^{V_{jn}}} \qquad \text{[Equation 5]}$$

In this study, the MNL is used to predict what types of tours the decision maker (the student) will chose for their individual school tours based on their specific attributes. The school tour choice set, C_n , in this model, based on the responses of the students, includes the following choices:

- **H**-**S**-**H**
- **H**-**S**-O-**H**
- **H**-O-**S**-**H**
- **H**-O-**S**-O-**H**

Where: H=home; S=school, O=non-school trip, where "O" activities may include more than one stop.

The utilities of the alternatives is developed as a function of the student and household characteristics, trip attributes, attributes of the built environment and participation in out-of-home activities. Based on the MNL formulation, the utility that student *n* obtains from tour type *i* is:

$U_{ni} = \beta_0$ (constant)

$+ \beta_{1\ldots k} (X_{1\ldots k})$ (student characteristics: age category, race, gender)

$+ \beta_{k+1\ldots m} (X_{k+1\ldots m})$ (attributes of the household: HH income, HH composition, vehicle ownership, parent's work status)

$+ \beta_{m+1\ldots p} (X_{m+1\ldots p})$ (tour to school characteristics: mode, and accompaniment on trip)

$+ \beta_{p+1\ldots q} (X_{p+1\ldots q})$ (land use characteristics: population density)

$+ \beta_{q+1\ldots r} (X_{q+1\ldots r})$ (children's participation in out of home activities: mandatory, discretionary, maintenance, passenger-serve, other)

$+ \varepsilon_{ni}$

For the case study model, due to a smaller sample size, only two alternatives are provided for the school tour choice: home-school-home (HSH) tours and tours where at least one other activity occurs within the tour (either before or after school). Therefore a binary logit model is specified instead. In addition, another difference in the case study tour choice model, is that because it provides geocoded trip ends for all trips, additional urban form variables are able to be created (including accessibility to transit and land use mix indicators). In addition, another important trip characteristic

available is distance to school. Therefore the school tour choice set, C_n, in this model, based on the responses of the students, includes the following choices:

- **Home-School-Home Tour**
- **Tours with activities within the tour**

Where one or more activities can occur before and/or after school.

The utilities of the alternatives is developed as a function of the student and household characteristics, trip attributes, attributes of the built environment and participation in out-of-home activities. Based on the MNL formulation, the utility that student *n* obtains from tour type *i* is:

$U_{ni} = \beta_0$ (constant)

$+ \beta_{1\ldots k} (X_{1\ldots k})$ (student characteristics: age category, race, gender)

$+ \beta_{k+1\ldots m} (X_{k+1\ldots m})$ (attributes of the household: HH income, HH composition, vehicle ownership, parent's work status)

$+ \beta_{m+1\ldots p} (X_{m+1\ldots p})$ (tour to school characteristics: mode, distance to school and accompaniment on trip)

$+ \beta_{p+1\ldots q} (X_{p+1\ldots q})$ (urban form characteristics: land use mix and transit accessibility)

$+ \beta_{q+1\ldots r} (X_{q+1\ldots r})$ (children's participation in out of home activities: mandatory, discretionary, maintenance, and passenger-serve)

$+ \varepsilon_{ni}$

3.3.2 Model 2: Mode Choice Model

The binary logit model structure is used to perform the mode choice part of this analysis. For the purposes of this analysis, the mode choice is based on the mode for the trip to school only. The binary logit model also a type of a discrete choice model that can be used to predict a decision maker's choice of one alternative over another. Similar to the previous model, binary discrete choice models are also based on the random utility theory, which assumes that the decision maker's preference for an alternative can be captured by the value of an index, called utility. It is assumed that the decision maker *n* chooses the alternative that yields the highest utility. The probability of any alternative *i* being selected by individual *n* from a choice set C_n is given by the following:

$$P_n(i) = \Pr(U_{in} \geq U_{jn}, \forall j \in C_n) \qquad \text{[Equation 6]}$$

Where, U is the utility of the given alternative and $J_n \leq J$ is the number of feasible choices.

Because the analyst has imperfect information about an individual's utility level, uncertainty is introduced into the utility equation (Ben-Akiva & Lerman 1985). Equation 7 represents the utility (U_{in}) of alternative *i* in the choice set C_n for decision-maker *n*.

$$U_{in} = V_{in} + \varepsilon_{in} \qquad \text{[Equation 7]}$$

V_{in} is the systematic (observed) component of the utility of alternative j, and
ε_{in} is the error term (not observed)

In this model, two alternatives are available to the decision maker for school trips: 1) using a personal automobile or 2) using other mode of transportation. To model this decision, binary logit models are specified. The binary logit model arises from the assumption that the difference of the error terms is logistically distributed. Under this assumption, the choice probability for alternative *i* is given by:

$$P_n(i) = \Pr(U_{in} \geq U_{jn}) \qquad \text{[Equation 8]}$$

$$P_n(i) = \frac{e^{V_{in}}}{e^{V_{in}} + e^{V_{jn}}} \qquad \text{[Equation 9]}$$

$$P_n(i) = \frac{1}{1 + e^{(V_{jn} - V_{in})}} \qquad \text{[Equation 10]}$$

In this study, the binary mode choice is used to predict what mode the decision maker (student) will chose for the individual trip to school to test for the effect of engagement in out-of-home activities on autodependence. Therefore, the utilities of the alternatives will be developed as a function of the student and household characteristics, trip attributes, attributes of the built environment and participation in out-of-home activities. Based on the binary logit formulation, the utility that person *n* obtains from mode choice *i* is:

$U_{ni} =$ β_0 (constant)

$+ \beta_{1\ldots k} (X_{1\ldots k})$ (student characteristics: age category, gender, race, condition that affects mobility)

$+ \beta_{k+1\ldots m} (X_{k+1\ldots m})$ (attributes of the household: HH income, HH composition, vehicle ownership, parent's work status)

$+ \beta_{m+1\ldots p} (X_{m+1\ldots p})$ (trip characteristics: distance to school* and accompaniment on trip)

$+ \beta_{p+1\ldots q} (X_{p+1\ldots q})$ (characteristics of the built environment: urban form*)

$+ \beta_{q+1\ldots r} (X_{q+1\ldots r})$ (children's participation in out of home activities: mandatory, discretionary, maintenance, and passenger-serve)

$+ \varepsilon_{ni}$

** Note: A variety of urban form measures have been calculated for the Baltimore Add-on cases because the geocoded trip ends are available for these cases. These variables include measures of mixed use, population and housing density, road connectivity, and transit availability. For the National Data, the urban form measure used is population density, whereas for the case study, transit accessibility and land use mix are chosen. In addition, the distance to school variable is only available for the Baltimore Area Case study.*

3.3.2 Model 3: Joint Tour Type and Mode Choice Model

After the individual effects of out of home activities on school tour type and mode choice have been evaluated, a joint multinomial logit model was chosen to test the effect of out-of-home activities on the simultaneous decision of type of tour and mode choice to school. A joint multinomial logit is then specified to perform this analysis as shown in Figure 5 and Figure 6 for the national sample model and the Baltimore Area case study model respectively.

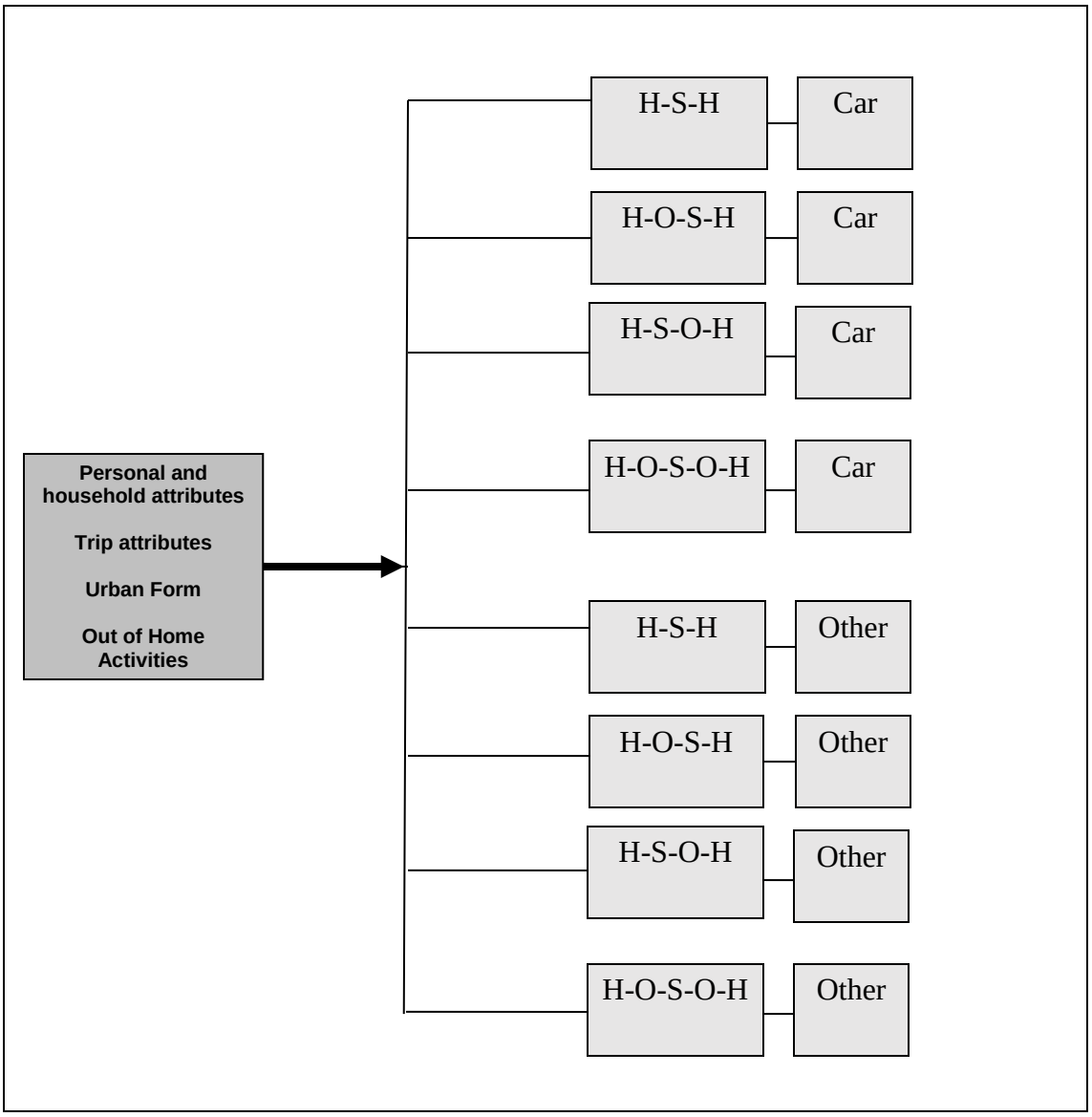

Figure 5: Conceptual Framework for National Sample Joint Model

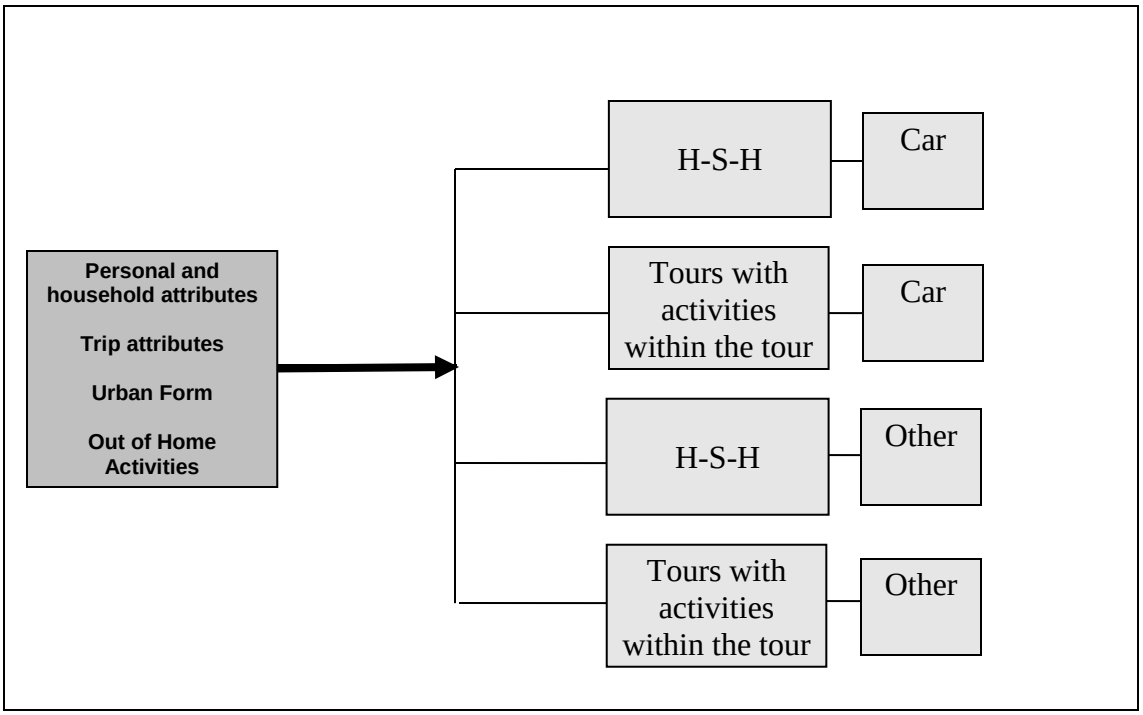

Figure 6: Conceptual Framework for Case Study Joint Model

The joint logit model is an extension of the multinomial logit (MNL) model. In this study, the joint logit model is be used to predict the simultaneous decision of what types of tours and what mode to use that the decision maker (student) will chose for their individual school tours based on attributes of the person, household, school trip, urban form, and participation in out-of-home activities.

The school tour and mode choice set, C_n , in this model, based on the responses of the students, includes the following choices for the national sample model:

- **Car and H-S-H**
- **Car and H-S-**O**-H**
- **Car and H-**O**-S-H**
- **Car and H-**O**-S-**O**-H**
- **Other mode and H-S-H**
- **Other mode and H-S-**O**-H**
- **Other mode and H-**O**-S-H**
- **Other mode and H-**O**-S-**O**-H**

Where: H=home; S=school, O=non-school trip, where "O" activities may include more than one stop.

Whereas for the case study model, the school tour and mode choice set, C_n , in this model, based on the responses of the students, includes the following choices:

- **Car and H-S-H**
- **Car and Tour with activities within the tour**
- **Other mode and H-S-H**
- **Other mode and Tour with activities within the tour**

The utilities of the alternatives is developed as a function of the student and household characteristics, trip attributes, attributes of the built environment and participation in out-of-home activities. Based on the MNL formulation, the utility that student *n* obtains from tour type *i* is:

$U_{ni} = \beta_0$ (constant)

$+ \beta_{1\ldots k} (X_{1\ldots k})$ (student characteristics)

$+ \beta_{k+1\ldots m} (X_{k+1\ldots m})$ (attributes of the household)

$+ \beta_{m+1\ldots p} (X_{m+1\ldots p})$ (tour to school characteristics)

$+ \beta_{p+1\ldots q} (X_{p+1\ldots q})$ (land use characteristics)

$+ \beta_{q+1\ldots r} (X_{q+1\ldots r})$ (children's participation in out of home activities)

$+ \varepsilon_{ni}$

Chapter 4: Data

As previously discussed, recent studies of adult travel suggest travel decisions have become more complex over the years and that travel is largely derived from the demand to engage in activities. Therefore, researchers are now studying travel behavior of adult using activity-based travel theory (Bowman & Ben-Akiva 2001; Akar et al. 2012; Cirillo & Axhausen 2009; Chen 2012). This study applies the same assumptions to children's travel as described in Chapter 2.

Data available for transportation analysis is most often single day trip diary datasets (Cirillo & Axhausen 2009) and activity-travel surveys are more difficult to obtain. Furthermore, information on children's activities patterns is even rarer and therefore activity-based modeling for children's travel is difficult to study. This research uses a different approach to activity-based modeling, where the out-of-home activities of school aged children are extracted from a large trip data survey.

The data chosen to conduct the analysis in this study is household travel survey data from the 2001 National Household Travel Survey (NHTS).

4.1 National Household Travel Survey Data

The NHTS survey is a population-based, random survey that captures information on all trips taken by all household members for a given day. The data set includes information on households, demographic characteristics of the population as well as

detailed information on mode, purpose and location of travel. In addition, it provides additional information from other sources that are linked to individual respondents, such as information derived from the 2000 U.S. Census. The survey gathered information on 66,000 households in the U.S. between March 2001 and May 2002 (US Department of Transportation, 2004).

The 2001 NHTS sample is arranged into four hierarchical files: household, person, vehicle and travel day. For the household file, the data are collected once for each household and contains information about the household characteristics and the household members, such as location of home, type of residence, household income, and person data. The person file includes information for each member of the household, such as age, race, driver status, education, and person income. The vehicle file contains data relating to each of the household's vehicles including make, model, model year, annual miles and odometer readings. For the travel day file, the NHTS collected data about each trip the person made on the household's randomly-assigned travel day, consisting of a 24-hour period. The 24-hour travel day starts at 4:00 am of the day assigned and continues until 3:59 am of the following day.

The 2001 NHTS sample includes 38,027 children between the ages of 0 and 17 and 28,284 children between the years of 5 and 17. The latter group will be considered school-age children for the purposes of this research. A distribution of age groups from the NHTS is shown in Table 2.

Table 2: Distribution of NHTS sample by age group

	N	Percent
Nursery (0-4)	9,743	6.2
Elementary (5-10)	12,938	8.2
Middle (11-13)	6,804	4.3
High (14-17)	8,542	5.4
Adult (18+)	120,332	76.0
Total	158,359	100.0

This study only includes school-age children and teenagers (from 5 to 17 years of age) that have made a school trip on the particular day of the survey. Therefore 13,210 cases were available for the analysis. The data is segmented by age categories (elementary, middle and high school) for a complete analysis of the effect of activities (especially before and after school activities) on travel by these age groups. Local land use data and 2000 U.S. Census information supplements the travel surveys.

There are over 600,000 trips present in the NHTS travel day dataset. Table 3 shows the distribution of trips taken in the assigned 24-hour period for each age group.

Table 3: Distribution of NHTS trips by age group

	N	Percent
Nursery (0-4)	29,728	4.7
Elementary (5-10)	43,607	6.9
Middle (11-13)	23,076	3.6
High (14-17)	30,910	4.9
Adult (18+)	506,105	79.9
Total	633,426	100.0

The NHTS 2001 data set provides a trip data set with detailed information on each person's trips for the day of the survey. The trip purpose for a particular trip is based on the response provided by the individual who chooses from over 30 categories of trip purposes. However, the responses do not indicate the reason that an individual engaged in that particular trip. Therefore, there is no way to decipher whether the trip is made for the benefit of the child or whether the child is accompanying another member of the household on their trip. The trip purposes provided by the survey are shown in Table 4.

Table 4: 2001 NHTS Trip Purpose Categories

Home
Go to work
Return to work
Attend business meeting/trip
Other work related
School/religious activity
Go to school as student
Go to religious activity
Go to library: school related
OS - Day care
Medical/dental services
Shopping/errands
Buy goods: groceries/clothing/hardware store

Buy services: video rentals/dry cleaner/post office/car service/bank
Buy gas
Social/recreational
Go to gym/exercise/play sports
Rest or relaxation/vacation
Visit friends/relatives
Go out/hang out: entertainment/theater/sports event/go to bar
Visit public place: historical site/museum/park/library
Family personal business/obligations
Use professional services: attorney/accountant
Attend funeral/wedding
Use personal services: grooming/haircut/nails
Pet care: walk the dog/vet visits
Attend meeting: PTA/home owners association/local government
Transport someone
Pick up someone
Take and wait
Drop someone off
Meals
Social event
Get/eat meal
Coffee/ice cream/snacks
Other reason

Regardless of whether the trip is to his/her benefit or they are just accompanying another household member on that trip, the fact remains that if a student has an associated trip reported, then the student made that particular trip.

For the purposes of this study, trip purposes are re-categorized into the following categories:

1. *Mandatory*

In adult travel, mandatory trips are usually work trips. For children's travel, school trips are the great majority of mandatory trips. However, some older students may also have before and after school jobs, therefore both school and work trips can be

considered mandatory trips for this age group. In this study, because the school tour is being analyzed, work trips are considered as a separate category.

2. Maintenance

Maintenance trips include the categories of shopping trips and trips to personal services. Some of categories from the NHTS survey that are classified into the shopping category includes: shopping, errands, buying goods (groceries, clothing, hardware), buying services (video rental, dry cleaner, post office, car), and buying gas. Similarly, the personal services classification includes the following categories of trips from the NHTS: personal services (haircut, nails, grooming), family personal business obligations, professional services (attorney/accountant), attending religious activities, visiting library, daycare, medical/dental services, attending a funeral or wedding,), and attending meeting (PTA/home owners association/local government)

3. Discretionary

Discretionary trips are mostly comprised of trips to leisure and social activities. Leisure trips destinations include: visiting friends/relatives, visiting public places, and trips to rest and relaxation or vacation destinations. Social trips classification include the following NHTS trip purpose choices: social or recreational, social events, meals, trip to the gym or to exercise, playing a sport, going to hangout (such as trips to: entertainment/theater/sports event/go to bar).

4. *Passenger-serve*

Passenger serve trips are the trips taken to pick up or drop off other household members. In the NHTS dataset, trips purposes that fall into this category include: transporting someone, pickups, take and wait trips, or dropping off someone.

5. *Other*

There was also an option for NHTS survey participants to respond "other reason" to the trip purpose question. Because there is no further information on the purpose of these trips, they are categorized as its own classification: other trips.

The dataset includes 14,054 school trips, made by school age children: 6,190 elementary school trips 3,386 middle school trips and 4,478 high school trips. The distribution of trips based on trip purpose groupings created and age categories are shown in Table 5.

Table 5: Distribution of Trip Purposes by Age

		Home	Work	School	Social/ Leisure	Passenger Serve	Shop/ Personal	Other	Total
Nursery (0-4)	*N*	10515	0	890	6202	3212	8489	381	29689
	% within Age Category	35.4%	.0%	3.0%	20.9%	10.8%	28.6%	1.3%	100.0%
Elementary (5-10)	*N*	16049	0	6190	9216	2514	9114	468	43551
	% within Age Category	36.9%	.0%	14.2%	21.2%	5.8%	20.9%	1.1%	100.0%
Middle (11-13)	*N*	8572	32	3386	5211	1002	4510	288	23001
	% within Age Category	37.3%	.1%	14.7%	22.7%	4.4%	19.6%	1.3%	100.0%
High (14-17)	*N*	11348	1101	4478	6621	1413	5610	317	30888
	% within Age Category	36.7%	3.6%	14.5%	21.4%	4.6%	18.2%	1.0%	100.0%
Adult (18+)	*N*	170139	70128	3380	86812	32617	139251	3531	505858
	% within Age Category	33.6%	13.9%	.7%	17.2%	6.4%	27.5%	.7%	100.0%

4.2 Out-of-Home Activities Dataset

As any trip based survey, the shortcomings of using the NHTS trip dataset for travel behavior analysis is that it does not include the activities that respondents engage in during the time frame analyzed by the survey. Although there is no information on the in-home activities of the survey's participants, this research will expand the use of the travel survey to develop an activity data set. The information on trip ends provided will transform the trip data into an out-of-home activities dataset.

The data set used for the analysis is a subsample for the 2001 NHTS trip dataset that includes only school aged children's trips (5 to 17 years of age) and any associated joint trips by other members of the household. This subsample was used to create the activity dataset.

To create the activity dataset, this study converted the NHTS trip dataset into an out-of-home activity dataset by identifying the beginning and end of each out-of-home activity based on trip times (trip end times and the start time for the next trip) and trip purpose. Figure 7 represents a sample trip day and shows how out-of-home activity information was extracted from the NHTS trip dataset.

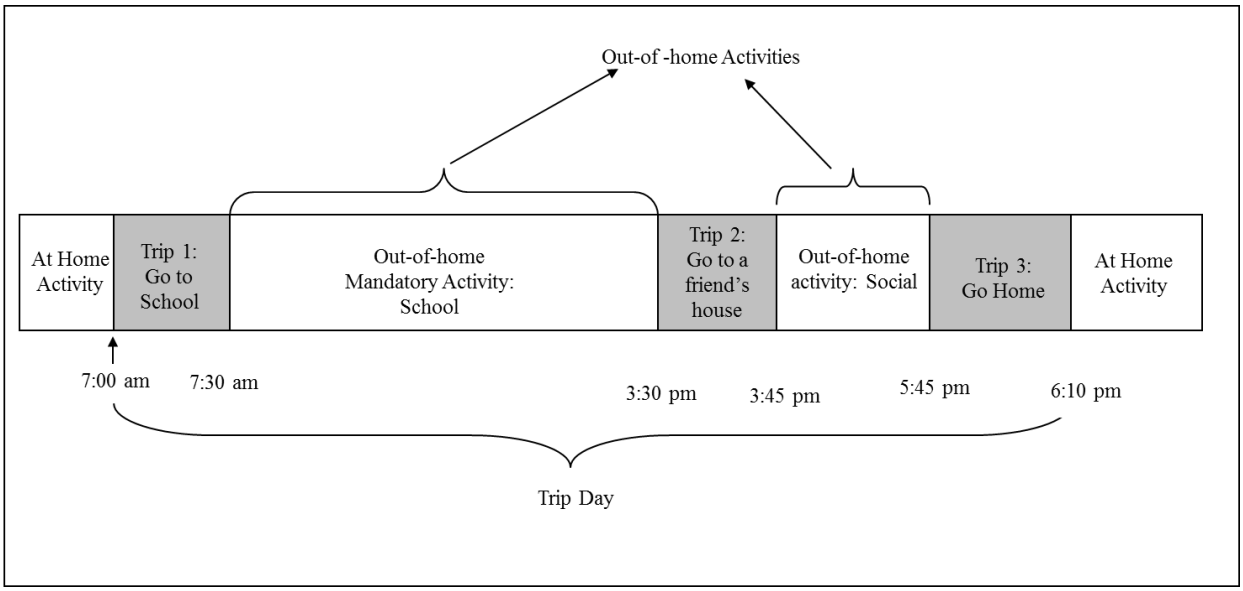

Figure 7: Conversion of Trip Data to Activity Dataset

It is important to note that the scope of this study only includes analysis of spatially separated out-of-home activities. However children may also participate in before or after school activities that occur at school. If these activities do not warrant an additional trip in the students daily tours, the activity would not be capture in the trip survey.

The converted dataset shows that children respondents in the NHTS survey that went to school on the day of the survey participate anywhere from 0 to 13 out-of-home activities per day not including going to school. On average approximately 1.2 additional out-of-home activities besides going to school. The distribution of children's participation in out-of-home activities by age group in shown in Table 6.

Table 6: Mean Number of Out-of-Home Activities for Children by Age

	Mean	N	Std. Deviation
Elementary (5-10)	1.12	5923	1.30
Middle (11-13)	1.06	3229	1.28
High (14-17)	1.30	4058	1.47
Total	1.16	13210	1.35

The NHTS data show that children who went to school on the day of the survey participate in other out-of-home activities other than school including shop or personal, social or leisure activities, drop off and pick up of other household members and work (for children in the high school category). The distribution of these activities by activity type is shown in Table 7.

Table 7: Distribution of Out-of-Home Activities for Children by Age and Activity Type

Age Categories		Out-of-home activities: Shop/Personal	Out-of-home activities: Social/Leisure	Out-of-home activities: Passenger Serve	Out-of-home activities: Work
Elementary (5-10)	Mean	0.69	0.72	0.29	0.00
	N	5923	5923	5923	5923
	Std. Dev.	1.19	0.81	0.59	0.00
Middle (11-13)	Mean	0.62	0.78	0.21	0.00
	N	3703	3229	3229	3229
	Std. Dev.	1.14	1.18	0.67	0.10
High (14-17)	Mean	0.69	0.88	0.24	0.18
	N	4058	4058	4058	4058
	Std. Dev.	1.22	1.31	0.74	0.57
Total	Mean	0.68	0.78	0.26	0.06
	N	13210	13210	13210	13210
	Std. Dev.	1.19	1.20	0.77	0.33

4.3 School Tours

As described previously, this dissertation will analyze school tours and the mode chosen by students for the school tour. School tours are defined as linked trips that begin at home and include travel to school as well as any other activities before returning home. Various tour types are possible, however, this dissertation identifies four types of tours for the analysis:

- **H**-**S**-**H**
- **H**-**S**-O-**H**
- **H**-O-**S**-**H**
- **H**-O-**S**-O-**H**

Where: H=home; S=school, and O=other non-school activity and where O activities may include more than one stop.

The out-of-home activities described earlier in this chapter are used to test whether engagement in out-of-home activities has an impact on the type of school tour and the mode choice to school.

It is important to note that a student could participate in multiple tours on the same day, however this study is only analyzing the first school tour. For example, if the student goes from home to school and then back home and later leaves home again for a different activity, then the student is categorized as having a Home-School-Home type of tour. The remainder tours on the same day will be accounted for in the "number of activities that the child participated on" based on each type of activity.

Although much of the data was categorized into the four tour types through automatic scripts, some manual data clean-up was required. For example, approximately 280

students (approximately 2%) had trips tours where the student went to school, then left school for some other activity and came back to school. These were manually input into the four tour categories by the following rules:

1) If a student leaves school for an activity in the middle of the day, such as a medical appointment, going to lunch, field trip or religious activity, and then returns to school, this tour is considered as a HSH tour.
2) Another scenario is that a student leaves school and returns during the school day, but then goes to an activity after the last school trip (such as going to a friend's house). This tour may have taken the shape of a HSOSOH tour and is classified in this study as a HSOH.
3) If student participates in an activity after the school day such as running errands or visiting friends and then comes back to school for a short while (possibly to pick up car or get ride), then the tour is considered as HSOH.

The NHTS dataset provides the type of mode used in each particular trip that the respondent took on the day of the survey. However, for the purposes of this study, we are only interested in children's auto-dependence and therefore only model whether a child took a personal vehicle or some other mode of transportation for the trip to school.

Another reason to only look at a binary decision of taking a car or not to school is that there are a few cases where the respondents reported multiple sequential trips to school (less than 2%). Some of these cases were due to reporting compound trips to school with different modes such as walking to the bus and then taking the bus to

school. Other times, it may the case that the student may have participated in an enrichment program at a different school during the school day and therefore two consecutive school trips were reported. In any case, only the mode for the first school trip is modeled in this study.

4.4 Baltimore Region Case Study

The 2001 NHTS Baltimore Add-On sample was used to supplement the national NHTS national sample data analysis. The Baltimore Area case study includes geocoded geographic coordinates for the location of residences and trip ends are included for more comprehensive spatial analysis with additional information on the school trip and more detailed features of the urban environment. Because of the absence of this data in the national survey it is only possible to control for these important trip and environmental conditions in the Baltimore case study models.

The geography of interest is the six county region of the Baltimore metropolitan area, including Baltimore County, Baltimore City, Howard County, Harford County, Carroll County and Anne Arundel County, shown in Figure 8. The sample data includes 616 school age children who made school trips on the day of the survey, as shown in Figure 8: 273 elementary school students, 154 middle school students and 189 high school students.

On average, children from the Baltimore Area Case Study participate in approximately one additional out-of-home activities besides going to school. The distribution of children's participation in out-of-home activities by age group is shown in Table 8.

Table 8: Mean Number of Out-of-Home Activities for Children in the Baltimore Case Study by Age Group

	Mean	N	Std. Deviation
Elementary (5-10)	1.08	259	1.11
Middle (11-13)	0.96	147	1.08
High (14-17)	0.93	174	1.17
Total	1.01	580	1.12

The Baltimore Area Case Study data show that children who went to school on the day of the survey participate in other out-of-home activities other than school including shop or personal, social or leisure activities, drop off and pick up of other household members and work (for children in the high school category). The distribution of these activities by activity type is shown in Table 9.

Table 9: Distribution of Baltimore Case Study Out-of-Home Activities for Children by Age and Activity Type

Age Categories		Out-of-home activities: Shop/Personal	Out-of-home activities: Social/Leisure	Out-of-home activities: Passenger Serve	Out-of-home activities: Work
Elementary (6-10)	Mean	0.35	0.44	0.16	0.00
	N	259	259	259	259
	Std. Dev.	0.71	0.67	0.42	0.00
Middle (11-13)	Mean	0.36	0.43	0.12	0.01
	N	147	147	147	147
	Std. Dev.	0.61	0.65	0.46	0.08
High (14-17)	Mean	0.33	0.40	0.09	0.06
	N	174	174	174	174
	Std. Dev.	0.67	0.69	0.33	0.24
Total	Mean	0.34	0.42	0.13	0.02
	N	580	580	580	580
	Std. Dev.	0.67	0.67	0.41	0.14

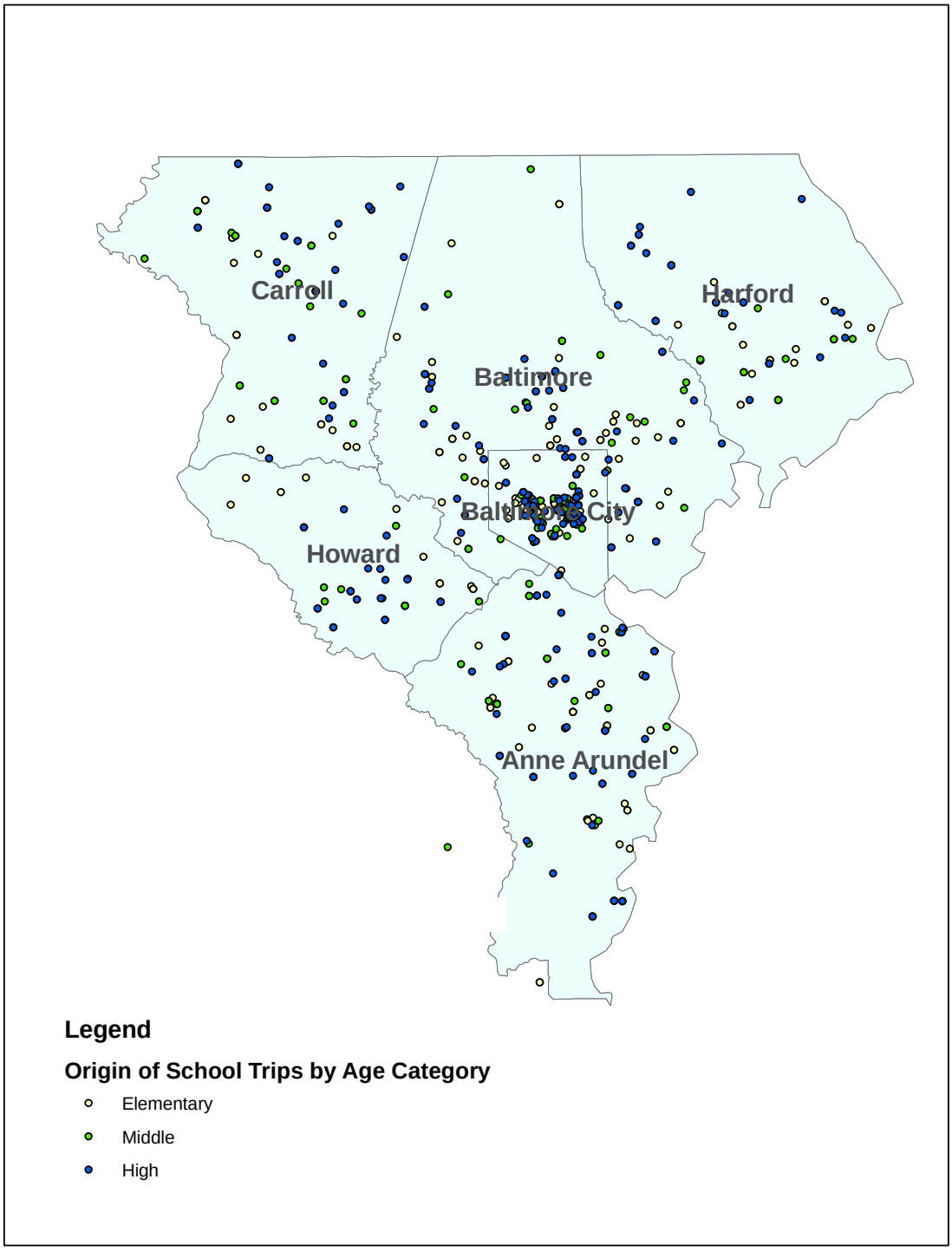

Figure 8: Distribution of School Trips by Age Category in the Baltimore Region

4.4.1 Additional Trip and Urban Environment Variables

Because of the geocode household locations and trip ends, a better spatial analysis is possible for the Baltimore Area data set. Based on existing literature, distance to school is an important control variable in mode choice models. For this dataset, the network distance from home to the school for each individual student was calculated.

In addition, the geocoded home location for each student, made it possible to create a variety of urban environment measures to be used in the analysis. To supplement the NHTS dataset, a number built environment measures were calculated using ArcGIS from archived data from the U.S. 2000 Census, Maryland Land Use Land Cover, Maryland Property View, and Maryland Transit View using geographic information systems.

The urban form measures calculated in this study include measures of density of the particular neighborhood of the student such as population density, housing density, job density, and percent of high and low dwelling residential units. These measures were calculated in GIS by overlaying the individual household locations with the U.S. Census track level data.

In addition, a one mile radius buffer was created around each household, which is considered the boundary for a decision maker's local area or neighborhood. Within the 1 mile buffer, built environment measures were calculated including percent of particular land use categories (e.g. percent of commercial developed area and percent of institutional developed area), measures of the transportation structure such as road density within the student's neighborhood and accessibility measures including

accessibility to metro and buses, and density of transit stops around the neighborhood. Maryland Property View provided by the Maryland Department of Planning, Transit View 2000 supplied by the Maryland Department of Transportation, and the U.S. Census Enhanced Tiger file layers were superimposed onto the NHTS household 1-mile buffers to compute these measures.

In addition measures of land use mix were calculated that indicate how homogenous or diverse the developed land around the neighborhood is. The land use mix measure chosen for this analysis was a diversity index, which measures the amount of various types of development (such as residential and commercial uses) around the one mile buffer of each student's household. The higher the value of the value of the variable, the more evenly distribution of land use.. Higher levels of mixed land use are often consistent with environments that support walking, such as the environments in traditional neighborhoods and urban centers, which tend to have a grid-like street network and better access to transit.

Chapter 5: Descriptive Analysis

5.1 Introduction

To understand the effects of children's out-of-home activities on a child's travel to school patterns and in particular the question of how children's participation in out-of-home activities affect their school tour type and mode choice to school we first understand how children travel.

The analysis presented in this chapter describes the children's travel patterns based on household travel survey data from the 2001 National Household Travel Survey (NHTS) as well the Baltimore Add-On dataset. First, this chapter presents the socio-economic characteristics of the sample of children that participated in the NHTS. Then an analysis of the trend of children's trips is discussed. Finally, descriptive analysis of the out-of-home activities of children in NHTS survey is presented, as well as its impact on school tours and mode to school.

5.2 Socio-economics of Children in the NHTS

There are 38,027 children (0 to 17 years of age) on the NHTS survey representing approximately a quarter (24%) of the sample. However, this study is only interested in a subset of the data where children are between the ages of 5 and 17 years and that have taken a trip to school on the day of the survey. This subsample of 13,210 children is the data used for the analysis presented in this chapter. From this point on, unless otherwise stated, any reference to the children/student population or study

participants refers to those between ages of 5 to 17 years and that reported taking a trip to school on the day of the survey. The age distribution among children in the survey is shown in Table 10. Out of the school age children that participated in the survey and went to school on the day of the survey, 51.5% were male and 48.5% were female.

Table 10: Distribution of NHTS sample by age group

Age Categories	N	Percent
Elementary (5-10)	5,923	44.8%
Middle (11-13)	3,229	24.4%
High (14-17)	4,058	30.7%

For the Baltimore Area, there were 616 children between the ages of 5 and 16 years that reported a school trip on the day of the survey. The age distribution among children in the Baltimore Area is shown in Table 11 and is very similarly distributed to the national sample. Out of the students in the Baltimore Area data set, 54.1 percent are male and 45.9 percent are female.

Table 11: Distribution of Baltimore Area sample by age group

Age Categories	N	Percent
Elementary (5-10)	273	44.3%
Middle (11-13)	154	25.0%
High (14-17)	189	30.7%

The distribution of race among children participants is approximately 81% white, 6% black, 4% Asian and 4% Hispanic (as shown in Table 12). The distribution of Baltimore Area students in this study is quite different as presented in Table 13. Only

71% of students in the Baltimore are white and almost 27% of students are black. No students in this study reported being of only Hispanic or other origin.

Table 12: Distribution of NHTS children by race

Age Categories	White	African American/ Black	Asian/Native Hawaiian/ Pacific Islander	American Indian/ Alaskan Native	Hispanic/ Mexican	Multi-racial	Other	Total
Elementary (5-10)	78.9% (4633)	6.1% (358)	4.3% (253)	0.4% (24)	5.3% (314)	5.0% (292)	0% (1)	100% (5875)
Middle (11-13)	80.7% (2591)	6.5% (209)	3.5% (111)	0.7% (22)	3.8% (123)	4.8% (153)	0% (0)	100% (3209)
High (14-17)	83.0% (3341)	6.1% (246)	3.3% (131)	0.5% (20)	2.8% (111)	4.4% (177)	0% (1)	100% (4027)
Total (5-17)	80.6% (10565)	6.2% (813)	3.8% (495)	0.5% (66)	4.2% (548)	4.7% (622)	0% (2)	100% (13111)

Table 13: Distribution of Baltimore Area children by race

Age Categories	White	African American/ Black	Asian/Native Hawaiian/ Pacific Islander	American Indian/ Alaskan Native	Hispanic/ Mexican	Multi-racial	Other	Total
Elementary (5-10)	69.5% (1189)	28.7% (78)	1.1% (3)	0 % (0)	0 % (0)	0.7% (2)	0 % (0)	100% (272)
Middle (11-13)	70.8% (109)	26.6% (41)	1.3% (2)	1.3% (2)	0 % (0)	0.6% (1)	0 % (0)	100% (154)
High (14-17)	74.1% (137)	23.8% (44)	0.5% (1)	0.5% (1)	0 % (0)	0% (0)	0 % (0)	100% (185)
Total (5-17)	71.2% (435)	26.7% (163)	1.0% (6)	1.0% (6)	0 % (0)	0.2% (1)	0 % (0)	100% (611)

The average household characteristics of the children in the national sample are shown in Table 14 by age group. Almost 30% of children in the study came from households with family incomes of less than $40,000; and 26.5% come from households with family income of over $80,000. Elementary school children in this study come from the highest percentage of low income households (32%) and the

lowest percentage of high income families (25%). The average household composition of children in this study show that on average children live in households of 4.39 members, with 2.33 children. Over 10.5% of children in the survey come from single parent households (households were only 1 adult is present), with the lowest percentage being for elementary school children at just over 9% and the highest being for middle school children at almost 12%. Almost 73% of children in the survey live in urban areas (based on the urban/rural indicator supplied by the NHTS survey) with an average population density of 3,347 people/square mile.

Regarding access to vehicles, only 3% of the children in the survey come from households with no personal vehicles and the average number of vehicles per household is 2.4. Not surprisingly, the highest percentage of children from families with no access to vehicles is the elementary school category, since vehicle ownership often correlates with higher family income. Over 76% of children in the survey come from households where the mother works, and 95% come from households were the father works. As expected, the percentage of children with working mothers goes up with age group (74%, 78% and 80% respectively for elementary, middle and high school kids).

The average household characteristics of the students in the Baltimore Area are shown in Table 15 by age group. This study area had a greater percentage of children in both the lowest and highest income categories than the national sample. Over 30% of children in the study came from households with family incomes of less than $40,000; and over 35% come from households with family income of over $80,000.

The average household composition of children in this study show that on average children live in households of 4.06 members, with 2.13 children, both measures slightly smaller than the national averages. In this area, over 21% of children in the survey come from single parent households (compared to 10.5% in the national sample), with the highest percentage being for elementary school children at over 23% and the lowest being for high school children at over 18%. In the Baltimore Area, over 86% of children in the survey live in urban areas (based on the urban/rural indicator supplied by the NHTS survey) with a significantly higher average population density (7,008 people/square mile) than the national average. Regarding access to vehicles, over 12% of the children from the Baltimore Area come from households with no personal vehicles (compared to only 3% for the national sample) and the average number of vehicles per household is 2 vehicles. Consistent with the national sample, the highest percentage of children from families with no access to vehicles is the elementary school category, since vehicle ownership often correlates with higher family income. Similar to the national sample, over 76% of children in the Baltimore Area come from households where the mother works, and 94% come from households were the father works. Interestingly for the Baltimore Area, the highest percentage of children with working mothers is the elementary school group with 78%.

Table 14: Average Household Characteristics by age group for National Sample

	HH Income		HH composition			Vehicle Ownership		Parent work status		Area Type	
Age Categories	<$40,000	>$80,000	HH Size	Number of Children in HH	% of Single Parent HH	Average HH Vehicle Count	% HH with no vehicle	% of HH where Mother Works	% of HH where Father Works	% of HH in urban area	Population Density (pop/sq.mi)
Elementary (5-10)	31.8%	25.3%	4.51	2.49	9.4%	2.2	3.3%	73.6%	95.4%	72.4%	3537
Middle (11-13)	30.7%	25.3%	4.42	2.38	11.7%	2.4	3.1%	77.8%	94.8%	70.1%	3320
High (14-17)	25.8%	29.4%	4.19	2.05	11.1%	2.7	2.2%	80.4%	95.1%	70.5%	3091
Total (5-17)	29.7%	26.5%	4.39	2.33	10.5%	2.4	2.9%	76.7%	95.2%	71.3%	3347

Table 15: Average Household Characteristics by age group for Baltimore Area

	HH Income		HH composition			Vehicle Ownership		Parent work status		Area Type	
Age Categories	<$40,000	>$80,000	HH Size	Number of Children in HH	% of Single Parent HH	Average HH Vehicle Count	% HH with no vehicle	% of HH where Mother Works	% of HH where Father Works	% of HH in urban area	Population Density (pop/sq.mi)
Elementary (5-10)	32.3%	33.5%	4.17	2.31	23.2%	1.8	12.1%	78.4%	94.8%	87.9%	7745
Middle (11-13)	31.7%	28.9%	4.06	2.14	22.2%	2.0	13.6%	74.3%	90.9%	85.7%	7383
High (14-17)	26.4%	40.8%	3.91	1.86	18.6%	2.3	11.1%	76.5%	96.1%	84.1%	5639
Total (5-17)	30.4%	34.6%	4.06	2.13	21.5%	2.0	12.2%	76.8%	94.2%	86.2%	7008

5.3 Trips made by children

The NHTS provides all the trips made on the day of the survey for each household member. The data in the national full NHTS sample shows that over 20% of the total number of trips in the survey were made by children (Table 16).

Table 16: Distribution of NHTS sample trips by age group

Age Categories	N	Percent
Nursery (0-4)	29,728	4.7
Elementary (5-10)	43,607	6.9
Middle (11-13)	23,076	3.6
High (14-17)	30,910	4.9
Adult (18+)	506,105	79.9
Total	633,426	100.0

The 2001 NHTS shows that children of all ages spend a significant amount of time traveling. For the entire NHTS sample, on average, children took 3.35 trips per day spent almost 1 hour (58 minutes) travelling every day. Table 17 shows the average daily travel statistics for the students used in this study (5 to 17 years of age and that went to school on the day of the survey). The students in this study, took an average of 3.7 trips per day and spent 59.7 minutes travelling on the day of the survey. The numbers shows that age has a significant relationship with number of trips and travel time. Not surprisingly, amount of time spent travelling per day increases with age

and average number of trips per day is similar for elementary and middle school and highest for high school students. Not only do children experience a significant amount of travel, but their travel also impacts the travel of others. On average the majority of children's trips (74%) are accompanied by others. Because younger children cannot travel alone, it is not surprising that the number of joint trips per day decreases with age as shown on Table 17.

Table 18 shows the average daily travel statistics for the Baltimore Area. In Baltimore, children overall make less trips but spend more time travelling than when looking at the national data. In addition, children in Baltimore make more independent trips than the national average.

Table 17: Average Daily Travel for school children in National Sample

Age Categories	Average number of trips per person	Average time travelled per person per day (minutes)	Average number of trips accompanied by other HH members	Average number of accompanied trips
Elementary (5-10)	3.58	54.61	2.69	2.97
Middle (11-13)	3.57	61.63	2.17	2.58
High (14-17)	3.95	65.55	1.69	2.46
Total	3.69	59.67	2.26	2.72

Table 18: Average Daily Travel for Baltimore Area

Age Categories	Average number of trips per person	Average time travelled per person per day (minutes)	Average number of trips accompanied by other HH members	Average number of accompanied trips
Elementary (5-10)	3.49	55.36	2.00	2.17
Middle (11-13)	3.43	68.59	1.42	1.56
High (14-17)	3.37	74.61	1.16	1.65
Total	3.44	64.57	1.60	1.86

5.3.1 Trips by Mode

As previously discussed in this study, there is a growing concern with the increasing automobile dependence, especially for children's travel. Attention has been given to finding ways to decrease the automobile dependence of children and encourage alternative modes of transportation, particularly active modes. To study this issue, first a comparison of the whole NHTS 1990 and 2001 survey populations show that overall there was a significant increase in the number of trips and time traveled by car for all age groups, as shown in Figure 9. In particular, there was 29% increase in average number of daily trips by car, which shows that people are in fact taking more trips. But a larger increase (48%) can be seen in the average time traveled by car, which shows that either distances are getting longer or that trips are more congested. It is also interesting to note is that there is a 65% increase in average time spent traveling with other household members by car, this disproportional increase may point to greater dependencies in travel between children and other members of the household.

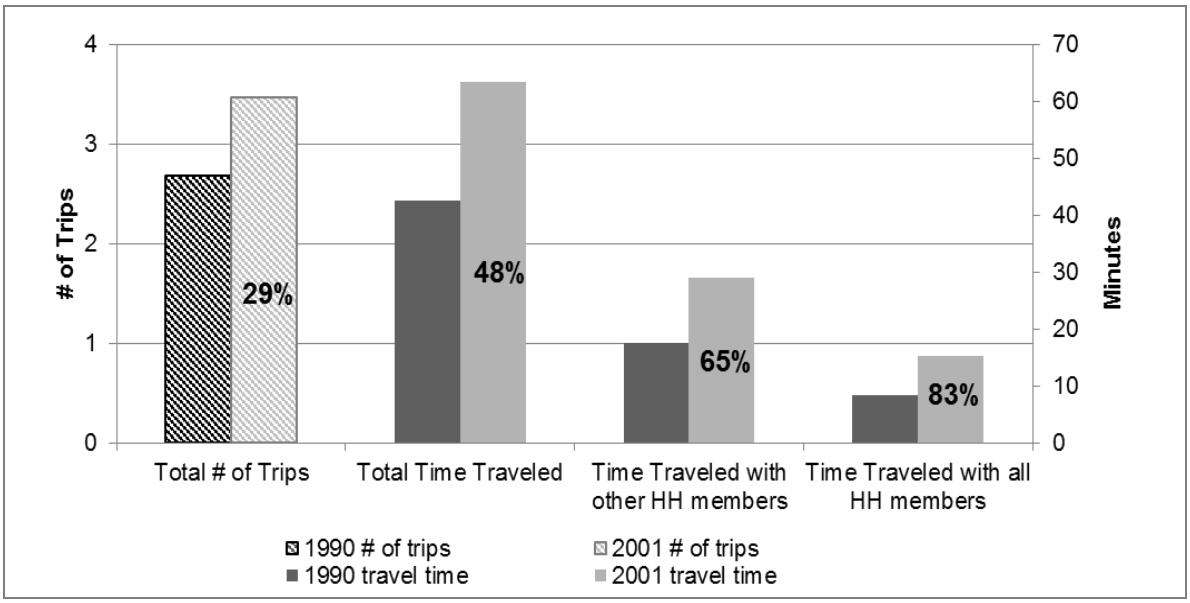

Figure 9: 1990 and 2001 comparison of daily trips and time traveled by car

To study these dependencies, a look at the 2001 data for all households with at least 2 members shows that in fact members of households with children take more car trips and spend more time in cars than their counterparts in households with no children present (Figure 10).

Figure 10 also shows the differences in children's car travel by age group which are important when trying to advise policy to combat auto-dependence. The total personal hours traveled (PHT) increases with age, however the curve by PHT by car shows a dip for children of elementary and middle school age groups. This is likely because they are at an age that they no longer need to be accompanied by their family members and may take a bus or walk to school or other activities. However, at the high school age group, they may switch back to the car, either because they have become drivers or because high schools are usually located further away and high

school students may rely more heavily in the automobile. Not surprisingly, when looking at the children age groups, time spent travelling with at least one family member decreases with age, since younger children are more likely to be accompanied on their trips.

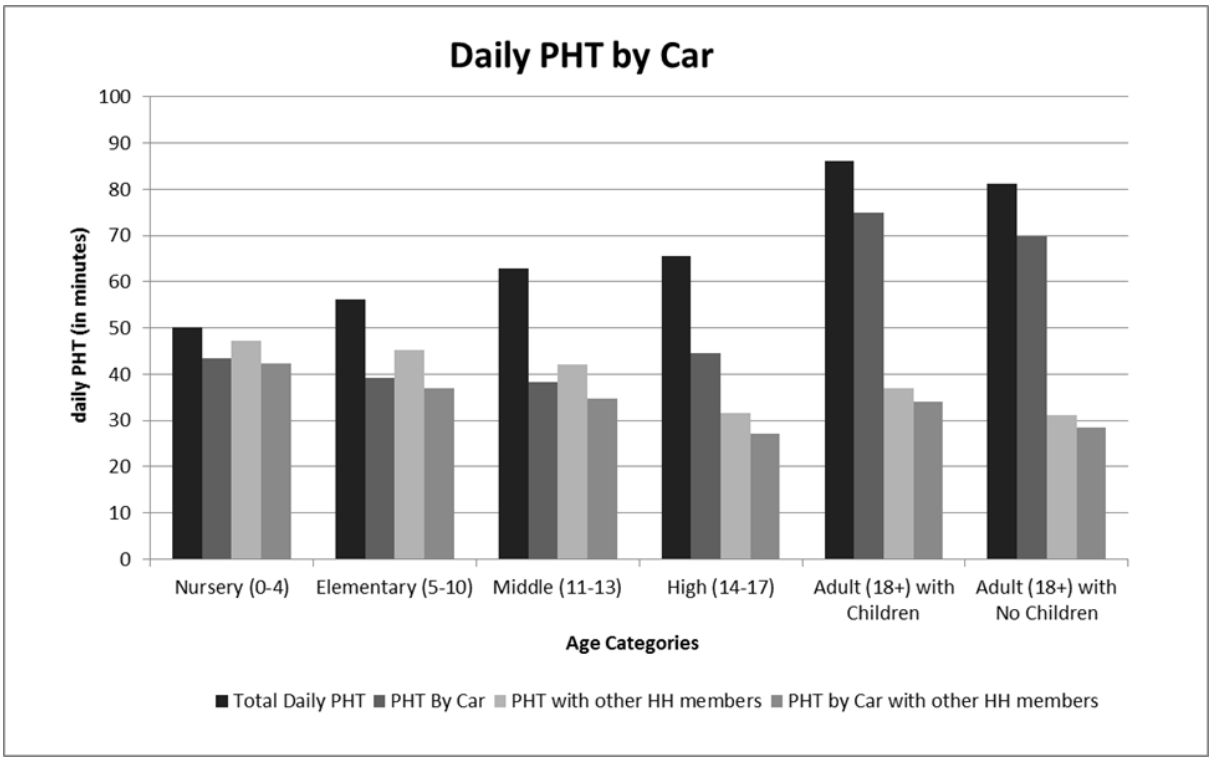

Figure 10: Average Personal Hours Traveled (PHT) by Age

Since automobile dependence has been increasing, and children's trips account for a significant part of household travel, a look at children's automobile dependence is important. Table 19 shows that for school children of every age group, a significant percentage of trips are made by car. The data also shows that children in the middle school age category are the least dependent on the automobile. This is likely because middle school children are allowed to walk alone or with friends but cannot yet drive. Table 20 shows the results for the Baltimore Area school children. Overall, children in the Baltimore area are less dependent on the car than the national average. Like

the national sample, middle school children in the Baltimore Area are the least dependent on the car.

Table 19: Percentage of Car Trips by Age Group – National Sample

Age Categories	Number of Trips per person	Number of Car Trips per person	% of Car Trips
Elementary (5-10)	3.58	2.25	62.8%
Middle (11-13)	3.57	1.88	52.7%
High (14-17)	3.95	2.74	69.5%
Total	3.69	2.31	62.6%

Table 20: Percentage of Car Trips by Age Group – Baltimore Area

Age Categories	Number of Trips per person	Number of Car Trips per person	% of Car Trips
Elementary (5-10)	3.49	2.17	62.2%
Middle (11-13)	3.43	1.56	45.6%
High (14-17)	3.37	2.06	61.2%
Total	3.44	1.99	57.8%

For trips to school, the same trend appears where middle school children are the least dependent on the automobile for both the national data and the Baltimore Area. In fact, Table 21 shows that out of middle school children in the national NHTS survey, over 46% take the school bus and only 39% take a car to school. For the Baltimore sample, the numbers are even more prominent (Table 22), over 55% of middle school children take either the school bus or transit to school. For the other age groups, the automobile is still the prominent mode of transportation to school; however there are significant percentages of children who take alternate modes of transportation in their travel to school.

Table 21: Mode to School – National Sample

Age Categories	Mode of School Trip						Total
	Auto	Transit (non-school bus)	School Bus	Walk	Bike	Other	
Elementary (5-10)	2875	42	2225	710	52	17	5117
	48.6%	0.7%	37.6%	12.0%	0.9%	0.3%	100.0%
Middle (11-13)	1262	55	1498	358	43	10	3223
	39.1%	1.7%	46.4%	11.1%	1.3%	0.3%	100.0%
High (14-17)	2429	142	1123	324	26	14	4055
	59.9%	3.5%	27.7%	8.0%	0.6%	0.3%	100.0%
Total	6566	239	4846	1392	121	41	14043
	49.7%	1.8%	36.7%	10.5%	0.9%	0.3%	100.0%
Statistically Significant at the 99% confidence level							

Table 22: Mode to School – Baltimore Area

Age Categories	Mode of School Trip					Total
	Auto	Transit (non-school bus)	School Bus	Walk	Bike	
Elementary (5-10)	128	11	77	56	1	273
	46.9%	4.0%	28.2%	20.5%	.4%	100.0%
Middle (11-13)	51	17	69	17	0	154
	33.1%	11.0%	44.8%	11.0%	.0%	100.0%
High (14-17)	94	24	58	13	0	189
	49.7%	12.7%	30.7%	6.9%	.0%	100.0%
Total	273	52	204	86	1	616
	44.3%	8.4%	33.1%	14.0%	.2%	100.0%
Statistically Significant at the 99% confidence level						

The analysis presented so far on the impact that children have in the overall travel of the household and on children's auto-dependence, calls for further study on children's travel by looking at their destinations or activities.

5.4 Children's Out-of-Home Activities

As discussed previously, the NHTS is a trip based survey and does not contain information on children's activities. However, out-of-home activities were extrapolated from the NHTS trip data as explained in Chapter 4. Table 23 shows the breakdown of the average daily out-of-home activities by activity type and age category for all children surveyed (0 to 17 years of age), including children surveyed in weekends or summer months and children that did not make any trips on the day of the survey. The data shows that children's out-of-home activities can have an impact in their travel patterns. On average, children engage in about 2.1 out-of-home activities that they need to travel to each day. Although studying children's school trips are important, the majority of their out-of-home activities are not school related; only about 18.5% of out-of-home activities are attending school. About 34% of out-of-home activities are social activities (such as dinning out, going to a friend's house and exercising) 34% are shopping or personal (such as doctor's visit, buying services and using professional services). From these data, we cannot discern whether the activity is for the benefit of the child or if the child is accompanying a parent on their out-of-home activities, however, the fact still remains that the child does participate in those activities and therefore these activities impact their travel patterns. Consequently, attention must be given to out-of-home activities that children engage in other than school and how children travel to those activities.

Table 23: Mean Daily Out-of-home Activities for all NHTS children

Age Categories	Total Average # of Out-of-home Activities	School	Shop/ Personal	Social	Passenger Serve	Work	Other
Nursery (0-4)	1.97	0.09 (4.64%)	0.87 (44.27%)	0.64 (32.35%)	0.33 (16.75%)	0.00 (0.00%)	0.04 (1.99%)
Elementary (5-10)	2.13	0.48 (22.51%)	0.70 (33.14%)	0.71 (33.51%)	0.19 (9.14%)	0.00 (0.00%)	0.04 (1.70%)
Middle (11-13)	2.12	0.50 (23.47%)	0.66 (31.26%)	0.77 (36.11%)	0.15 (6.94%)	0.00 (0.22%)	0.04 (2.00%)
High (14-17)	2.29	0.52 (22.92%)	0.66 (28.71%)	0.78 (33.88%)	0.17 (7.23%)	0.13 (5.63%)	0.04 (1.62%)
Total	2.12	0.39 (18.53%)	0.73 (34.38%)	0.72 (33.79%)	0.21 (10.09%)	0.03 (1.40%)	0.04 (1.80%)

The information in Table 23 shows the average number of activities extrapolated from all days in the NHTS survey. Table 24 shows the results of looking at children's out-of-home activities for only the children who are of school age (5-17 years of age) and who went to school on the day of the survey. Even when just looking at out-of-home activities for these students, school activities account for less than 50% of children's out-of-home activities. Similarly, Table 25 shows the average out-of-home activities for the Baltimore Area. In the Baltimore Area, just over 50% of out-of-home activities are school activities. These results reinforce the need to analyze out-of-home activities that children participate in (other than school) to understand their travel behaviors and consequently the travel patterns of the household.

Table 24: Mean Daily Out-of-Home Activities for school children – National Sample

Age Categories	Total Average # of Out-of-home Activities	School	Shop/ Personal	Social	Passenger Serve	Work	Other
Elementary (5-10)	2.16	1.05 (48.27%)	0.44 (20.33%)	0.44 (20.19%)	0.20 (9.21%)	0.00 (0.00%)	0.04 (2.00%)
Middle (11-13)	2.11	1.05 (49.66%)	0.38 (18.08%)	0.48 (22.69%)	0.15 (6.98%)	0.00 (0.15%)	0.05 (2.43%)
High (14-17)	2.40	1.10 (45.90%)	0.44 (18.16%)	0.56 (23.13%)	0.17 (7.04%)	0.10 (4.23%)	0.04 (1.53%)
Total	2.23	1.06 (47.80%)	0.42 (19.09%)	0.48 (21.75%)	0.18 (7.97%)	0.03 (1.44%)	0.04 (1.95%)

Table 25: Mean Daily Out-of-Home Activities for school children – Baltimore Area

Age Categories	Total Average # of Out-of-home Activities	School	Shop/ Personal	Social	Passenger Serve	Work	Other
Elementary (5-10)	2.14	1.05 (49.32%)	0.44 (15.92%)	0.44 (20.03%)	0.20 (7.71%)	0.00 (0.00%)	0.04 (7.02%)
Middle (11-13)	1.98	1.04 (52.46%)	0.36 (18.03%)	0.42 (20.98%)	0.12 (5.90%)	0.01 (0.33%)	0.05 (2.30%)
High (14-17)	1.96	1.03 (52.43%)	0.32 (16.49%)	0.40 (20.27%)	0.11 (5.41%)	0.06 (3.24%)	0.04 (2.16%)
Total	2.04	1.04 (50.99%)	0.34 (16.60%)	0.42 (20.33%)	0.13 (6.59%)	0.02 (1.03%)	0.09 (4.45%)

5.4.1 Children's out-of-home activities and auto-dependence

An interesting question is whether out-of-home activities contribute to children's auto dependence. Figure 11 shows the percent auto mode share by the number of out-of-home activities for all NHTS survey participants. Not surprisingly, nursery school age children and adults have similar curves since these children are traveling most of the time with an adult in the household. These two curves show that these age groups are very dependent on the automobile. For children ages 5 through 17, there is a

greater difference between those children that participate in more out-of-home activities. Middle school children are the least dependent in the automobile. Figure 11 shows that as children participate in more out-of-home activities per day, they are more likely to depend on the car as their mode of transportation.

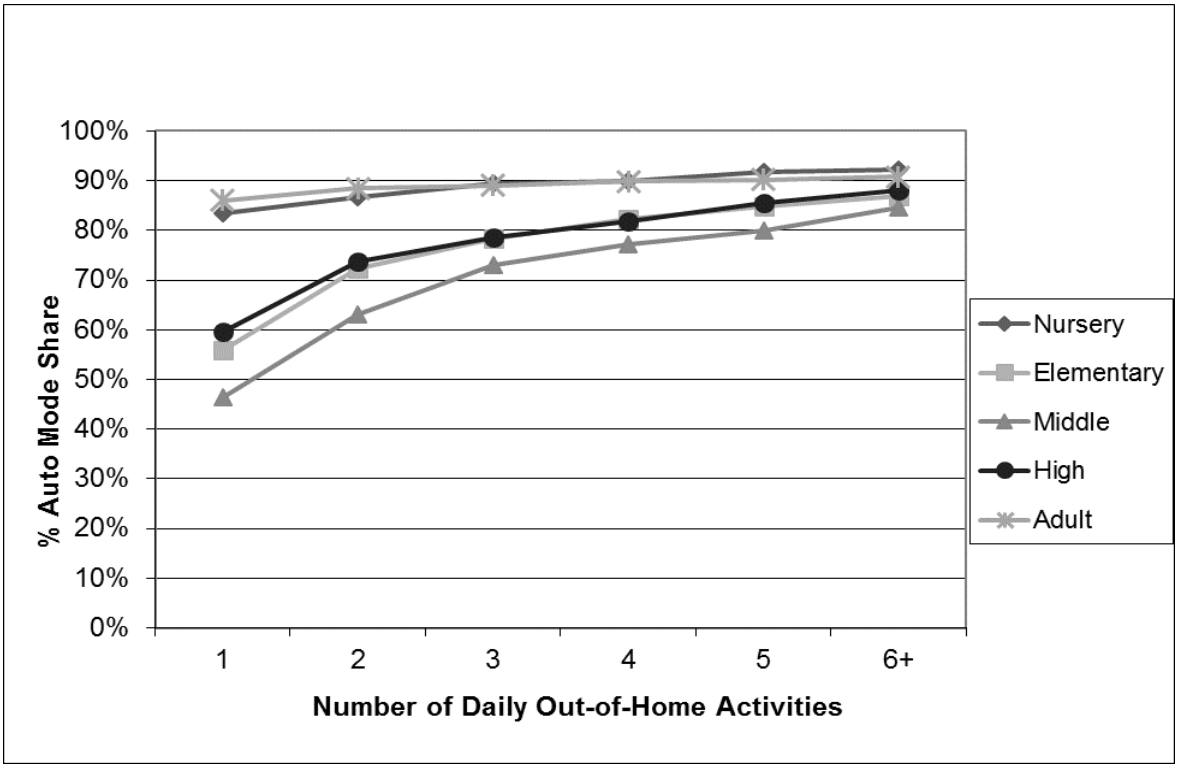

Figure 11: Distribution of Auto Mode Share by Number of Out-of-home activities

As we study children's travel to school and the impact of out-of-home activities on their auto dependence, the question arises to whether the participation of out-of-home activities is happening within the school tour or not.

5.4.2 Tour to School

To research children's school tours, this study analyzed school age children (5 to 17 years of age) that participated in the NHTS that had at least one trip to school on the

day of the survey. The focus of the analysis was to study children's school tours and the mode chosen by students for the trip to school. As described previously in this dissertation, school tours are defined as linked trips that begin at home and include travel to school as well as any other activities before returning home. For the purposes of this study, all school tour types were categorized as four types of tours:

- **H-S-H**
- **H-S**-O-**H**
- **H**-O-**S-H**
- **H**-O-**S**-O-**H**

Where: H=home; S=school, O=other non-school out-of home activities and where O activities may include more than one activity.

For school age children who participated in the NHTS survey and took a trip to school on the day of the survey, the majority (73%) took an H-S-H tour. However, a significant number of students (over 27%) took trips before or after school to another destination before returning home (H-O-S-H, H-S-O-H or H-O-S-O-H). The total distribution on school tours are shown in Table 26. For the Baltimore Area, the distribution is very similar to the national sample as seen in Table 27.

Table 26: Frequency of School Tours for children 5-17 years of age from the NHTS

Tours	Frequency	Percent
HSH	9604	72.7%
HOSH	572	4.3%
HSOH	2406	18.2%
HOSOH	628	4.8%

Table 27: Frequency of School Tours for children 5-17 years of age in the Baltimore Area

Tours	Frequency	Percent
HSH	441	71.6%
HOSH	35	5.7%
HSOH	112	18.2%
HOSOH	28	4.5%

By looking at the distribution of school tours by all children age groups (0 to 17 years of age), Table 28 shows statistically significant results where middle school children have the greatest percentage of children that take H-S-H tours (over 76%) and the lowest percentage of children that take HSOH tours (15.5%) when compared to the other age groups. Not surprisingly, the reverse is the case for nursery school children who are likely taken to school by a parent and therefore more likely to make a stop on their way home from school with the parent. Because nursery school children are very dependent on the travel of the parents and have little choice on their activities or mode of travel, the remainder of this study will concentrate on the travel of children ages 5 through 17 years of age.

Table 28: School Tours by Age Group from the NHTS

Age Group	HOSH	HOSOH	HSH	HSOH	Total
Nursery (0-5)	52	79	531	188	850
	(6.1%)	(9.3%)	(62.5%)	(22.1%)	(100.0%)
Elementary (6-10)	253	346	4218	1106	5923
	(4.3%)	(5.8%)	(71.2%)	(18.7%)	(100.0%)
Middle (11-13)	142	127	2459	501	3229
	(4.4%)	(3.9%)	(76.2%)	(15.5%)	(100.0%)
High (14-17)	177	155	2927	799	4058
	(4.4%)	(3.8%)	(72.1%)	(19.7%)	(100.0%)
Total	624	707	10135	2594	14060
	(4.4%)	(5.0%)	(72.1%)	(18.4%)	(100.0%)
Statistically Significant at the 99% confidence level					

The NHTS dataset provides the type of mode used in each particular trip that the respondent took on the day of the survey. An analysis of children's mode to school by age category was shown previously in Table 21. However, for the purposes of this study, we are only interested in children's auto-dependence and therefore will only model whether a child took a personal vehicle or some other mode of transportation (on the trip to school). Table 29 shows the distribution of school tours by mode used to school and age group. Although for both car and other modes, the majority of students made a HSH school tour, the results show that a larger percentage of students made a HSH tour when using alternate modes of transportation other than the car (81% for other modes; 64% for car). Furthermore, when comparing the distribution of tours for children who drove to school and those who took alternate modes, almost double of the car users (35%) chose school tours with activities within the tour, when compared to non-car users (19%). This points to a relationship between engaging in activities before and after school and mode chosen to travel to school. For the Baltimore Area, the story is similar (Table 30). A larger percentage of children who used non-auto transportation to school, chose an HSH tour (77% when compared to other tours) and then children who used a car to school (less than 65% of children who used a car chose a HSH tour).

Table 29: School Tours and Mode for the National Sample

Mode to School	Age Group	HSH	HOSH	HSOH	HOSOH	Total
Other Mode	Elementary (5-10)	2413 (79.2%)	102 (3.3%)	364 (12.0%)	167 (5.5%)	3046 (100%)
	Middle (11-13)	1640 (83.5%)	45 (2.3%)	212 (10.8%)	67 (3.4%)	1964 (100%)
	High (14-17)	1329 (81.6%)	41 (2.5%)	215 (13.2%)	44 (2.7%)	1629 (100%)
	Total	**5382 (81.1%)**	**188 (2.8%)**	**791 (11.9%)**	**278 (4.2%)**	**6317 (100%)**
Auto	Elementary (6-10)	1805 (62.8%)	151 (5.3%)	740 (25.7%)	179 (6.2%)	2875 (100%)
	Middle (11-13)	817 (64.7%)	96 (7.6%)	289 (22.9%)	60 (4.8%)	1262 (100%)
	High (14-17)	1598 (65.8%)	136 (5.6%)	584 (24.0%)	111 (4.6%)	2429 (100%)
	Total	**4220 (64.3%)**	**383 (5.8%)**	**1613 (24.6%)**	**350 (5.3%)**	**6566 (100%)**
Statistically Significant at the 95% confidence level						

Table 30: School Tours and Mode for the Baltimore Area

Mode to School	Age Group	HSH	HOSH	HSOH	HOSOH	Total
Other Mode	Elementary (5-10)	102 (70.3%)	5 (3.4%)	26 (17.9%)	12 (8.3%)	145 (100%)
	Middle (11-13)	87 (84.5%)	2 (1.9%)	8 (7.8%)	6 (5.8%)	103 (100%)
	High (14-17)	75 (78.9%)	4 (4.2%)	14 (14.7%)	2 (2.1%)	95 (100%)
	Total	**264 (77.0%)**	**11 (3.2%)**	**48 (14.0%)**	**20 (5.8%)**	**343 (100%)**
Auto	Elementary (6-10)	75 (58.6%)	8 (6.3%)	40 (31.3%)	5 (3.9%)	128 (100%)
	Middle (11-13)	33 (64.7%)	6 (11.8%)	10 (19.6%)	2 (3.9%)	51 (100%)
	High (14-17)	69 (73.4%)	10 (10.6%)	14 (14.9%)	1 (1.1%)	94 (100%)
	Total	**177 (64.8%)**	**24 (8.8%)**	**64 (23.4%)**	**8 (2.9%)**	**273 (100%)**
Statistically Significant at the 95% confidence level						

5.5 Descriptive Statistics for School Tours and Mode to School

To analyze the variables that may influence the school tours and mode to school, this study looks at socio-demographic variables (gender, race, age, family income), parent's work status, vehicle ownership, and land use of the child's home neighborhood. The descriptive statistics for school tours are shown in Table 31 for the national sample and Table 33 for the Baltimore Area. Similarly, the descriptive statistics for mode to school are shown in Table 32 for the national sample and Table 34 for the Baltimore Area.

5.5.1 Gender

Statistical significant results for school age children show that a greater percentage of male students (3.1 percentage points higher) take a HSH (home-school-home) tour to school, compared to their female counterparts. These statistics may indicate that female students are more likely to engage in non-school out-of-home activities within their school tour. Statistically significant results show that a greater percentage of male children took other modes of transportation other than a personal vehicle than female students (almost 52% for male students and less than 49% for female students). Interestingly, for the Baltimore Area, although the same trend is seen as the national sample, gender differences are not statistically significant.

5.5.2 Age

Age shows statistical significant results for both tour type and mode choice. For the national sample, elementary school children are the most likely to engage in activities within the school tour (1 percentage point higher than high school students and 5

percentage points higher than middle school children). Although the differences are not large they are statistically significant. In the Baltimore Area, the differences are much greater. Elementary school children are the most likely to have an activity within the school tour (35%), compared to less than 25% for high and middle school children.

Regarding auto-dependence for the national sample, middle school children are the least dependent in the automobile with over 60% taking alternatives modes of transportation on the trip to school. Not surprisingly, high school children are the most dependent on the automobile (almost 60% take a car to school). This is likely because a portion of high school children are of driving age. For the Baltimore Area, all age groups are more likely to take alternative modes of transportation other than the car (less than 50% of students take a car on the trip to school). Like the national sample, Baltimore Area high school students are more likely to take a car to school (almost 50%) when compared to elementary school and middle school children (47% and 33% respectively).

5.5.3 Race

A lesser percentage of white students participate in an H-S-H tour to school than any other race in the national sample. These numbers may indicate that white students are more likely to participate in out-of home activities within their school tours. For the Baltimore sample race shows insignificant results.

Statically significant results show that for the elementary and middle school students, the Asian/ Native Hawaiian/Pacific Islander category had the highest percentage of

students that used the personal automobile to school (over 59%), followed by the white student category (51%). Other race categories had significantly lower percentages of car use to school (43% or less), with the African American/Black category having the lowest (less than 35%).

Student in the Baltimore Area follow the same trend with the Asian/ Native Hawaiian/Pacific Islander and white student population having a higher dependence on the automobile to school (67% and 51% respectively used the automobile on the trip to school) and the black student and multi-racial student populations having a much lower percentages, 26% and 17% respectively. Although the American Indian/Alaskan native category has the highest percentage of auto-dependence, this number is suspect as there is only one case in this category.

5.5.4 Income

Regarding annual family income, statistical significant results show that for the national sample, as the annual family income increases, there is a decrease in the percentage of students that use a H-S-H tour to school, therefore we may infer that children who come from families with higher incomes are more likely to engage in out-of-home activities within the school tour. Not surprisingly, the statistically significant results show that as the family income increases, the percentage of children who take a personal vehicle to school also increases.

For the Baltimore Area students, there is a less significant relationship with tour choice. Children from households of income between $40,000 and $59,999 have the highest percentage of H-S-H school tours. These results are only significant to the

90% level of confidence. Like the national sample, students from households of lower incomes are less likely to take the car to school than those from higher income categories.

5.5.5 Household Composition

Children from two-parent household families are more likely to make a H-S-H tour to school than those from single parent households for both the national and Baltimore Area samples (although the difference is greater in the national sample, at 4 percentage points, compared to only a 0.5 percentage point difference for the Baltimore Area case study).

Children from single parent households are less auto dependent on their travel to school. This is possibly due to the fact single parent households do not have another adult to share chauffeuring duties and therefore children from those households are more likely to take alternative modes of transportation to school.

5.5.6 Parent Work Status

Both mother and father's employments have an effect of the choices of school tour for children in the national sample. Children from households where the mother and father work are more likely to have school tours with activities within the tour for both the national and Baltimore samples.

Children from households where the father does not work, are more likely to take other modes of transposition other than the car for both the national and Baltimore samples (54% and 72% respectively). For mother employment, statistically

significant results are only present for the national sample, where 52.5% of students from households where the mother does not work take alternative modes of transportation to school.

These statistics may imply that when a parent works, they have additional time constraints and therefore use the car to take their children to school, possibly on their way to work. Similarly, children from households with working parents are more likely to trip chain and engage in activities within the school tour as they may not have time to go home before engaging in other out-of home activities.

5.5.7 Vehicle Ownership

Statistical significant results show that for both the national and Baltimore datasets, children from households that own at least 1 vehicle are less likely to use a H-S-H tour to school (Baltimore Case Study results are not statistically significant). These numbers may point to the fact that children that have access to personal vehicles may be less constrained to make a HSH tour to school and therefore may have more options to make school tours with activities within the tour (HOSH, HSOH and HOSOH). As expected, children from households that have at least 1 vehicle are significantly more likely to use a car on their trip to school than students whose household does not own a vehicle.

5.5.8 Land Use

For the national sample, population density of the track where the student resides was used as a measure of land use. Regarding population density, those students that

reside in high density (over 10,000 people per square mile) show the highest percentages of using an H-S-H tour to school. In regards to mode to school, students in the high density category are the most likely to use other modes to school other than the car, followed by the students in the low density category (<1,000 persons per square mile).

For the Baltimore Area case study, there is geocoded information provided for the individual's household and trip ends. Therefore, other measures of the built environment were calculated to test the effect of the built environment on school travel choices. Regarding population density, contrary to the results of the national sample, those students that reside in high density areas (over 10,000 people per square mile) show the lowest percentages of using an H-S-H tour to school. In regards to mode to school, students in the high density category are the most likely to use other modes to school other than the car. High density areas are often associated with higher levels of mixed-use, better accessibility to other modes of transportation and better walking infrastructure. Measures of land use mix and accessibility to transit were calculated for this dataset. Although not statistically significant, the results of the built environment measures of mix-use level and accessibility to transit support the findings for the population density measure. Students living in areas with higher levels of mixed land use are less likely to make an H-S-H school tour, possibly due to more opportunities of activities on the way to and from school. However, students with accessibility to transit are more likely to make an H-S-H tour to school, but again, these results are not statically significant. In regards to mode choice, not

surprisingly, students living in areas with higher levels of land use mix and better transit accessibility are less dependent on the car for their trip to school.

Table 31: School Tours Statistics for School Children from the National Sample

		HSH	HOSH	HSOH	HOSOH	Total
Gender ***	Male	5044	285	1158	309	6796
		74.2%	4.2%	17.0%	4.5%	100.0%
	Female	4559	287	1247	319	6412
		71.1%	4.5%	19.4%	5.0%	100.0%
Age ***	Elementary (5-10)	4218	1106	253	346	5923
		71.2%	18.7%	4.3%	5.8%	100.0%
	Middle (11-13)	2459	501	142	127	3229
		76.2%	15.5%	4.4%	3.9%	100.0%
	High (14-17)	2927	799	177	155	4058
		72.1%	19.7%	4.4%	3.8%	100.0%
Race ***	White	7558	465	1998	544	10565
		71.5%	4.4%	18.9%	5.1%	100.0%
	African American/Black	616	31	145	21	813
		75.8%	3.8%	17.8%	2.6%	100.0%
	Asian/Native Hawaiian/Pacific Islander	378	19	75	23	495
		76.4%	3.8%	15.2%	4.6%	100.0%
	American Indian/Alaskan Native	57	1	8	0	66
		86.4%	1.5%	12.1%	.0%	100.0%
	Hispanic/Mexican	434	24	71	19	548
		79.2%	4.4%	13.0%	3.5%	100.0%
	Multi-racial	483	26	95	18	622
		77.7%	4.2%	15.3%	2.9%	100.0%
	Other	1	0	1	0	2
		50.0%	.0%	50.0%	.0%	100.0%
Annual Family Income ***	<$20,000	965	49	153	44	1211
		79.7%	4.0%	12.6%	3.6%	100.0%
	$20,000 - $39,999	1880	101	449	108	2538
		74.1%	4.0%	17.7%	4.3%	100.0%
	$40,000 - $59,999	2317	149	594	158	3218
		72.0%	4.6%	18.5%	4.9%	100.0%
	$60,000 - $79,000	1654	97	428	122	2301
		71.9%	4.2%	18.6%	5.3%	100.0%
	>$80,000	2341	148	689	172	3350
		69.9%	4.4%	20.6%	5.1%	100.0%

		HSH	HOSH	HSOH	HOSOH	Total
Household Composition - Single Parent HH ***	No	8639	491	2134	551	11815
		73.1%	4.2%	18.1%	4.7%	100.0%
	Yes	956	81	271	76	1384
		69.1%	5.9%	19.6%	5.5%	100.0%
Parent Work Status-Father Works **	No	438	17	88	21	564
		77.7%	3.0%	15.6%	3.7%	100.0%
	Yes	8080	497	2034	532	11143
		72.5%	4.5%	18.3%	4.8%	100.0%
Parent Work Status-Mother Works ***	No	2330	112	451	99	2992
		77.9%	3.7%	15.1%	3.3%	100.0%
	Yes	6976	444	1895	520	9835
		70.9%	4.5%	19.3%	5.3%	100.0%
Vehicle Ownership ***	No	316	12	49	9	386
		81.9%	3.1%	12.7%	2.3%	100.0%
	Yes	9288	560	2357	619	12824
		72.4%	4.4%	18.4%	4.8%	100.0%
Pop Density *	Low (<1,000)	4698	272	1235	319	6524
		72.0%	4.2%	18.9%	4.9%	100.0%
	Medium (1,000 - 10,000)	4256	266	1007	283	5812
		73.2%	4.6%	17.3%	4.9%	100.0%
	High (>10,000)	650	34	164	26	874
		74.4%	3.9%	18.8%	3.0%	100.0%

Note: *Statistically significant at the 10% level, ** Statistically significant at the 5% level, *** Statistically significant at the 1% level

Table 32: Mode to School Statistics for School Children from the National Survey

		Other	Auto	Total
Gender	Male	3514	3281	6795
***		51.7%	48.3%	100.0%
	Female	3124	3284	6408
		48.8%	51.2%	100.0%
Age	Elementary (5-10)	3046	2875	5921
***		51.4%	48.6%	100.0%
	Middle (11-13)	1964	1262	3226
		60.9%	39.1%	100.0%
	High (14-17)	1629	2429	4058
		40.1%	59.9%	100.0%
Race	White	5176	5386	10562
***		49.0%	51.0%	100.0%
	African American/Black	532	281	813
		65.4%	34.6%	100.0%
	Asian/Native Hawaiian/Pacific Islander	201	294	495
		40.6%	59.4%	100.0%
	American Indian/Alaskan Native	39	27	66
		59.1%	40.9%	100.0%
	Hispanic/Mexican	311	235	546
		57.0%	43.0%	100.0%
	Multi-racial	337	285	622
		54.2%	45.8%	100.0%
Annual Family Income	<$20,000	783	426	1209
***		64.8%	35.2%	100.0%
	$20,000 - $39,999	1415	1122	2537
		55.8%	44.2%	100.0%
	$40,000 - $59,999	1618	1600	3218
		50.3%	49.7%	100.0%
	$60,000 - $79,000	1115	1185	2300
		48.5%	51.5%	100.0%
	>$80,000	1419	1930	3349
		42.4%	57.6%	100.0%
Household Composition -	No	5840	5971	11811
		49.4%	50.6%	100.0%
Single Parent HH	Yes	790	593	1383
***		57.1%	42.9%	100.0%
Parent Work Status- Father Works	No	304	259	563
		54.0%	46.0%	100.0%
*	Yes	5555	5584	11139
		49.9%	50.1%	100.0%

		Other	Auto	Total
Parent Work Status- Mother Works ***	No	1569	1422	2991
		52.5%	47.5%	100.0%
	Yes	4879	4952	9831
		49.6%	50.4%	100.0%
Vehicle Ownership ***	No	343	42	385
		89.1%	10.9%	100.0%
	Yes	6296	6524	12820
		49.1%	50.9%	100.0%
Pop Density ***	Low (<1,000)	3507	3014	6521
		53.8%	46.2%	100.0%
	Medium (1,000 - 10,000)	2552	3259	5811
		43.9%	56.1%	100.0%
	High (>10,000)	580	293	873
		66.4%	33.6%	100.0%

Note: *Statistically significant at the 10% level, ** Statistically significant at the 5% level, *** Statistically significant at the 1% level

Table 33: School Tours Descriptive Statistics for School Children – Baltimore Area

		HSH	HOSH	HSOH	HOSOH	Total
Gender	Male	240	18	61	14	333
		72.1%	5.4%	18.3%	4.2%	100.0%
	Female	201	17	51	14	283
		71.0%	6.0%	18.0%	4.9%	100.0%
Age ***	Elementary (5-10)	177	13	66	17	273
		64.8%	4.8%	24.2%	6.2%	100.0%
	Middle (11-13)	120	8	18	8	154
		77.9%	5.2%	11.7%	5.2%	100.0%
	High (14-17)	144	14	28	3	189
		76.2%	7.4%	14.8%	1.6%	100.0%
Race	White	311	25	78	21	435
		71.5%	5.7%	17.9%	4.8%	100.0%
	African American/Black	116	7	33	7	163
		71.2%	4.3%	20.2%	4.3%	100.0%
	Asian/Native Hawaiian/Pacific Islander	4	2	0	0	6
		66.7%	33.3%	.0%	.0%	100.0%
	American Indian/Alaskan Native	1	0	0	0	1
		100.0%	.0%	.0%	.0%	100.0%
	Multi-racial	5	1	0	0	6
		83.3%	16.7%	.0%	.0%	100.0%
Annual Family Income *	<$20,000	44	0	14	1	59
		74.6%	.0%	23.7%	1.7%	100.0%
	$20,000 - $39,999	79	4	27	4	114
		69.3%	3.5%	23.7%	3.5%	100.0%
	$40,000 - $59,999	75	3	15	5	98
		76.5%	3.1%	15.3%	5.1%	100.0%
	$60,000 - $79,000	71	6	15	10	102
		69.6%	5.9%	14.7%	9.8%	100.0%
	>$80,000	137	16	36	8	197
		69.5%	8.1%	18.3%	4.1%	100.0%
Household Composition - Single Parent HH ***	No	344	33	77	27	481
		71.5%	6.9%	16.0%	5.6%	100.0%
	Yes	95	2	34	1	132
		72.0%	1.5%	25.8%	.8%	100.0%
Parent Work Status-Father Works	No	21	2	2	0	25
		84.0%	8.0%	8.0%	.0%	100.0%
	Yes	283	32	68	24	407
		69.5%	7.9%	16.7%	5.9%	100.0%
Parent Work Status-Mother Works	No	104	5	22	5	136
		76.5%	3.7%	16.2%	3.7%	100.0%
	Yes	315	25	87	23	450
		70.0%	5.6%	19.3%	5.1%	100.0%
Vehicle Ownership	No	56	1	15	3	75
		74.7%	1.3%	20.0%	4.0%	100.0%
	Yes	385	34	97	25	541
		71.2%	6.3%	17.9%	4.6%	100.0%
Pop Density *	Low (<1,000)	126	8	27	9	126
		74.1%	4.7%	15.9%	5.3%	74.1%
	Medium (1,000 - 10,000)	222	21	49	11	222
		73.3%	6.9%	16.2%	3.6%	73.3%
	High (>10,000)	93	6	36	8	93
		65.0%	4.2%	25.2%	5.6%	65.0%

		HSH	HOSH	HSOH	HOSOH	Total
Mixed Use	Low	82	2	18	6	108
		75.9%	1.9%	16.7%	5.6%	100.0%
	Medium	121	6	31	5	163
		74.2%	3.7%	19.0%	3.1%	100.0%
	High	210	20	60	16	306
		68.6%	6.5%	19.6%	5.2%	100.0%
Accessibility to Transit	No	148	11	36	15	210
		70.5%	5.2%	17.1%	7.1%	100.0%
(Transit Stop within 1 mile)	Yes	267	17	74	12	370
		72.2%	4.6%	20.0%	3.2%	100.0%

Note: *Statistically significant at the 10% level, ** Statistically significant at the 5% level, *** Statistically significant at the 1% level

Table 34: Mode to School Descriptive Statistics for School Children – Baltimore Area

		Other	Auto	Total
Gender	Male	192	141	333
		57.7%	42.3%	100.0%
	Female	151	132	283
		53.4%	46.6%	100.0%
Age ***	Elementary (5-10)	145	128	273
		53.1%	46.9%	100.0%
	Middle (11-13)	103	51	154
		66.9%	33.1%	100.0%
	High (14-17)	95	94	189
		50.3%	49.7%	100.0%
Race ***	White	212	223	435
		48.7%	51.3%	100.0%
	African American/Black	120	43	163
		73.6%	26.4%	100.0%
	Asian/Native Hawaiian/Pacific Islander	2	4	6
		33.3%	66.7%	100.0%
	American Indian/Alaskan Native	0	1	1
		.0%	100.0%	100.0%
	Multi-racial	5	1	6
		83.3%	16.7%	100.0%
Annual Family Income ***	<$20,000	51	8	59
		86.4%	13.6%	100.0%
	$20,000 - $39,999	84	30	114
		73.7%	26.3%	100.0%
	$40,000 - $59,999	47	51	98
		48.0%	52.0%	100.0%
	$60,000 - $79,000	45	57	102
		44.1%	55.9%	100.0%
	>$80,000	92	105	197
		46.7%	53.3%	100.0%
Household Composition - Single Parent HH ***	No	252	229	481
		52.4%	47.6%	100.0%
	Yes	89	43	132
		67.4%	32.6%	100.0%
Parent Work Status-Father Works ***	No	18	7	25
		72.0%	28.0%	100.0%
	Yes	201	206	407
		49.4%	50.6%	100.0%
Parent Work Status-Mother Works	No	78	58	136
		57.4%	42.6%	100.0%
	Yes	251	199	450
		55.8%	44.2%	100.0%

		Other	Auto	Total
Vehicle Ownership ***	No	70	5	75
		93.3%	6.7%	100.0%
	Yes	273	268	541
		50.5%	49.5%	100.0%
Pop Density ***	Low (<1,000)	82	88	170
		48.2%	51.8%	100.0%
	Medium (1,000 - 10,000)	157	146	303
		51.8%	48.2%	100.0%
	High (>10,000)	104	39	143
		72.7%	27.3%	100.0%
Mixed Use	Low	54	54	108
		50.0%	50.0%	100.0%
	Medium	91	72	163
		55.8%	44.2%	100.0%
	High	179	127	306
		58.5%	41.5%	100.0%
Accessibility to Transit (Transit Stop within 1 mile)	No	112	98	210
		53.3%	46.7%	100.0%
	Yes	214	156	370
		57.8%	42.2%	100.0%

Note: *Statistically significant at the 10% level, ** Statistically significant at the 5% level, *** Statistically significant at the 1% level

5.6 Out-of-home Activity Participation

An analysis of the relationship of non-school out-of-home activities and travel to school are presented in this section. The analysis looks at the distribution of out-of-home activities throughout the day for school tour type and mode of travel to school (Table 35 and Table 36).

The number of out-of-home activities that children participate in seems to have a significant impact on the choice of type of tour to school. The majority of children who used a HSH tour to school (54.1% for the national sample and 56.2% for the Baltimore Area) did not engage in other out-of-home activities, whether these activities happened within the school tour or not. These statistics may point to the fact that children who go straight home after school are less likely to leave the home again and engage in other out-of-home activities than children who make stops on their way to or from school. It is also noteworthy that a large percentage of children who chose more complex school tours (HOSOH), participate in a large number of out-of-home activities (4 or more out of home activities).

Regarding mode to school, children who use other modes of transportation other than the car for their trip to school engaged in fewer activities. Both the national and Baltimore area samples show that approximately 45% of children who used alternative modes of transportation to school did not engage in any out-of-home activities on the day of the survey. In comparison, 67% of children in the national sample (and almost 65% in the Baltimore area) who used a car to school engaged in at least one out of home activity on the day of the survey.

Table 35: Out-of-home activities and school travel for the National Sample

		Number of Non-School Out-of-home Activities					
		0	1	2	3	4+	Total
Tour Type ***	HSH	5191	2720	1021	440	232	9604
		54.1%	28.3%	10.6%	4.6%	2.4%	100.0%
	HOSH	0	275	171	73	51	570
		.0%	48.2%	30.0%	12.8%	9.0%	100.0%
	HSOH	0	1029	669	361	344	2403
		.0%	42.8%	27.8%	15.0%	14.3%	100.0%
	HOSOH	0	0	261	169	196	626
		.0%	.0%	41.7%	27.0%	31.3%	100.0%
Mode to School ***	Other	3024	1932	948	449	286	6639
		45.5%	29.1%	14.3%	6.8%	4.31%	100.0%
	Auto	2170	2093	1173	594	536	6566
		33.0%	31.9%	17.9%	9.0%	8.16%	100.0%
*** Statistically significant at the 1% level							

Table 36: Out-of-home activities and school travel for the Baltimore Sample

		Number of Non-School Out-of-home Activities					
		0	1	2	3	4+	Total
Tour Type ***	HSH	248	127	46	15	5	441
		56.2%	28.8%	10.4%	3.4%	1.1%	100.0%
	HOSH	0	20	11	2	2	35
		.0%	57.1%	31.4%	5.7%	5.7%	100.0%
	HSOH	0	61	34	13	4	112
		.0%	54.5%	30.4%	11.6%	3.6%	100.0%
	HOSOH	0	0	11	9	8	28
		.0%	.0%	39.3%	32.1%	28.6%	100.0%
Mode to School **	Other	151	99	62	21	10	343
		44.0%	28.9%	18.1%	6.1%	2.9%	100.0%
	Auto	97	109	40	18	9	273
		35.5%	39.9%	14.7%	6.6%	3.3%	100.0%
*** Statistically significant at the 1% level; ** Statistically significant at the 5% level							

5.6.1 Out-of-home Activity Participation by Activity Type

The relationship of type of out-of-home activities and travel to school was analyzed and reveals interesting results. Table 37 shows the percent of children in the National sample that participated in at least one out-of-home activity of each category by tour types and mode to school. Similarly, Table 38 shows the results for the Baltimore Sample. The results show a variation of participation in out-of-home activities based on the type of activity by tour type and mode to school.

For the national sample, the percentage of children that engage in shop/personal activities is much higher for HOSOH (62%) and HSOH (58%) tour types than for HSH (20%) and HOSH (39%) types. In other words, out of the kids that take HOSOH and HSOH tours, the majority of them participate in at least one shop/personal activity. This may be indicative of children participating more in shop/personal activities on their way home from school rather than making another trip after they arrive home from school. For the other activity categories: social and work, the same pattern is seen but the differences are not as significant. However, for passenger serve activities (dropping off, picking up etc.), the HOSH tour type shows the greatest percentage of children that participate in passenger serve activities (55%), followed by the HOSOH tour type (51%). Meanwhile, the HSH tour types show the least percent of children that participate in passenger serve activities (5%). These number may indicate that children do most of their passenger serve activities on the way to school.

For the Baltimore sample, the percentage of children that engage in shop/personal activities is highest for HSOH (46%) tour types, followed by HOSH (40%) tour types. In other words, out of the kids that take HSOH and HSOH tours, over 40% of them participate in at least one shop/personal activity. Interestingly, for HOSOH tours, the percentage of children engage in at least one shop/personal activity is much lesser for the Baltimore sample (36%) then the national sample (62%).

The percentage of children that engage in social activities is much higher for HOSOH (57%) and HSOH (57%) tour types than for HSH (25%) and HOSH (29%). These numbers may indicate that children in the Baltimore Area are participating more in social activities on their way home from school rather than making another trip after they arrive home from school.

In regards to mode to school, both the national and Baltimore Area samples show similar trends. For all activity types, the percentage of kids who participate in out-of-home activities are higher for kids who took a car to school than those who used alternate modes of transportation. However, it is notable that differences are higher for the passenger serve and work activity categories. As this study speculates, these numbers point to the fact that children's participation in out-of-home activities have an impact on their choices of travel mode to school, whether these activities occur within the school tour or at other times during the day.

Table 37: Out-of-home activities by type – National Sample

		Shop/Personal	Social	Passenger Serve	Work
		Percent Participation			
Tour Type	HSH	20.0%	29.7%	5.3%	2.4%
	HOSH	39.0%	37.2%	54.4%	2.8%
	HSOH	57.8%	56.3%	23.4%	5.8%
	HOSOH	61.8%	49.4%	51.1%	3.7%
Mode to School	Other	26.6%	32.5%	8.2%	1.5%
	Auto	32.8%	39.1%	17.5%	4.7%

Table 38: Out-of-home activities by type – Baltimore Sample

		Shop/Personal	Social	Passenger Serve	Work
		Percent Participation			
Tour Type	HSH	19.0%	25.2%	5.4%	1.8%
	HOSH	40.0%	28.6%	42.9%	2.9%
	HSOH	45.5%	57.1%	16.1%	3.6%
	HOSOH	35.7%	57.1%	39.3%	0%
Mode to School	Other	22.2%	33.8%	9.3%	1.5%
	Auto	29.3%	31.1%	13.2%	2.9%

5.7 Conclusions

The analysis in this chapter shows a variation of relationships between children's participation in out-of-home activities and tour types and travel mode to school. However, these dependencies need to be further analyzed in conjunction with control variables to reveal the true impacts of children's out-of-home activities on their choice of tours and their auto-dependency on their trip to school. The next chapter

(Chapter 6) will discuss the results of the choice models that aim to show the relationship of participation in out-of-home activities on choice of tour type and mode to school, based on the type of activity.

Chapter 6: Results

6.1 Introduction

The descriptive analysis of the trip data suggests that the participation of the individual student in out-of-home activities has an impact in both the choice of what type of tour to school to take and the choice to take a personal vehicle on the trip to school. To further the descriptive analysis of the trip data discussed in Chapter 5, this chapter discusses the results of the tour and mode choice models estimated in this study. The purpose of these models is to inform the importance of out-of-home activities on the travel behavior choices of the student, while controlling for personal, household and trip characteristics as well as urban form. The binary and multinomial logit models described in the methodology Chapter 3 are estimated for this analysis.

This study had a breadth of control variables available for estimating these models, including personal and household attributes, trip characteristics and land use variables. Thus multiple iterations and estimations were tested in an attempt to find the best fit models for showing the impact of out-of-home activities on travel behavior of trips to school. Although many different variations of the models were estimated as part of this study, only the final models are presented in this chapter.

Results of estimation of the various binary and multinomial logit choice models for both the national sample and Baltimore Area case study are discussed in this chapter. First, a multinomial logit choice model is presented that shows the impact of out-of-

home activities on the choice of type of tour to school: home to school and back home with no other activities within the tour (H-S-H), home to school to home tours with other activities on the way to school (H-O-S-H), home to school to home tours with other activities on the way back from school (H-S-O-H), or home to school to home tours with other activities on the way to and from school (H-S-O-S-H).

Then a binary logit model is shown presenting the interaction of participation in out-of-home activities and mode choice. In particular, it shows the impact of participation in different types of out-of-home activities on the choice of taking a personal vehicle to school.

Although the influence of participation in activities is an important consideration in the choice of type of tour to school and the choice of mode to school, in reality, these choices are most likely not independent from each other. In the choice of travel to school, students or their parents make the choice of school travel based on both the mode choices they have and what other activities they need or want to participate in within the school tour. For example, if a student takes the school bus to and from school, it may preclude them from making a trip to the grocery store. However, if a student has to go to a dentist appointment immediately after school, a decision would be made to use a personal vehicle for the appointment and participate in this activity before returning home due to time and distance constraints. Therefore, the more likely scenario is that the choices of mode and type of tour and mode are done simultaneously. The third model presented in this chapter tries to capture the

influence of the participation in different types of activities in the joint decision of tour and mode choice.

After discussion on the results of the models using the national sample, this chapter discusses the models using the data from the Baltimore Area case study. These models are used to further inform the study on the relationship of activities and travel behavior. The results of the Baltimore Area case study models are used to confirm the results found in the national study models by testing if the relationship of travel behavior and activity participation found in the previous models hold for a particular geographic area. In addition, the Baltimore Area case study sample contains geocoded information that allows the study to obtain specific trip attributes such as distance to school for each individual and better land use variables for each individual's specific neighborhood.

The Baltimore Area data set allows us to both measure the relationship between features of the urban environment and distance to school on the decision of mode and tour to school, and give us a further test of the remaining independent variables by controlling for these important trip attributes and environmental conditions. Because of the absence of location data in the national survey it is only possible to test these variables in this Baltimore Area models.

There are a few very important items to note for interpreting the results of this chapter:

1. The main point of the models estimated is to measure the influence of out-of-home activities on mode and tour choices while controlling for other characteristics known to influence mode and tour. It is not the point of this study to estimate models that fully explain the dependent variables.
2. It is also important to note that when the analysis refers to the travel choice of mode and tour type, it is not necessarily the choice of the student. In the case of a young elementary school student, it is most likely that the choice of mode and tour is made by the parent. However, the choices estimated in these models are based on the characteristics of the child, and it is unimportant, in this study, to make the determination of who made the travel choice. Therefore for the purposes of this analysis, this chapter will refer to the choice as the student's choice.
3. For succinctness, the word "activities" will be used to refer to out-of-home activities other than school activities.

6.2 Variables for Choice Models

This chapter presents the results of the final model estimations for this study. The following sections will discuss the variables for personal, household and trip characteristics, as well as land use and activity participation that were used in the choice model analysis.

6.2.1 Personal Characteristics

The personal characteristics variables used in the model draw from previous literature described in Chapter 2 and include age, race and gender. Regarding age, because the

dataset includes children in elementary, middle and high school, controlling the models for age of the student is important. However, because there are inherit differences in the attributes and decision making of these different groups of students, it is not appropriate to use a continuous age variable. When children are younger, they tend to be driven more because the parents may not allow them to travel on their own. However, middle school children may be free to make their own travel decisions but cannot drive themselves to school. High schools students are likely to make most of their own travel decisions and for a sector of these students (16 years of age and over), they may be able to drive themselves to school. Therefore, the best variables for measuring mode choice and tour is achieved by using a binary variable separating the age groups into two groups: students of driving age (16 years old or older) and non-drivers (5 to 15 years of age). While both the national and Baltimore data sets include several race categories (white, black, Hispanic, Asian, and others), a binary indicator variable was used to control for race by specifying whether the student was white or non-white.

6.2.2 Household Characteristics

Again here, the variables used to control for household characteristics were drawn from previous literature as described in Chapter 2. The models include two such variables: household size and household income as continuous variables. In addition, four binary indicator variables control for household composition (single parent household indicator), vehicle ownership, and father and mother work status.

Although vehicle ownership is an obvious explanatory factor in a model of mode choice, this variable was dropped from the joint logit models (testing the simultaneous decision of mode and tour choice) because there wasn't enough variation. Even for the national sample, there were only two cases of students from households with no vehicles available but a HOSH or HOSOH tour types.

For Baltimore case study, father work status was dropped because of too many missing variables. In addition, the indicator variable for single parent household was removed because it was highly correlated with household income in the Baltimore case study.

6.2.3 Trip Characteristics

For trip characteristics, an indicator of accompaniment on the trip was used in the models. This is an important variable in children's travel behavior because the majority of the children in the dataset are of non-driving age and therefore taking a car means that they are being driven by a parent, sibling or other. Mode to school was also used for the school tour type models.

Previous literature shows that distance from home to school is an important explanatory variable of mode choice. The Baltimore Area models are an improvement over the national sample, because it contains geocoded locations for home and trip origins and destinations, and therefore distance from home to school could be calculated for each individual student.

6.2.4 Land Use

Literature points to a relationship between land use and travel behavior. For the national model, measures of density from the U.S. Census for the individual's household tract level were used to test urban form. Based on literature, population density is a measure commonly used in travel behavior literature and therefore was chosen for these models. Other density variables such as, housing density, employment density and percent renter occupied units were also available. However, because these measures did not produce significant results and presented multi-collinearity issues, they were not used in this analysis.

The advantage of including the Baltimore Area analysis in this study is that geocoded information of each individual's home, and trip origins and destinations are provided and a variety of urban form variables were created for each specific student as described in Chapter 4.

Measures of land use mix were calculated that indicate how homogenous or diverse the developed land around the neighborhood is. Accessibility measures were also calculated and tested including accessibility to metro and buses, and density of transit stops around the neighborhood.

Other measures of urban form were also calculated including measures of density of the particular neighborhood of the student, such as population density, housing density, job density, percent of high and low dwelling residential units, and percent of particular land use categories (e.g. percent of commercial developed area and percent

of institutional developed area). Also measures of the transportation structure were also computed such as road density within the student's neighborhood. As with the national sample data, many land use measures were correlated to each other and/or resulted in statistically insignificant results. As a results, the land use measures chosen for the final models are land use mix and accessibility to transit.

6.2.5 Out-of-home Activities

The policy variables of interest in this study are the variable for out-of-home activities. These activities may occur within the school tour (i.e. on the way to or from school) or they may occur on a separate tour (after returning home from school). As previously discussed in the data chapter, the out-of-home activities were grouped into five categories: maintenance activities (including shopping and personal services), discretionary activities (including leisure and social activities), passenger serve activities (i.e. dropping off of picking up members of the household or others), work activities, and other activities (activities where the individual reported as "other" type of trip in the National Household Travel Survey).

In the Baltimore Case study models, activities in the "other" category were dropped from the analysis because there were not enough occurrences to specify the model.

6.3 National Sample Model Results

This section presents the results of the binary and multinomial logit choice models estimated using the national sample data.

6.3.1 Multinomial Logit Model of Tour Choice

In Chapter 5, the data analysis showed a correlation between children participating in out-of-home activities and whether these activities occurred during the tour to school, meaning that these activities occurred either on the way to or from school. The analysis showed that almost 55 percent of students that chose a home-school-home tour, did not participate in any additional out-of-home activities at all, whether these activities occurred within the school tour or not. However, as previously stated, it is important to remember that because the activity information was extrapolated from a trip data set, this study could not account for extra-curricular activities that occurred at school. Accounting for these activities is beyond the scope of this study but will be included in future analysis on this topic.

Over thirty percent (33%) of children that chose a school tour where activities occurred during the school tour (HOSH, HSOH, HOSOH) participated in more than three activities. Only seven percent of students that chose a HSH tour participated in more than three activities (either before the school tour or after returning home from school).

To examine these trends in more detail and test the influence of children's participation in out-of-home activities on the choice of school tours, a multinomial logit choice model of individual-level school tours is estimated using the National sample dataset. Results including the estimated coefficients, and z-statistics as well as log-likelihood statistics are shown in Table 39. The model is an estimation of school tours based on personal, household and trip characteristics, land use characteristics

and level of participation in out of home activities. For all models in this chapter only statistically significant results are discussed.

In the model presented in Table 39, the base case is the home-school-home tour where any additional out-of-home activities would occur outside of the school tour (e.g. after arriving home from school, the student would leave again from home to engage in an activity). The model yields an R^2 value of 0.2421. For personal characteristics, age yielded a statistically significant impact on type of tour. Being of driving age (over 15 years of age) yield negative statistically significant associations with choosing a HSOH or HOSOH tour types when compared with choosing a HSH tour type. This result implies that the driving age group is less likely to participate in after school activities before returning home from school. However, when looking at the data by age group, the data shows that children of driving age are more likely to participate in at least one out-of-home activity (71%) when compared to other age groups with less than 60% participation rate. Possibly, because they have access to vehicles and have a chance to return home before leaving for out-of-home activities. Interestingly, race and sex did not show a significant association with school tour choice.

Household size showed a statistically significant negative association with choosing a tour type with activities on the way to and from school (HOSOH) when compared with the HSH tour type. The descriptive statistics analysis showed that children from larger household sizes (5 household members or more) had lesser participation in activities (57%) than children from smaller households (63%). These results may be

due to the time constraints of households with more children, where the parents have a more difficult job taking several children to activities, especially in the school tours. Possibly varying dismissal times may have an effect on children from larger households not being able to coordinate trips to activities on the way home from school.

Children from a single parent household are more likely to choose tour types where activities occur within the school tour, however the results are only statistically significant for the HOSH and HOSOH school tour when compared with the HSH tour choice. Possibly due to higher time constraints for these parents, it is easier for them to take children to activities before returning home.

Children from households where the mother works are also more likely to choose tour types where activities occur within the school tour when compared with the HSH tour choice. Again here, working mothers may find it easier to take their children to activities (whether it is music class or grocery shopping) on the way home. Both results may speak to the fact that children from households where there isn't a stay at home parent may have greater time constraints and are more likely to participate in activities within the tour to school. Household income also shows a positive effect in choosing school tours with activities on the way to and from school (HOSOH) when compared to home-school-home tours. Possibly, children from higher income households may be able to participate in more activities than their counterparts.

Not surprisingly, mode to school is associated with the choice of tour to school. Taking a personal vehicle to school has a strong positive association with choosing

school tours where activities occur within the school tour. Having access to a personal vehicle on the school tour may facilitate trips to other activities before returning home from school. In addition, this model also controlled for accompaniment on the school trip. Children who are accompanied to school are more likely to choose a HSOH tour over the HSH tour. It is likely that children who are accompanied in their school trips by a parent or sibling, may engage in more activities such as grocery shopping or picking up other siblings on their way home.

Several land use measures were tested in this model and yielded similar results. Although population density has a positive effect on choosing tour types where activities occur within the school tour, the coefficients are very small. More urbanized locations with higher population densities may represent the environments in traditional neighborhoods and urban centers, which have shorter distances between origins and destinations and greater opportunities for activities along the way to school or on the return trip home.

The significant policy variables of interest, participation in out-of-home activities of different types (maintenance, discretionary, work and passenger serve), yield positive statistically significant associations with choosing tours where activities occur within the school tour (HOSH, HSOH, HOSOH) when compared to choosing a home-school-home tour. This model is trying to get at what and when out-of–home activities are done: are activities done within the school tour before coming back home or are children more likely to engage in activities after they have returned home from school? The results of this model suggest that children who choose school tours

where activities occur within the tours are more likely to participate in more maintenance, discretionary, work and other out-of home activities than those that choose the home-school-home tours. This is an important finding because choosing more complex tours can have implications for overall household travel patterns, especially mode choice.

Table 39: Multinomial logit model: Choice of school tours using the national sample

Dependent Variable: Type of School Tour (Base Case is choosing HSH)			
Variables	Coefficients for HOSH (z value)	Coefficients for HSOH (z value)	Coefficients for HOSOH (z value)
Personal Characteristics			
Age – Driving Age (16+)	-0.279* (-1.71)	-0.324*** (-3.55)	-0.419** (-2.43)
Sex – (Male=1)	-0.076 (-0.74)	-0.072 (-1.26)	0.023 (0.21)
Race – (White=1)	-0.057 (-0.38)	0.003 (0.04)	-0.007 (-0.04)
Household Characteristics			
Household Size	-0.019 (-0.41)	-0.034 (-1.3)	-0.152*** (-2.79)
Household Composition - Single Parent	0.780*** (3.80)	0.118 (0.84)	0.511** (2.14)
Vehicle Ownership – Vehicle Available	0.604 (1.10)	-0.082 (-0.32)	0.064 (0.12)
Father Work Status – Father Works	0.545 (1.62)	-0.067 (-0.46)	-0.405 (-1.48)
Mother Work Status – Mother Works	0.294** (2.30)	0.324*** (4.45)	0.750*** (4.98)
Household Income	0.022 (0.50)	0.031 (1.25)	0.088* (1.84)
Trip Characteristics			
Mode - Auto to School	0.853*** (6.60	0.877*** (12.46)	0.653*** (4.8)
Accompanied on Trip	0.230 (1.52)	0.183** (2.26)	-0.012 (-0.08)
Urban Form			
Population Density	+0.000* (1.81)	+0.000* (0.97)	-0.000* (-0.28)
Activities (Number of Activities)			
Maintenance (shopping, personal services)	0.630*** (9.58)	0.985*** (27.29)	1.370*** (25.77)
Discretionary (leisure, social)	0.270*** (3.9)	0.700*** (20.06)	0.655*** (10.58)
Passenger Serve	1.813*** (25.04)	1.151*** (18.95)	2.158*** (28.5)
Work	0.625** (2.12)	1.191*** (8.22)	1.063*** (3.75)
Other	3.257*** (17.87)	2.623*** (16.36)	4.394*** (25.08)
Constant	-5.872*** (-8.39)	-3.240*** (-9.66)	-5.411*** (-7.81)
Number of observations	10769		
Log likelihood at convergence	-6748		
Pseudo R2	0.2421		
Absolute value of z-statistics in parentheses *, **,*** significant at 10% level, 5% level and 1% level respectively			

6.3.2 Binary Logit Model of Mode Choice

The descriptive data analysis showed an association between use of a personal automobile for the trip to school and participation in activities. Over 65 percent of children who took a personal vehicle to school participated in at least one other out-of-home activity, compared to less than 55 percent of children that took modes other than a car to school. To examine these trends in more detail and test the influence of participation in out-of-home activities, results of a binary logit model of mode choice is presented in Table 40. The model is an estimation of the choice of taking a car to school or not based on personal and household characteristics, land use conditions and participation in different types of out-of-home activities.

In this model, the base case is choosing not to take a personal vehicle (car) for the trip to school. The model yields an R^2 value of 0.2570. All personal characteristics show a statistically significant association with mode choice. Not surprisingly, children of driving age are more likely to choose a car for the trip to school. Interestingly, being male and being white are negatively associated with choosing a car to school. It may be the case that parents feel more comfortable letting their male children walk or take the bus to school and may be more likely to drive their female children to school.

Several household characteristics also yielded significant associations with mode choice. Children from both a larger household size and from a single parent family are less likely to take a personal vehicle to school. Both types of households are consistent with greater time constraints for parents to take their children to school. Consistent with literature, both vehicle ownership and higher household incomes are

strongly associated with choosing a personal vehicle to school. Because most of the children in this dataset are not of driving age, as expected, being accompanied on the trip shows a positive effect on choosing a car to school. In this model again, the land use variable of population density is not statistically significant.

For the policy variables of interest, higher levels of participation in maintenance, discretionary, work and passenger serve activities are all positively associated with taking a car to school. However participation in activities categorized as "other" has a negative association with taking a car to school. It is difficult to speak to this result as only 3.5 percent of children reported participating in an activity classified as "other".

The results of this model speak to the auto-dependency of students who participate in additional out-of-home activities. The results are shown in Table 40, where positive significant value indicates an increased likelihood of taking an auto to school for children who participate in more out-of-home activities.

Table 40: Logit model of mode choice using the national sample data

Dependent Variable: Mode: Auto or Non-auto (Base Case is choosing non-auto)	
Variables	Coefficients for Auto (z value)
Personal Characteristics	
Age – Driving Age (16+)	2.222*** (23.93)
Sex – (Male=1)	-0.090* (-1.94)
Race – (White=1)	-0.201*** (-2.96)
HH Characteristics	
HH Size	-0.236*** (-11.51)
HH Composition - Single Parent	-0.577*** (-5.26)
Vehicle Ownership – Vehicle Available	1.541*** (6.61)
Father Work Status – Father Works	-0.006 (-0.05)
Mother Work Status – Mother Works	0.009 (0.16)
HH Income	0.177*** (8.98)
Trip Characteristics	
Accompanied on Trip	3.178*** (40.54)
Urban Form	
Population Density	+0.000 (0.43)
Activities	
Maintenance (shopping, personal services)	0.058** (1.97)
Discretionary (leisure, social)	0.142*** (4.56)
Passenger Serve	0.496*** (9.96)
Work	0.991*** (6.36)
Other	-0.398*** (-3.9)
Constant	-3.750*** (-12.92)
Number of observations	10769
Log likelihood at convergence	-5546
Pseudo R2	0.2570
Absolute value of z-statistics in parentheses *, **,*** significant at 10% level, 5% level and 1% level respectively	

6.3.3 Joint Multinomial Logit Model of Mode and Tour Choice

The two models previously presented speak to the importance of considering children's activities in both the tour choice and mode choice of school trips. However, the more realistic scenario is that the choice of tour and mode is done simultaneously. The fact that a student takes the bus to school may not allow him to play a sport or go to a friend's house on the way home. The question arises as to whether that child still participates in that particular activity some other time during the day (not on the school tour) or does he/she not do the activity at all. On the other hand, the fact that a child has to go to an extra-curricular activity after school that is not walking distance (either by himself or accompanied by a parent), may require that the mode chosen for the school trip is the personal vehicle.

To study these questions in more detail, this study tests the influence of children's participation in out-of-home activities on the joint choice of school tours and mode. For this analysis a joint multinomial logit choice model of individual-level decisions of both school tour and mode choice is estimated using the National sample dataset. The model results are presented in Table 41 and show an estimation of the joint decision of tour and mode based on personal, household and trip characteristics, land use characteristics and level of participation in out-of-home activities.

In this model, the base case is choosing the personal vehicle and the home-school-home tour (Auto and HSH) where any additional out-of-home activities would occur outside of the school tour (e.g. after arriving home from school, the student would

leave again from home to engage in an activity). Similar to the individual tour and mode choice models, this joint model yields a R^2 value of 0.2411. Every result for the seven cases presented in Table 41 is compared to the base case. Besides the base case, the other choices for this model are:

- Auto and HOSH
- Auto and HSOH
- Auto and HOSOH
- Non-auto and HSH
- Non-auto and HOSH
- Non-auto and HSOH
- Non-auto and HOSOH

Regarding personal characteristics, children of driving age are less likely to choose a car and a tour where an activity occurs on the way back from school (auto and HSOH) when compared with the base case (auto and HSH). This result is consistent with the model presented in Table 39, implying that the driving age group is less likely to participate in after school activities before returning home from school. When examining the four cases where the trip to school was not taken by a personal vehicle, the results imply that students of driving age are more likely to take a car regardless of the tour type. This result is consistent with the coefficient on age presented in the previous model (Table 40).

Regarding the variables for race and sex, both only yielded a positive statistically significant association with choosing non-auto, HSH tours. This result can only be

compared to the base case, and shows that being male and being white increases the probability that the student will choose non-auto modes for the school tour with no activities within the tours.

Regarding household characteristics, children coming from larger household sizes, are more likely to choose a non-auto mode and HSH tour or a non-auto mode and the HSOH tour than the base case (auto and HSH tour). These results could indicate that parents of larger families may not be able to drive all of their children to school, and therefore children of larger families are more prone to taking other modes of transportation to school, whether they participate in activities within the school tour or not.

Statistically significant results for the household composition variable suggest that children from a single parent household are more likely to choose non-auto school tours or very complex auto tours rather than the base case. It may be inferred that children from a single parent family are less likely to take a personal vehicle to school and choose tour types where activities do not occur within the school tour. It is possible that in these types of households, parents may have greater time constraints and cannot drive their children to school. In addition, these children are more likely to participate in these out-of-home activities within the school tour; whether these activities are for their benefit (sports team or extra-curricular classes) or to the benefit of the family (grocery chopping or picking up other children)

Mother's work status also shows a positive association with choosing more complex tours whether by auto or not than the base case. Statistically significant results are

obtained for the following joint choices: auto and HOSH, auto and HSOH, auto and HOSOH, non-auto and HSOH, and non-auto and HOSOH. These results imply that children from households where the mother works are more likely to participate in activities within the school tour. Here again, these results may speak to the time constraints of the families with working mothers and that activities are prior to going to school or before arriving back home from school, whether these activities are to the benefit of the child or not.

Children from families of higher incomes are more likely to travel by auto in HSH tours or HSOH tours when compared with the base case (auto and HSH tour). These results could indicate that children of wealthier families have greater accessibility to personal vehicles (whether being driven or driving the car) and are able to drive to school more often, whether they participate in activities within the school tour or not.

As a reminder, this model does not include the vehicle ownership variable. There was not enough variance for this particular variable for a robust estimate of the model. Because this model estimated an eight choice set, some of the choice cases had a very low number of occurrences. For example there were only two cases of students that came from households with no vehicles but went to school by car and chose an HOSH tour.

In this model, the variable for accompaniment on the school trip, shows a positive association with choosing auto and engaging in other activities on the way to school (auto and HOSH) when compared to the base case. Children who are accompanied in his/hers school trips by a parent or sibling, may have more opportunities to engage in

activities on the way to school (possibly running errands or dropping off other household members). This variable also has a strong negative association with choosing non-auto modes for all of the tour types when compared with the base case. Children who are accompanied in his/hers school trips by a parent or sibling are more likely to be driving or be driven to school.

It is a little surprising that the land use variable did not yield significant results in these models. This model shows a very marginal effect of higher population densities being associated with choosing non-auto modes (HSH and non-auto) when compared with the base case. Although this association is very weak, the positive sign is consistent with the literature that shows that more urbanized locations are associated with lesser auto-dependence.

For the policy variables of interest, higher levels of participation in maintenance and discretionary activities are positively associated with most of the joint choices over the base case. The exception is that non-auto and HSH tour choice yields negative results, however not statistically significant. Similarly, higher levels of participation in passenger serve, work and other types of activities also yields positive statistically significant associations with choosing most of the joint decision cases over the base case (auto and HSH). Here again, the exception is that choosing non-auto and HSH yield a negative statistically significant results for all three activity types.

Students engaging in more passenger serve, work and other activities are more likely to both choose the car and chose school tours where out-of home activities occur within the school tour. Participation in maintenance and discretionary activities are

also clearly associated with choosing school tours where activities occur within these school tours, however the association with mode choice to school is less clear.

Overall, these results are indicative of the trend that increase participation in out-of-home activities of all types leads to choices of school tours where the activities occur within the tours and to choosing the personal vehicle for the trip to school.

Table 41: Joint Multinomial Logit model of mode and tour choices using the national sample data

	Dependent Variable: Joint Decision of Type of School Tour and Mode (Auto and HSH)						
Variables	Coefficients for Auto & HOSH (z value)	Coefficients for Auto & HSOH (z value)	Coefficients for Auto & HOSOH (z value)	Coefficients for Non-auto & HSH (z value)	Coefficients for Non-auto & HOSH (z value)	Coefficients for Non-auto & HSOH (z value)	Coefficients for Non-auto & HOSOH (z value)
Personal Characteristics							
Age – Driving Age (16+)	-0.141 (-0.80)	-0.368*** (-3.62)	-0.283 (-1.48)	-2.258*** (-22.24)	-2.881*** (-6.83)	-2.428*** (-13.62)	-2.704*** (-8.20)
Sex – (Male=1)	-0.023 (-0.18)	-0.007 (-0.1)	0.036 (0.26)	0.112** (2.14)	-0.059 (-0.34)	-0.061 (-0.65)	0.112 (0.67)
Race – (White=1)	-0.037 (-0.21)	0.107 (1.00)	-0.117 (-0.55)	0.211*** (2.79)	0.120 (0.46)	0.066 (0.49)	0.404 (1.46)
HH Characteristics							
HH Size	0.039 (0.70)	-0.048 (-1.42)	-0.111 (-1.62)	0.231*** (10.05)	0.108 (1.36)	0.217*** (5.41)	0.013 (0.15)
HH Composition - Single Parent	0.366 (1.23)	-0.082 (-0.44)	0.649** (2.09)	0.549*** (4.35)	1.675*** (5.63)	0.834*** (4.13)	0.825** (2.36)
Father Work Status – Father Works	0.441 (1.1)	-0.021 (-0.11)	-0.309 (-0.87)	0.030 (0.24)	0.743 (1.23)	-0.074 (-0.33)	-0.494 (-1.21)
Mother Work Status – Mother Works	0.356** (2.28)	0.304*** (3.42)	0.624*** (3.42)	0.012 (0.19)	0.208 (0.96)	0.355*** (3.03)	0.994*** (4.1)
HH Income	-0.027 (-0.52)	0.015 (0.48)	0.063 (1.06)	-0.202*** (-9.10)	-0.072 (-0.96)	-0.160*** (-4.05)	-0.095 (-1.31)
Trip Characteristics							
Accompanied on Trip	0.604** (2.13)	-0.031 (-0.25)	0.252 (0.98)	-3.197*** (-35.95)	-3.061*** (-15.61)	-2.886*** (-23.66)	-3.209*** (-16.84)
Urban Form							
Population Density	+0.000 (1.27)	+0.000 (1.04)	-0.000 (-0.53)	+0.000* (1.80)	+0.000 (1.45)	+0.000 (1.47)	+0.000 (0.68)

Variables	Coefficients for Auto & HOSH (z value)	Coefficients for Auto & HSOH (z value)	Coefficients for Auto & HSOH (z value)	Coefficients for Non-auto & HSH (z value)	Coefficients for Non-auto & HOSH (z value)	Coefficients for Non-auto & HSOH (z value)	Coefficients for Non-auto & HOSOH (z value)
Activities							
Maintenance (shopping, personal services)	0.509*** (6.09)	0.940*** (20.9)	1.229*** (18.29)	-0.013 (-0.3)	0.785*** (7.52)	1.008*** (18.84)	1.530*** (20.55)
Discretionary (leisure, social)	0.295*** (3.6)	0.695*** (16.33)	0.703*** (9.47)	-0.047 (-1.15)	0.182 (1.46)	0.646*** (11.89)	0.519*** (5.21)
Passenger Serve	1.928*** (22.05)	1.247*** (16.35)	2.265*** (24.95)	-0.150* (-1.76)	1.498*** (11.06)	0.950*** (9.52)	1.863*** (15.37)
Work	0.518 (1.61)	1.003*** (6.21)	1.028*** (3.40)	-1.057*** (-5.59)	-0.211 (-0.28)	0.593** (2.35)	-0.301 (-0.40)
Other	2.119*** (7.07)	2.225*** (10.32)	3.141*** (11.88)	-0.448* (-1.67)	3.490*** (14.09)	2.415*** (10.32)	4.687*** (19.7)
Constant	-4.765*** (-7.92)	-2.248*** (-7.38)	-4.814*** (-7.96)	2.359*** (11.52)	-2.890*** (-3.65)	-0.987*** (-2.77)	-3.206*** (-4.65)
Number of observations	10769						
Log likelihood at convergence	-12226						
Pseudo R2	0.2411						
	Absolute value of z-statistics in parentheses *, **,*** significant at 10% level, 5% level and 1% level respectively +0.000 and -0.000 results indicted very small coefficients (less than 0.001)						

6.4 Baltimore Area Case Study Model Results

This section presents the results of the binary and multinomial logit choice models estimated using the Baltimore Area case study data. These models further inform the relationship between out-of-home activities and travel behavior.

Because this sample contains geocoded information of the individual's household and every trip's origin and destination, this study was able to calculate specific attributes (such as distance from home to school) and land use variables, such as accessibility to transit and degree of land use mix. The addition of these variables adds value to the models because it allow us to both measure the relationship between urban environment and travel behavior and further test the impact of activities on school travel behavior by controlling for important variables of distance to school and environmental conditions.

6.4.1 Binary Logit Model of Tour Choice

Similar to the national sample tour choice, this model is an estimation of school tours based on personal, household and trip characteristics, built environment characteristics and level of participation in different types of out-of-home activities. However, due to the smaller sample size, some changes were made to the specification of the national sample model. Regarding school tour choices, this model is specified with only two choices: home-school-home and tours where at least one out-of-home activity occurs during the school tour (i.e. H-O-S-H, H-S-O-H and H-O-

S-O-H categories have been combined). Some variables were removed from this sample data due to either small variation or too many missing cases. For this reason, the variables for both father's work status and number of activities categorized as other were removed from the analysis. In addition, the variable for household composition was highly correlated with household income and was therefore also removed from the case study dataset. Other variations from the national sample model will be highlighted throughout the discussion of the model.

In addition, this case study model uses specific variables calculated from the geocoded location of an individual's home, including distance to school and urban form based on the individual's home neighborhood attributes.

In the model presented in Table 42, the base case is the home-school-home tour where any additional out-of-home activities would occur outside of the school tour (e.g. after arriving home from school, the student would leave again from home to engage in an activity). This joint model yields a R^2 value of 0.1974, which is slightly lower than the national sample model result. For personal characteristics, only age yielded a statistically significant impact on type of tour. Students of driving age are less likely to participate in after school activities before returning home from school. The result is consistent with the national survey results. However it does not speak to whether they participate in activities at other times of the day.

Of all the household characteristics tested, only household income yielded statistically significant results. Unlike the national sample, the higher the household income the less likely the student will choose school tours with activities on the way

to or from school when compared to home-school-home tours. These results imply that students from households of higher income in the Baltimore Area that participate in out-of home activities tend to do so outside of the school tours.

Consistent with the results from the national sample, this model shows a strong positive effect of being accompanied on the school trip and choosing a tour with activities within the school tour. It may be likely that children who are accompanied in his/hers school trips by a parent or sibling, may engage in more activities such as grocery shopping or picking up other siblings on their way home. A new variable added to this case study model is distance to school which is an important control variable for school tour choices based on previous school travel behavior research. Not surprisingly, as the distance to school increases, there is a greater chance of that student to engage in other activities within the school tour. Possibly because there are more opportunities of additional activities along the way (e.g. passes by more grocery stores or friend's houses along the way), or because of time constraints that longer trips create and therefore the student does not have time to return home before engaging in additional activities.

Because literature points to a relationship between land use and travel behavior, several urban form variables were created for each specific student as described in the data and methodology chapters. Multiple urban form variables were tested in this model, population density, housing density, job density, percent of high and low dwelling residential units, percent of particular land use categories (e.g. commercial and institutional) and land use mix measures. Measures of the transportation structure

were also tested such as road density and density of transit stops around the neighborhood and accessibility to metro and buses. Most of these variables of urban form are highly correlated with each other and therefore it is not appropriate to include them all in the model. Therefore the model shown in Table 42 only includes two urban form measures to illustrate the trends found; land use mix and transit accessibility. It is important to note that changing the land use variables combination in the model does not have a significant impact on the coefficients and signs of the other variables. Non-land use variables remain consistent in the different specifications tested in this analysis.

Although not all urban form measures resulted in statistically significant results, the testing of these measures in several model specifications, showed a common trend. Measures of population and housing density, percentage of high dwelling residential units, and land use mix showed significant positive associations with choosing school tours where other activities occur within the tours. To represent this group of variables, a land use diversity index, which is a commonly used land use measure that incorporates the amount of different types of land development, was chosen to be presented in the model. Higher values of these measures are consistent with denser residential environments in more urbanized locations and therefore students living in these neighborhoods may have more opportunities to make more stops on their way to and from school.

Meanwhile, results in Table 42 shows accessibility to transit, measured as presence of public transit within a mile of the home, having a negative association with tour types

where other activities occur within the tours. As a note, other land use variables tested such as job density, road density and percent commercial, transit stop density did not yield in significant results.

Regarding the policy variables of out-of-home activities, all four activity variables (maintenance, discretionary, passenger serve and work) yield strong positive relationships with choosing tours where other activities occur within the school tour. Students who engage in higher levels of out-of-home activities, including shopping, social, work, and drop-offs and pickups, are more likely to choose school tours where they stop for other activities before returning home from school. These results suggest that students are participating in more activities within the school tour and not leaving home again after returning home from school.

Table 42: Binary logit model of school tour choice using the Baltimore Area data

Dependent Variable: Type of School Tour (Base Case is choosing HSH)	
Variables	Coefficients for Tours with activities within tours (z value)
Personal Characteristics	
Age – Driving Age (16+)	-0.683* (-1.72)
Sex – (Male=1)	0.050 (0.22)
Race – (White=1)	-0.279 (-0.88)
HH Characteristics	
HH Size	-0.146 (-1.24)
Vehicle Ownership – Vehicle Available	-0.022 (-0.05)
Mother Work Status – Mother Works	0.364 (1.25)
HH Income	-0.048* (-1.66)
Trip Characteristics	
Mode – Auto to School	-0.483 (-0.70)
Accompanied on Trip	1.427** (2.06)
Distance to School	0.059** (2.20)
Urban Form	
Land Use Mix	0.720 (1.63)
Accessibility to Transit	-0.609* (-1.95)
Activities	
Maintenance (shopping, personal services)	0.663*** (4.08)
Discretionary (leisure, social)	1.128*** (6.63)
Passenger Serve	1.819*** (5.65)
Work	2.310*** (2.62)
Constant	-1.476** (-2.05)
Number of observations	506
Log likelihood at convergence	-244
Pseudo R2	0.1974
Absolute value of z-statistics in parentheses *, **,*** significant at 10% level, 5% level and 1% level respectively	

6.4.2 Binary Logit Model of Mode Choice

To extend the analysis of the association between use of a personal automobile for the trip to school and participation in activities, this study also looks at the relationship fusing the Baltimore Case Study data. Similar to the national sample tour choice, the model shown in Table 43 is an estimation of mode choice to school based on personal, household and trip characteristics, built environment characteristics and level of participation in different types of out-of-home activities. This model yielded a much higher R^2 value of 0.8833 than the respective national sample model. This result supports the theory that the localized case study model with the addition of geocoded information results in a better fit.

In this model, the base case is also the choosing to not take a personal vehicle (car) for the trip to school. The only personal characteristic that shows a statistically significant association with mode choice is being of driving age. Similar to the national sample, children of driving age are more likely to choose a car for the trip to school.

Not all results for household characteristics yielded statistically significant results. Consistent with the national sample results, household size showed a negative statistically significant coefficient, meaning that children from larger household sizes are less likely to take a personal vehicle to school. Interestingly, although the vehicle ownership variable showed the expected relationship with choosing a car, the variable did not yield statistically significant results. Consistently with literature, students from households were the mother works are more likely to take a car to school.

Regarding trips characteristics, only accompaniment on the trip yields statistically significant results. Because most of the children in this dataset are not of driving age, as expected, being accompanied on the trip shows a positive effect on choosing a car to school. Surprisingly, distance to school does not yield statically significant association with mode choice for this data set.

The literature points to an important association between urban form and mode choice. However, in this model the land use variables of land use mix and accessibility to transit presented in the model do not show statistically significant results. Here again, other variables of land use were also tested but none yielded significant results.

For the policy variables of interest, only the variable for participation in work or passenger serve activities yield statically significant results. Higher levels of participation in work and passenger serve activities are positively associated with taking a car to school. The results of these variables help confirm the results of the national sample model that students who participate in additional out-of-home activities are more likely to be auto-dependent.

Table 43: Binary logit model of mode choice using the Baltimore Area data

Dependent Variable: Mode Choice (Base Case is choosing Non-Auto)	
Variables	Coefficients for Auto (z value)
Personal Characteristics	
Age – Driving Age (16+)	4.314*** (4.67)
Sex – (Male=1)	-0.371 (-0.56)
Race – (White=1)	1.563 (1.63)
HH Characteristics	
HH Size	-0.594* (-1.66)
Vehicle Ownership – Vehicle Available	0.891 (0.68)
Mother Work Status – Mother Works	2.102** (2.05)
HH Income	0.119 (1.56)
Trip Characteristics	
Accompanied on Trip	11.068*** (7.22)
Distance to School	-0.141 (-1.29)
Urban Form	
Land Use Mix	-1.097 (-0.92)
Accessibility to Transit	-0.187 (-0.21)
Activities	
Maintenance (shopping, personal services)	0.309 (0.69)
Discretionary (leisure, social)	-0.327 (-0.80)
Passenger Serve	1.407* (1.81)
Work	2.866** (2.33)
Constant	-7.382*** (-3.35)
Number of observations	506
Log likelihood at convergence	-40.4
Pseudo R2	0.8833
Absolute value of z-statistics in parentheses *, **,*** significant at 10% level, 5% level and 1% level respectively	

6.4.3 Multinomial Joint Logit Model of Mode and Tour Choice

To further study the influence of children's participation in out-of-home activities on the joint choice of school tours and mode, a choice model is estimated using the Baltimore Area case study dataset. For his analysis a joint multinomial logit choice model of individual-level decisions of both school tour and mode choice is estimated. The model results are presented in Table 44 and show an estimation of the joint decision of tour and mode based on personal, household and trip characteristics, land use characteristics and level of participation in out-of-home activities.

This model differs from the national sample model because the Baltimore Area case study has a much smaller sample size. So rather than having eight joint mode and tour choices, this model is estimated with only four choices:

- Auto and HSH
- Auto and tours with activities within tours
- Non-auto and HSH, and
- Non-auto and tours with activities within tours.

In this model, the base case is choosing the personal vehicle and the home-school-home tour (Auto and HSH) where any additional out-of-home activities would occur outside of the school tour (e.g. after arriving home from school, the student would leave again from home to engage in an activity). This model also yields a higher R^2 value than the corresponding national data model. The R^2 value of this model is 0.5703 showing that the localized dataset with additional variables results in a better model fit.

Regarding personal characteristics, being of driving age showed a negative association with choosing a car and a tour where an activity occurs on the way back from school when compared with the base case (auto and HSH). This result is consistent with the national sample models, implying that the driving age group is less likely to participate in after school activities before returning home from school. When examining the two cases where the trip to school was not taken by a personal vehicle (regardless of the tour type), there is a consistent negative association with being of driving age. Not surprisingly, students of driving age are less likely to choose a mode other than car to school. This result is also consistent with the national sample model.

Regarding race, being white shows a negative association with picking choices other than the base case, however the results are only statically significant for choosing the two choices with non-auto modes (non-auto and school tours with activities within the tour or non-auto and HSH). These results suggest that non-white students are more likely to take alternative modes of transportation rather than the car.

Regarding household characteristics, children coming from larger household sizes, have positive associations with choosing a non-auto mode and HSH tour when compared with the base case (auto and HSH tour). These results are consistent with the national sample and seem to only impact the choice of mode. They could indicate that parents of larger families may not be able to drive all of their children to school, and therefore children of larger families are more prone to taking other modes of transportation to school.

This model shows an interesting results with mother work status. In contrast with the results from the national sample, mother work status shows a negative statistically significant association with the joint choice types that include non-auto mode (non-auto and HSH, and non-auto and school tours with activities within the tours), when compared to the base case. These results imply that children from households where the mother works are more likely to use a personal vehicle for the school tour. The results are somewhat contrasting with the national sample model, where the association of mother work status aligned more with the tour type choice rather than the mode choice. However, the results presented in the Baltimore Area case study model are consistent with the literature that shows that students from households with working mothers are more likely to drive.

Children from families of higher incomes have negative associations with choosing a non-auto mode and HSH tour or a non-auto mode and tours with activities within the tour when compared with the base case (auto and HSH tour). These results are consistent with the national sample results and support the notion that children of wealthier families may have greater accessibility to personal vehicles (whether being driven or driving the car) and are able to drive to school more often, whether they participate in activities within the school tour or not.

The trip characteristics variables also had significant results. Consistent with the previous models presented in this research, the variable for accompaniment on the school trip yields a strong negative association with choosing non-auto modes for all of the tour types when compared with the base case. Children who are accompanied

in his/hers school trips by a parent or sibling are more likely to be driving or be driven to school. Not surprising is that distance to school shows a positive association with the joint decision of taking a car and choosing a school tour with activities within the tour, when compared to the base case. Consistent with the tour choice logit model presented in Table 42, the distance to school variable indicates that there is a greater chance of that student to engage in other activities within the school tour, possibly because there are more opportunities of additional activities along the way.

Of the built environment attributes, only the measure for land use mix had a positive significant influence on the joint choice of taking a car and choosing a school tour with activities within the tour. A higher level of mixed land use represents environments in traditional neighborhoods and urban centers, which tend to have more opportunities for destinations and thus a higher potential of engaging in more activities on the way to and from school.

For the policy variables of interest, higher levels of participation in maintenance, discretionary, and passenger serve activities are positively associated with choosing a car and a tour choice where activities occur within the school tour, when compared to the base case (auto and HSH).

At the same time, higher levels of participation in passenger serve and work activities yield negative statistically significant associations with choosing non-auto and HSH tour when compared to the base case. In addition, higher levels of participation in discretionary activities yield a significant positive association with choosing non-auto and school tours with activities within the tours.

Consistently with the results from the national sample, in general, higher levels of participation in out-of home activities are consistent with choosing the car on the trip to school and school tours where the activities occur within the tours.

More specifically, participation in maintenance and discretionary activities are clearly associated with choosing school tours where activities occur within these school tours, however the association with mode choice to school is less clear. In contrast, work activities are more associated with the choice of mode to school. Students participating in work activities are more likely to choose the car on the trip to school.

Regarding passenger serve activities, students engaging in higher levels of these types of activities are both more likely to both choose the car and chose school tours where out-of home activities occur within the school tour.

Table 44: Joint Multinomial Logit model of joint decision of mode and tour using the Baltimore Area data

	Dependent Variable: Joint Decision of Type of School Tour and Mode (Base Case: Auto and HSH)		
Variables	Coefficients for Auto & Tours with activities within tours (z value)	Coefficients for Non-auto & HSH (z value)	Coefficients for Non-auto & Tours with activities within tours (z value)
Personal Characteristics			
Age – Driving Age (16+)	-1.058* (-1.93)	-4.427*** (-4.53)	-4.960*** (-4.77)
Sex – (Male=1)	0.226 (0.68)	0.399 (0.58)	0.283 (0.4)
Race – (White=1)	-0.243 (-0.52)	-1.658* (-1.76)	-2.096** (-2.16)
HH Characteristics			
HH Size	0.022 (0.12)	0.649* (1.80)	0.315 (0.84)
Mother Work Status – Mother Works	0.132 (0.31)	-2.394** (-2.23)	-1.886* (-1.79)
HH Income	-0.051 (-1.26)	-0.127* (-1.68)	-0.170** (-2.16)
Trip Characteristics			
Accompanied on Trip	0.554 (0.62)	-11.824*** (-6.89)	-9.431*** (-5.84)
Distance to School	0.114*** (2.84)	0.154 (1.37)	0.154 (1.37)
Urban Form			
Land Use Mix	1.063* (1.65)	1.023 (0.83)	1.489 (1.16)
Accessibility to Transit	-0.236 (-0.54)	0.557 (0.61)	-0.584 (-0.61)

Variables	Coefficients for Auto & Tours with activities within tours (z value)	Coefficients for Non-auto & HSH (z value)	Coefficients for Non-auto & Tours with activities within tours (z value)
Activities			
Maintenance (shopping, personal services)	0.890*** (3.87)	-0.111 (-0.24)	0.173 (0.37)
Discretionary (leisure, social)	1.098*** (3.81)	0.198 (0.43)	1.427*** (3.11)
Passenger Serve	1.633*** (3.78)	-1.708* (-1.88)	0.365 (0.43)
Work	1.668 (1.43)	-3.501** (-2.25)	-0.356 (-0.24)
Constant	-2.405 (-1.63)	6.676*** (2.86)	6.604*** (2.8)
Number of observations	506		
Log likelihood at convergence	-277		
Pseudo R2	0.5703		
Absolute value of z-statistics in parentheses *, **,*** significant at 10% level, 5% level and 1% level respectively			

A comparison of the R^2 values between the two sets of models (using the national data versus the Baltimore Area Case Study) is shown in Table 45.

Table 45: R^2 value comparison

	Model 1: Tour Type Choice	*Model 2: Mode Choice*	*Model 3: Joint Choice of Tour Type and Mode to School*
National Data	0.2421	0.2570	0.2411
Baltimore Area Case Study Data	0.1974	0.8833	0.5703

The table shows that the R^2 values for the mode choice (model 2) and the joint mode and tour choice (model 3) models are significantly higher for the Baltimore Area case study models than the corresponding national data models. The results show that the addition of location specific attributes (such as distance from home to school) and land use variables does in fact improve the fit of the models. These results reinforce the fact that the addition of these variables adds value to the models because it allows us better test the impact of activities on school travel behavior by controlling for important variables of distance to school and environmental conditions.

6.5 Conclusions

Results from the national sample models and the Baltimore Area case study remained mostly consistent for the policy variables tested. Overall, students engaging in higher levels of out-of-home activities are both more likely to travel by car and participate in school tours where out-of home activities occur within the school tour.

More specifically, participation in maintenance and discretionary activities are clearly associated with choosing school tours where activities occur within these school tours. However for the Baltimore Area Case study model, the association of these activities and mode choice to school is less clear. In contrast, work activities are more associated with the choice of mode to school, where students participating in work activities are more likely to choose the car on the trip to school. This result was expected as students with jobs are more likely those who are of driving age and are not dependent on other members of the household for their activities.

Not surprisingly, for both sets of models, students engaging in higher levels of passenger serve activities are both more likely to choose the car and chose school tours where out-of home activities occur within the school tour.

Regarding the control variables, the models showed that results of personal and household characteristics are consistent with literature. Students coming from households with greater time constraints such as families where the mother works or single parent families, seem to correlate with more activities within the school tour.

Interestingly, trip distance had a greater significant impact on choice of school tour than mode choice. In addition, accompaniment to school yielded a strong negative association with choosing non-auto modes, therefore children who are accompanied in his/hers school trips by a parent or sibling are more likely to be driving or be driven to school.

Another somewhat surprising result is that land use measures did not have as significant an impact as expected. Land use measures showed a greater impact on the

tour choice over the mode choice. An explanation may be that environments in traditional neighborhoods and urban centers tend to have more opportunities for destinations and thus a higher potential of engaging in more activities on the way to and from school.

6.6 Discussion

Previous research in children's travel behavior has found that over the last few decades, children's active transport to school has significantly decreased in both the US and abroad (McDonald 2007; Killingsworth and Lamming 2001; Martin and Carlson 2005; Gavin 2009; He 2013; Fyhri et al. 2011; Simons et al. 2013; Mackett 2013), while rates of overweight children have risen dramatically (McDonald 2007; Ogden et al. 2006; Kapell and Dill 2009; Gavin 2009; White House Task Force on Childhood Obesity 2010). As researchers and policy makers pursue ways combat these trends, researchers look to understand what factors influence the travel decisions of school children in order to better inform current and future policies trying to decrease children's auto-dependence.

Researchers agree that several factors have an effect on school travel decisions (McMillan 2007; Hsu and Saphores 2013; Deka 2013; McDonald and Aalborg 2009; Lawrence Frank and Company, Inc. 2008; Kapell and Dill 2009; Sidharthan et al. 2011; Simons et al. 2013; Pont et al. 2013), including personal and household characteristics, distance from home to school, and urban form, as well as attitudes towards children's safety and household convenience.

The results of this study support some previous findings discussed in Chapter 2. For both national sample and Baltimore Area Case study, findings of the relationship of personal and household characteristics and mode choice are consistent with literature. As with previous studies (Lawrence Frank and Company, Inc. 2008; McDonald 2008b), students of driving age are more likely to take a car to school than other

modes of transportation. The results also suggest, consistent with previous work (McDonald 2008a; McDonald 2008b; Yarlagadda and Srinivasan 2008; Hsu and Saphores 2013), that non-white students as well as male students are more likely to take alternative modes of transportation other than the car than their white and female counterparts.

This study is also consistent with the previous findings that children from families of higher income and children from households with better accessibility to personal vehicles are more likely to take a car to school (McDonald 2007; McDonald 2008a; Yarlagadda and Srinivasan 2008; Hsu and Saphores 2013). Students of wealthier households may have greater accessibility to personal vehicles (whether being driven or driving the car) and are able to drive to school more often. In addition, the results show that, similarly to existing research (McDonald 2008a; McDonald 2008b; Hsu and Saphores 2013), children from larger households are more likely to take alternative modes to school. It is possible that parents of larger families may not be able to drive all of their children to school, and therefore children of larger families are more prone to taking other modes of transportation to school.

The rising concern with children's dependence on the automobile and its suspected ties with the decrease in health and increase in obesity of today's youth, has driven policy makers to implement strategies to address the growing shift of children's travel to the automobile. One way that policy makers are trying to address this issue is with policies and programs aimed at children's school travel. In fact, the White House Task Force on Childhood Obesity has as one of its mission to increase active trips to

school by 50 percent in a five year time frame. As discussed previously, a nationwide program to address school travel is the Safe Routes to School program. However, these programs were implemented to encourage children's non-motorized travel through built environment solutions despite little evidence that these solutions would affect children's travel behavior (McMillan 2007).

As researchers began evaluating these programs, they found mixed results (Boarnet et al. 2005; McDonald 2008a; McMillan 2005; McMillan 2007). Similarly, this study tests several measures of land use on the joint decision of tour type and mode choice to school. While controlling for other factors, this study finds the land use measures to have minimal or no effect on the tour type and mode choices. In addition, the results seem to indicate that the land use measure that showed significant results (land use mix) has a greater impact on the tour choice rather than the choice of mode. Therefore this study supports the previous claim (McMillan 2007; Boarnet et al. 2005; McDonald 2008a; Lawrence Frank and Company, Inc. 2008; Hsu and Saphores 2013; Deka 2013) that although urban form and built environment designs may be necessary for lessening auto-dependence and promoting active modes of transportation, it is not the sole factor nor the most important factor in children's choice of mode to school. However, it is important to note that the models presented in this study used larger neighborhood level land use measures calculated within 1 mile from the child's home. These measures do not account for more detailed infrastructure differences. The addition of other built environment measures could reveal stronger impacts on school tour type and mode choices and therefore must be included in extensions of this work.

Without better understanding of the barriers and promoters of active travel, policies targeting built environment solutions to address auto-dependence cannot be fully successful. The results in this study maintain that to achieve reduction in auto-dependence, a better understanding is needed of the factors affecting the choice of using a car on the trip to school.

The issue of household time constraints and convenience has been recently undertaken by researchers in studies of school travel decisions. The notion is that increasingly complex schedules and a desire for convenience may undermine the effects of policies combating auto-dependence. The results presented in this paper support this claim.

For one, this study shows that, consistently with previous research (McDonald 2008b; Sidharthan et al. 2011; Yarlagadda and Srinivasan 2008), children from households with working mothers are more likely to drive. McDonald (2008b) suggests that for convenience, mothers who work prefer to take young children to school on the way to work rather than spend the time accompanying them by walking. The results of this study support this claim and find that children who are accompanied in their school trips by a parent or sibling are more likely to drive or be driven to school. Therefore, policies to encourage children's active travel must address, among other factors, parental convenience and time constraints (McDonald 2008b).

This study finds that including indicators of joint trips (accompaniment of students) is important in children's travel behavior analysis. In addition, it points to the

interconnectivity of children's and adult travel and therefore to the importance of considering children's characteristics in adult travel behavior.

As previously presented in Chapter 2, researchers agree that travel is derived from the demand to engage in activities, and therefore travel behavior research is now focusing on activity-based travel theory. However, even in children's travel research, most studies focus on the activities of adults, whereas the impact of children's activities are understudied. Paleti, Copperman, and Bhat (2011) argue that this is an important limitation of current activity- based travel behavior research.

The results of the analysis presented in this dissertation support the importance of considering children's participation in activities in travel behavior research, especially in children's school travel patterns. Overall, this study finds that students engaging in higher levels of out-of-home activities are both more likely to travel by car and participate in school tours where out-of home activities occur within the school tour. Although this study finds that a large percentage of children (approximately 45%) who choose a home-school-home tour participate in out-of-home activities after returning home from school, children are more likely participate in activities within the school tour.

The point of this study is not to discredit policy programs such as Safe Routes to School that aim to promote safer travel and decrease children's auto-dependence on the travel to school through urban design measures. These programs are important and necessary to facilitate active travel behavior, however they may not be sufficient. The goal of this study is rather to shed light on children's travel needs and behaviors

based on their activity participation so that these programs and policies can better target solutions to combat children's auto-dependence.

Some researchers have advocated that one method to increase the effectiveness of Safe Routes to School programs is to complement infrastructure improvements with other methods, such as education and awareness of the benefits of active travel (Lawrence Frank and Company, Inc. 2008). However, this solution does not address the issue of children's activity participation and scheduling constraints.

To combat children's lack of physical activity, policy makers need to target additional means, other than travel to school, for example increasing participation in other physical activity programs or creating new attractive spaces such as parks, playgrounds, gymnasiums or community centers where children can be active.

That is not to say that active travel is not important. Besides improving children's health, active travel can also address issues of congestion and emissions and promote children's independent mobility. In addition, research has shown that children who walk more are generally more active than those who travel mostly by car (Mackett 2013).

Other researchers advocate the benefits of Walking School Bus programs that can address several issues, such as safety concerns and parents' time constraints, if the programs are supported by schools or local government (Kingham and Ussher 2005; McDonald and Aalborg 2009). However, these program do not address the constraints on children's schedules. If a child participates in before or after school

activities, they may not be able to participate in such programs. This is certainly true for children who participate in out-of-home activities within the school tour. However, children who participate in activities after returning home from school may also have time constraints that do not allow them to participate in the longer Walking School Bus commute.

The results of the choice model to school presented here can help inform school travel programs intended to promote a shift towards other modes of transportation, especially active modes. The results speak to the importance of considering children's participation in out of home activities, especially spatially separated activities that require travel by car. Possible ways to decrease school travel by car include encouraging additional in-school or near-school activities that reduce the need for travel. In addition, providing transportation for children who do participate in before or after school programs could help address auto-dependence. Programs that provide buses or walking school buses to early (prior to before school activities) or late (after late activities) riders could be explored.

Besides the issues of transportation and health, studies addressing children's participation in activities may have an impact on other policies. For one, jurisdictions across the country are currently considering changing bell times for elementary, middle and high schools. These changes could affect children's participation in before and after school activities which in turn could affect their choices of mode and tour to school.

This study contributes to children's travel behavior research in two ways. First, it shows a novel approach at studying children's travel behavior to school by analyzing the school tour rather than the single trip. In addition, the results of this study support the hypothesis that children's participation in out-of-home activities has an impact on the joint decision of school travel mode and tour complexity.

As previous studies did not consider the direct relationship between children's activity patterns and school travel decisions of tour type and mode choice to school, the findings of this research contributes to the understanding of the factors influencing children's travel decisions to school and informs policy makers of new factors to consider when making policy decisions. In addition, because children's travel is so interconnected with adult travel, the link between children's activities and travel choices may have implications to overall transportation policy.

As this paper reports on early findings of the effect of children's out-of-home activities on travel patterns to school, future work is warranted to determine the strength of the relationship between children's activities and mode choice to school.

6.6 Shortcomings and Future Work

This study shows that there is a significant relationship between children's out-of-home activities and school travel decision making. As there are very few studies looking at the relationship between children's participation in activities and mode to school, this study is a first attempt at quantifying this relationship. However, the results of this study also call for additional work in this area to better inform policies and programs that aim at reducing children's auto-dependence.

This dataset is derived from a survey trip dataset and therefore is only as good as the responses from the participants. In addition, the activity participation profile for each student was derived from their trip purpose responses. Therefore, if a survey participant did not report a particular trip, then that activity is not captured.

Because the activity information is derived from a trip survey, non-spatially separated activities are not captured. For example, the study could not account for extra-curricular activities that occurred at school. If activities occur within the school (e.g. sports practice) and the student does not report it as a new trip, the activity is not accounted for. Accounting for these activities is beyond the scope of this study but is a very important part of understanding the relationship between student's activities and mode choice and therefore will be included in future analysis on this topic.

In addition, because the activity data used is derived from trip data, this study cannot properly differentiate between children's activities and household activities that children participate in. In other words, there is no information on who benefits from the activities, the student or the parent. Household activities that children participate

in such as picking up siblings or riding along with mom to the grocery store are still activities that are part of the child's daily schedule.

To further our understanding on the impacts of these activities, future research should consider collecting primary data of children's activities, such as an activity survey with specific questions about reasons for each activity. Additionally, better activity data would allow researchers to further disaggregate activity types in order to expand our understanding of children's participation in activities and its impact of travel patterns to school. As an extension to this study, future work should include an analysis of the choice of type of children's activities and timeframe when children choose to participate in these activities.

Regarding the effects of land use on children's mode choice to school, much further work is warranted. As this was a first attempt at looking at the impact of children's activities on the joint choice of more and tour type, this study only used area level land use measures, calculated at a 1 mile buffer of the child's home. Additional measures of micro-scale infrastructure and more localized urban form could have stronger effects on school tour type and mode choices. More detailed and better measures of land use should be included in future analysis.

In terms of activity based modeling, this study does a first look at children's tours to school and how activities either within or outside the school tour can affect their travel choices. Further research in this topic should also consider including an analysis of the other non-school daily tours to evaluate differences in mode choice of school tours versus non-school tours.

Regarding mode choice, this study only analyzed the mode to school. Mode for the return trip was not in the scope of this work. There were several reasons why the trip to school was chosen. For one, the trip to school is most often during rush hour and shifting children to other modes could help alleviate congestion. In addition, studies have shown that the majority of students use the same mode to and from school (Sidharthan et al. 2011; Yarlagadda and Srinivasan 2008). However, for those that use different modes to and from school, a greater percentage of children take a car on the trip to school than on the return trip (National Center for Safe Routes to School 2010; Schlossberg et al. 2006). Nonetheless, future work may consider analyzing mode choice for both the trip to school and the trip home.

Another limitation is that only the mode choice to school of the first trip to school is analyzed. Therefore, if a person reported compound trips (e.g. walk then bus) as two separate trips with the destination as "school", then only the mode of the first trip is captured. There were very few cases of compound modes to school reported in the dataset and therefore it is not expected that the results of this study would differ significantly. In addition, this study focused on auto-dependence of children and therefore only differentiated between personal vehicle and all other modes. Further work in this field should consider additional modal categories.

Additional research on this topic should also look at longitudinal data by including data from recent and future national or regional travel surveys. A longitudinal study would reveal whether the effect of participation in out-of-home activities on school travel decisions remains constant or increases over time.

Appendix

The following tables shows the correlation values for variables in the national data model:

	Tour Type	Mode (Auto = 1)	Age (Driving age = 1)	Sex (Male=1)	Race (White=1)	Household Size	Household Composition (Single Parent=1)	Vehicle Ownership (Vehicle Available=1)	Father Work Status (Father Works=1)	Mother Work Status (Mother Works=1)
Tour Type	1.0000									
Mode (Auto = 1)	0.1714	1.0000								
Age (Driving age = 1)	0.0372	0.1949	1.0000							
Sex (Male=1)	-0.0342	-0.0232	0.0052	1.0000						
Race (White=1)	0.0516	0.0316	0.0409	0.0111	1.0000					
Household Size	-0.0528	-0.0611	-0.1004	-0.0139	-0.1283	1.0000				
Household Composition (Single Parent =1)	0.0122	-0.0448	-0.0059	-0.0047	-0.0287	-0.2244	1.0000			
Vehicle Ownership (Vehicle Available=1)	0.0331	0.0987	0.0233	0.0035	0.1828	0.0006	-0.1194	1.0000		
Father Work Status (Father Works=1)	0.0213	0.0199	0.0033	0.0256	0.0718	0.0128	-0.0268	0.0421	1.0000	
Mother Work Status (Mother Works=1)	0.0570	0.0223	0.0383	0.0110	0.0815	-0.1326	0.0169	0.0638	0.0513	1.0000
Household Income	0.0594	0.1133	0.0510	0.0073	0.2154	-0.0365	-0.2372	0.1840	0.1439	0.0996
Accompaniment on Trip	0.0718	0.4345	-0.1423	-0.0183	-0.0004	0.1127	0.0156	0.0343	0.0072	-0.0172
Population Density	-0.0233	-0.0366	-0.0367	-0.0166	-0.3429	0.0159	0.0937	-0.3398	-0.0606	-0.0778
Number of Activities: Maintenance	0.3490	0.0591	0.0427	-0.0547	0.0403	-0.0378	-0.0072	0.0133	0.0137	0.0087
Number of Activities: Discretionary	0.2275	0.0770	0.0716	0.0024	0.0931	-0.0653	-0.0067	0.0443	0.0326	0.0155

	Tour Type	Mode (Auto = 1)	Age (Driving age = 1)	Sex (Male=1)	Race (White=1)	Household Size	Household Composition (Single Parent=1)	Vehicle Ownership (Vehicle Available=1)	Father Work Status (Father Works=1)	Mother Work Status (Mother Works=1)
Number of Activities: Passenger Serve	0.3277	0.1302	0.0199	-0.0324	0.0354	0.0263	-0.0089	0.0345	0.0323	-0.0109
Number of Activities: Work	0.0688	0.0954	0.3527	0.0015	0.0301	-0.0370	-0.0021	0.0213	0.0124	0.0357
Number of Activities: Other	0.2807	-0.0588	-0.0271	0.0010	0.0241	-0.0204	0.0204	0.0033	0.0142	0.0118

	Household Income	Accompaniment on Trip	Population Density	Number of Activities: Maintenance	Number of Activities: Discretionary	Number of Activities: Passenger Serve	Number of Activities: Work	Number of Activities: Other
Household Income	1.0000							
Accompaniment on Trip	-0.0111	1.0000						
Population Density	-0.1227	0.0016	1.0000					
Number of Activities: Maintenance	0.0264	0.0278	-0.0124	1.0000				
Number of Activities: Discretionary	0.1129	-0.0015	-0.0566	0.0704	1.0000			
Number of Activities: Passenger Serve	0.0184	0.0703	-0.0218	0.1078	0.0780	1.0000		
Number of Activities: Work	0.0150	-0.0854	-0.0195	0.0031	0.0162	-0.0036	1.0000	
Number of Activities: Other	0.0139	-0.0464	-0.0140	-0.0066	0.0137	-0.0093	-0.0144	1.0000

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