WALKING TO SCHOOL: INDIVIDUAL, FAMILY, NEIGHBORHOOD, AND BUILT ENVIRONMENT

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BY

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In this thesis, I ask “What factors impact the choice to have children walk to school?” Because the physical environment of a city is an expression of social dynamics, the social and built environment should be considered together. I test the hypothesis that the choice to walk to school can be explained by influences in the built environment, a family’s demographic characteristics, and social influences, especially the sense of community.

Using Baltimore, Maryland as a sample, I use data from a Household Travel Survey, data from the Baltimore Neighborhood Indicators Alliance, and Walk Score data that measure ease of walking in a location. I use a binomial logit model to predict the probability that a child will walk to school given individual, family, neighborhood, and physical environment characteristics.

Variables positively associated with walking include child’s age and the number of community gardens in a neighborhood. Other variables, such as distances greater than one mile, higher Walk Score, greater economic diversity, and being non-white are negatively associated with walking.

The results of this study suggest that influences on children’s walking behavior highlight the strengths and weaknesses of policies meant to create sustainable cities. Additionally, schools impact their communities by making it easier or harder for children to walk to school. Finally, holistic assessments of costs and benefits by policymakers would better support walking.
Thanks to the Faculty and Staff of the Georgetown Public Policy Institute, especially Andrew Wise, for his help in the completion of this thesis. Special thanks to my husband, Robert, for his patience and hard work to support me. Thanks to my children for their constant love. Thanks to my parents for their love and support in all of my endeavors.

Many thanks,
Hilary A. Ligon
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INTRODUCTION

Families choose the type of transportation methods children will use to travel to and from school in response to social norms, habits, and constraints, including constraints on their transportation options, time, and resources. People’s choice of transportation method is called their mode choice. In this thesis, I ask “What factors affect children’s mode choice for travel to and from school?” I assume that families make decisions together about how children will travel to school. I test the hypothesis that children’s mode choice can be explained by a combination of factors which include the built environment, demographic characteristics, and social influences. In particular, the model includes variables that measure the sense of community in a neighborhood.

The results of this thesis have implications for several policy areas including urban and regional planning and environmental, labor, and social policy. While mode choice is the technical term, I will use walk or drive when technical jargon would be a distraction.

Over the last several decades, people world-wide have shifted away from using active modes of transportation, such as walking or biking, to passive modes, such as driving. When the option exists, people usually choose to travel by car rather than by bus, train, or other mass transit. Recently, the increasing rates of childhood obesity in the United States were frequently featured in the news. Studies in medical journals associate more time spent riding in cars with lower overall activity levels in children. For example, a study published in the American Journal of Preventive Medicine is titled “Obesity Relationships with Community Design, Physical Activity, and Time Spent in Cars” (Andresen & Schmid, 2004). However, the effect on health is not the only concern. The link noted by many natural scientists between greenhouse gas
emissions and global climate change calls into question the environmental sustainability of car-dependent lifestyles.

These trends sparked policy initiatives to reduce car-dependence and encourage greater physical activity. Initiatives such as national- and state-level Safe-Walk-to-School programs, the Center for Disease Control’s KidsWalk-to-School program, and the Walking School Bus initiatives supported by the Department of Transportation all aim to increase the number of children walking and biking to school. However, research into the reasons why some children walk while others are driven to school is a very new field of study.

Most research conducted before 2000 focused only on adults’ mode choice. In the early 2000s, researchers first started looking at the unique determinates of children’s behavior. Of the growing number of studies published on children’s mode choice, most test the assumption that the primary determinate is the built environment (e.g. number of houses, street layout and size, mix of residential and commercial uses). Decades of studies demonstrate that the built environment influences adult mode choice. The determinants of children’s mode choice are complex and so far have been incompletely defined. The role of the built environment on children’s mode choice is ambiguous in children-focused studies.

Researchers have also included typical demographic variables and various social variables, such as perception of traffic safety, to help explain which children are likely to walk to school. However, the impact of social variables on children’s mode choice is also ambiguous. Some studies find that social factors matter more than the built environment while other studies find that their impact is negligible.
I assume that choices are influenced by a variety of factors. Importantly, thinking about the built environment as separate from the social environment is unrealistic. Studying the determinates of sustainable lifestyles, which for the purpose of this thesis is defined as children walking to school, requires acknowledging interconnection between variables that seem to describe only the physical or only the social environment. As stated in the preeminent writing on sustainability, “[t]he reality is that humanity is dependent on the environment, with society existing within, and dependent on, the environment, and the economy exists within society” (Brundtland, 1987). In addition to being more plausible theoretically, there is greater predictive power in including several variables to measure aspects of the built and social environment rather than just one type.

This thesis is organized as follows. The Background and Previous Research section presents a brief review of the relevant literature. Next, I present the general mathematical relationship in the Theoretical Framework. Subsequently, the section on the Empirical Model further specifies how the mathematical model acts as a testable proxy for the theoretical relationship. This is followed by a description of the sample characteristics (Data and Descriptive Statistics) of the variables. I then discuss the results of the empirical model in detail (Results). In the final section, Conclusions and Policy Implications, I compare the findings of this thesis to current ideals of sustainable design to highlight areas where the empirical data support and/or contradict the proposed ideals. Specifically, I consider what the results imply about how schools impact their communities by making it easier or harder for children to walk to school. I briefly consider implications for programs designed to increase the number of children
who walk to school. Finally, I argue that more accurate and holistic assessments of costs and benefits will create environments more conducive to walking.
BACKGROUND AND PREVIOUS RESEARCH

In recent decades the majority of Americans moved to urban and metropolitan areas. As of 2000, the last year for which Census data is available, almost 60% of Americans lived in areas with populations above 200,000 people (Census, 2004). Another 10% lived in urban areas with populations over 50,000 people. These changes coincided with changes in work force structure, the type of industries employing American workers, and family income-earning dynamics.

During the same decades, environmental degradation of waterways, poor air quality, and loss of forestland became increasingly well-known problems. More recently, changes in air and sea temperatures and other environmental changes predict the possibility of long-term global climate change (IPCC, 2007). Other demographic, social, and economic changes have taken place as well. One result is that scientists and policy makers want to influence people to travel differently. The thinking is that if people are able to walk or take public transportation, they will; and the trends of unhealthy lifestyles and environmental degradation can be reversed.

Governments, researchers, and transportation planners became more interested in studying what factors people take into account when making travel decisions – what options can people choose from, what are the effects of limited resources, and what social or cultural values influence decision-making?

Transportation planners have long studied how and why people travel in order to forecast the need for roads, plan regular maintenance, and design transit infrastructure. Typically, travel patterns are studied using a household travel survey in which households record each trip made by each member of the household on a given day. All of the information about trips, individuals, and households are compiled into a database.
Planners also compile detailed descriptions of the built environment mapped to traffic analysis zones, which are “special area[s] delineated by state and/or local transportation officials for tabulating traffic-related data, especially journey-to-work and place-of-work statistics, . . . [and] usually consist of one or more census blocks, block groups, or census tracts” (Census, 2005).

Transportation planners then match the information about people’s travel behavior to their models of the built environment and identify which areas suffer from traffic congestion, heavy wear on the pavement, lack of sidewalks, and so forth. Because household travel surveys already collect data about transportation choices, it made sense to start asking people questions about their attitudes and the constraints they face when deciding how to travel. More recent household travel surveys ask additional questions, such as respondents’ concerns about traffic congestion or neighborhood safety. These surveys are designed to enable research beyond planning new roads; however, the surveys remain influenced by the traditional uses for which they were designed.

While research on transportation mode historically focused on adults and their decisions, studies increasingly look at children’s behavior. Transportation modeling began to recognize the interactions between family members in making decisions about travel. As one study explained, “realistic travel-demand forecasts and policy evaluation require that the underlying models capture children-parents interactions” (Yarlagadda & Srinivasan, 2008). The family is an appropriate unit of analysis because families must take into account the needs and schedules of all family members when planning travel.
As previously mentioned, doctors observed several negative trends in children’s health over the last few decades. These trends are rising obesity rates, higher rates of chronic disease, and higher asthma rates (NCHS, 2004; CDC, 1998). Research indicates that children need more physical activity than they currently get on average in order to reduce obesity and chronic illness, such as diabetes (CDC, 2003). Since increased emissions from cars result in poorer air quality, the greater number of cars, time spent driving, and density of urban living all play a role in increased asthma rates (Dockery et al, 1993). Poor air quality in many cities causes children to suffer from asthma. Increasing active modes of transportation and decreasing automobile use are posited to alleviate all three health problems (Tudor-Locke et al, 2001).

Historically, children were more active in daily activities such as walking to and from school. Research comparing children from 1969 and 2001 found that, in 1969, 87% of children who lived less than a mile from school walked or biked to school. Of children living less than a mile from school in 2001, only 55% walked or biked. The number of children who were driven to school in 2001 had risen nearly 30 percentage points to 36% (McDonald, 2005). These numbers reflect the broader picture that approximately 85% of trips made by Americans are made in a personal vehicle (U.S. Department of Transportation, 2003).

In reaction to the decline in children’s activity and increase in health problems, several studies analyzed factors that potentially influence children’s mode of travel to and from school. Using a household travel survey and geographic data to study children’s mode choice is a relatively new application, but the idea is clearly an extension of techniques already in use. The previous research varies in emphasis. One group of analysis focuses almost exclusively on urban form. Urban form is the physical design of a city. The second group considers urban form
but includes more demographic and social variables, particularly in regard to perceptions of neighborhood safety. Very recent studies incorporate the techniques of spatial statistics, which will be described below.

The Environmental Protection Agency (EPA) conducted an analysis of the built environment’s effects on children’s mode choice for travel to school. The study used a sample of students living in Gainesville, Florida. The EPA concluded that proximity to school was a major factor in determining whether children will walk to school. In addition the EPA found that having more sidewalks and other destinations within walking range made children more likely to walk to school. When residential and retail buildings are allowed to be collocated in an area, it is called mixed-use zoning. The EPA study’s results are consistent with many studies that show adults walk more in mixed-use areas. The study also found that households with more cars were more likely to drive rather than walk. This study and most that followed used a multinomial logit model. (EPA, 2003)\textsuperscript{a}

An EPA-sponsored study conducted in Atlanta, Georgia, in 2008, found similar results regarding the effects of distance and availability of sidewalks. It also found that children who traveled through higher density neighborhoods tended to be more likely to walk. In contrast to the 2003 EPA study, the 2008 study found that once density was controlled for, mixed-use zoning had no clear effect. The household travel survey used in this study included questions about perceptions of the neighborhood such as respondents’ perception of ease of walking. The study did not include measures of household income or neighborhood crime rates, and the

\textsuperscript{a} A logit model is used to calculate the probability of each potential outcome. A binomial logit model is used when results are either-or, yes or no. A multinomial logit model is used when there are three or more possible results.
authors noted the difficulty in interpreting the results of household perceptions when more objective measures of neighborhood quality were lacking. The study used a multinomial logit model. (Lawrence Frank and Co., Inc., 2008)

McDonald (2007) used national-level data from the 2001 National Household Travel Survey. The analysis identified travel time, determined by distance, to be the most important factor in children’s mode choice. The author also noted that older children and those with siblings were more likely to walk. The study found no difference between genders although the author noted that other researchers have found gender differences to be significant. The effect of higher income and a greater number of household vehicles reduced the likelihood of walking. Again, population density was positively associated with walking. The study used a multinomial logit model. (McDonald, 2007)

McMillan (2006) studied school children in 26 California school districts to assess the relative influence of urban form in relation to other factors that affect children’s mode choice. The author found that urban form is an important factor, but it was not the most important factor. Household transportation options, social norms, and perceptions about neighborhood safety had a larger impact on mode choice, although including urban form did improve the overall fit of the model. This study consolidated walking and biking into one category (active modes of transportation) and used a binomial logit model. (McMillan, 2006)

In contrast, a study of children in Melbourne, Australia found that most demographic variables had no impact on mode choice. A household’s perception of having few other children in the neighborhood was the only significant social variable found in the study. The significant variables were all measures of the built environment or perceptions of it, such as a belief that
traffic was heavy in the neighborhood. This study also used a binomial logit model. (Timperio et al, 2006)

A study of the San Francisco Bay area focused on the interdependence between children and parents in choosing transportation modes. Yarlagadda and Srinivasan also found that parents’ employment and job flexibility strongly impacted children’s mode choice. Again, the analysis found that child age and gender affected mode choice. Interestingly, factors affecting travel to school in the morning, such as everyone trying to get to school and work on time, differed from factors affecting travel from school to home at the end of the day. This study found that urban form was not significantly associated with mode choice. The only factor in the physical environment that mattered was distance. This finding contradicts the findings of the other studies and raises important questions about what is actually being measured by the variables used in the research. This analysis used a more complex version of a multinomial logit model. (Yarlagadda & Srinivasan, 2007)

In just the last couple of years, econometricians began applying the techniques of spatial statistics to models of children’s mode choice. This development is theoretically important because it is a recognition of the autocorrelation problem. For example, neighborhoods tend to be home to households in the same socioeconomic groups. Households located near each other are probably similar to each other and different from households located in other neighborhoods. In other words, something about a geographic location attracts households that have similar characteristics, and so, the households are correlated with each other rather than randomly distributed. Standard statistics assumes that observations are uncorrelated, but spatial data is often correlated. Models that compensate for the effects of correlation will produce better
estimates and have more reliable statistical significance, but including spatial statistics is beyond the capabilities of many studies.

One analysis of spatial interaction effects found results for distance, child’s age, and household income were similar to other models. When looking at the spatial interaction effects, the authors found that interactions between households based on socioeconomic characteristics were insignificant whereas interactions based on geographic proximity were significant. In addition, the magnitude of the interaction was great, implying that households are greatly affected by the choices of other, nearby houses. The authors summarized the effect as follows:

When other children in the neighborhood use a mode like bicycling or walking, this creates a positive externality by improving the safety of bicycling and walking in the neighborhood, thus enhancing the utility of these modes for any particular household in the neighborhood.

The study used a survey of school children in California and compared a regular probit model\(^b\) to the spatial correlation model. (Sidharthan & Bhat, et al, 2010)

Mitra considered the extent to which high likelihood of walking was geographically clustered in the Toronto, Canada area. Urban neighborhoods, residential neighborhoods, and low and medium income households living in high-rise apartment buildings were some of the characteristics shared by “hot spots.” Mitra used a spatial logit model. (Mitra, 2010)

Pont et al. (2009) reviewed and compared the literature on children’s active transportation. They identified common variables used in several models of children’s mode choice. The review divided variables into measures of the built environment, economic variables, and social variables.

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\(^b\) A probit model uses a different technique but gets the same results as a logit model; the coefficients of a logit model are a consistent multiple of those from a probit model. The choice of which model to use is merely a matter of preference.
For measures of the built environment, the variables included distance, density, proximity to recreation facilities, availability of walking/bike paths, and mixed use zoning. Unfortunately, for most variables, approximately half the studies found the variables to be significant while the other half of the studies found that the variables had no effect.

For economic variables, higher income and greater number of vehicles per household were both associated with a lower probability that children walk to school. Again, there was a split between studies that found the effect significant and those that found it not statistically significant.

For social variables, commonly-used variables included parental concerns about traffic and crime. Not all studies found safety concerns significant, but those that did noted that as safety concerns grew the probability of walking decreased. No study found a significant association between parental education and likelihood of children walking or biking. Several studies found that being from a minority background increased the likelihood of using an active mode of transportation, but again, not all studies found the relationship to be significant. The authors of the review emphasized that the effects of marital status on mode choice were particularly unstable. (Pont et al, 2009)

In summary, there is broad-based agreement on the need to change incentives so that all people, including children, use more active forms of transportation. The review of previous literature is not exhaustive, but it is representative of the studies that attempt to identify which factors matter most. The built environment continues to be a major focus because it can be readily changed to produce different incentives. Social incentives are more difficult to design, but there is evidence that they matter. Because all of the studies used logit or probit models, this
review suggests the use of a logit model. This thesis will contribute to the body of knowledge by redefining and expanding the social variables to include measuring the sense of community in a neighborhood and looking at the impact of employer commuting incentives on the children of employees.
THEORETICAL FRAMEWORK

The general relationship I propose is:

\[ \Pr(\text{ActiveMode}=1) = f(D + BE + SE + PW + NS + e) \]  \hspace{1cm} (1)

Where:
- D represents distance,
- BE represents characteristics of the built environment,
- SE represents socioeconomic characteristics of the family,
- PW represents parent work characteristics,
- NS represents neighborhood and social characteristics, and
- e is a random error.

This model estimates the probability that a child, traveling between home and school, will use an active mode of transportation, such as walking. Each category of variables above describes a set of characteristics that may affect the decision to use an active mode of transportation. Distance is the distance between home and school. The built environment variables were chosen as measures of the physical environment in which children travel to and from school. The socioeconomic variables measure differences in families that might affect the probability that a child walks to school. Parent work characteristics measure the effect of employer commuting incentives on the children of employees. Neighborhood and social characteristics attempt to measure the sense of community within an area.
EMPIRICAL MODEL

I examine the theoretical relationship between children’s active transportation mode and the independent variables by estimating the following binomial logit equation:

\[ \text{Pr(ActiveMode}=1) = \beta_0 + \beta_1 \text{MILE} + \beta_2 \text{WALKSCORE} + \beta_3 \text{TREES} + \beta_4 \text{DIRTY} + \beta_5 \text{AGE} + \beta_6 \text{AGESQ} + \beta_7 \text{NONWHITE} + \beta_8 \text{INCOME} + \beta_9 \text{INCOMESQ} + \beta_{10} \text{CARS} + \beta_{11} \text{FREEPARKING} + \beta_{12} \text{ECONOMID} + \beta_{13} \text{COMMGARDEN} + \beta_{14} \text{MVOLUN} + u \]  

Pr is the probability that a child will walk to school, given the independent variables. Table 1 links each type of variable from the theoretical model to the specific independent variables used in the empirical model. AGE and INCOME are both included in the model as squared terms (AGESQ and INCOMESQ) because the quadratic form better fit the data and is consistent with standard practice.

Table 1: Independent Variables

<table>
<thead>
<tr>
<th>D represents distance:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MILE</td>
<td>trip is greater than 1 mile</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BE represents characteristics of the built environment:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WALKSCORE</td>
<td>proximity to amenities</td>
</tr>
<tr>
<td>TREES</td>
<td>% tree coverage</td>
</tr>
<tr>
<td>DIRTY</td>
<td>rate of dirty streets</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SE represents socioeconomic characteristics of the family:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td>child’s age</td>
</tr>
<tr>
<td>NONWHITE</td>
<td>race/ethnicity is not white, non-Hispanic</td>
</tr>
<tr>
<td>INCOME</td>
<td>family’s income</td>
</tr>
<tr>
<td>CARS</td>
<td># cars in the household</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PW represents parent work characteristics:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FREEPARKING</td>
<td>employer provides free parking</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NS represents neighborhood and social characteristics:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ECONOMID</td>
<td>economic diversity index</td>
</tr>
<tr>
<td>COMMGARDEN</td>
<td># community gardens</td>
</tr>
<tr>
<td>MVOLUN</td>
<td>Does the mother volunteer regularly?</td>
</tr>
</tbody>
</table>
Dependent Variable

*Active Mode:* Active transport mode is a binary variable that equals 1 if the child walks to school and 0 if the child does not. Active Mode is calculated from the Household Travel Survey, which is described below. A positive coefficient for any independent variable indicates a higher probability of walking to school.

Independent Variables

*MILE:* This variable is an indicator that the distance between home and school is greater than 1 mile. It is calculated based on the distance data from the Household Travel Survey. The coefficient should be negative, indicating that children are unlikely to walk or bike more than a mile from home to school. More generally, as distance increases, probability of active mode should decrease.

*WALKSCORE:* WalkScore is a measure of how easy it is to walk around a neighborhood and live a car-free lifestyle. A neighborhood’s Walk Score ranges from 0 to 100 and is based on the number of amenities within 1 mile of an address. WalkScores are obtained from WalkScore.com. The coefficient is expected to be positive, indicating that a more dense urban built environment and closer proximity to destinations will increase the likelihood of children walking.

*TREES:* This variable is a measure of the concentration of tree coverage in a neighborhood. The source of data is Ikonos satellite imagery from the Maryland Department of Natural Resources provided to the Baltimore Neighborhood Indicators Alliance. The coefficient may be positive if a more pleasant streetscape increases the likelihood of walking or biking.
However, the coefficient may be negative if a greater concentration of trees indicates a less-dense, more suburban area where distances between homes and schools would be greater and sidewalks or public access might be limited.

**DIRTY:** This variable is the number of reported incidents of dirty streets and alleys per 1,000 people in the area using Census 2000 data. The data come from Baltimore CitiStat, an office in Baltimore’s City Hall, and are reported by the Baltimore Neighborhood Indicators Alliance. The coefficient should be negative, indicating that the perception of residents that the streets are dirty will reduce the likelihood that children will walk along those streets.

**AGE:** This variable is the child’s age. For the purpose of this thesis, a child is someone who is under 18 years old. AGE is a continuous variable and comes from the Household Travel Survey. Based on previous research sited in the literature review, the coefficient should be positive, because older children often have more freedom to be outside alone or travel away from home without an adult.

**NONWHITE:** This variable is an indicator that the child is anything other than white, non-Hispanic so that it equals one for African Americans, Hispanics, and so forth. The reference is white, non-Hispanic race/ethnicity. The data come from the Household Travel Survey. I expect the coefficient to be positive, based on research noted in the literature review. Previous research found a positive association between Hispanic ethnicity and walking and a positive relationship between being born outside of the United States and walking.

**INCOME:** This is an ordinal variable ranging from 1 to 12 that measures family income. Appendix A contains a table of the ordinal values and the dollar amounts of each income level.
The data come from the Household Travel Survey. The coefficient should be negative, possibly because people in higher income households value the convenience of private transportation.

*CARS:* This variable is the number of cars owned by the household. It is a continuous variable and comes from the Household Travel Survey. The coefficient should be negative, indicating that households with more cars will spend more time driving and less time walking.

*FREEPARKING:* This variable is an indicator that the parent’s employer provides free parking. The variable comes from the Household Travel Survey and was one of several measures of employer-provided incentives. The other measures of employer-provided incentives had too few observations to make them useful.\(^c\) The coefficient of FREEPARKING should be negative, indicating that employees who have free parking available at work are more likely to drive rather than use public transportation or an active mode of transportation. If parents are driving to work, they are probably more likely to drive their children to school.

*ECONODIVERSE:* This variable is an index of economic diversity. The Baltimore Neighborhood Indicators Alliance calculated this variable using 2000 Census data and described it as the “probability that two households chosen at random will earn a household income in different median income range groups” (BNIA, 2007). Current thinking of urban planners and architects suggests that mixed housing, building different types of housing in one neighborhood (such as apartments, townhouses, and single family houses mixed together), would allow people to live in the same neighborhood throughout life and simply move from one size of dwelling to another as their needs change. This idea would also mean that people with different income levels live together in the same neighborhood. This variable is a proxy for the idea that people of

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\(^c\) Other employer-provided incentives included preferential parking for carpools, transit benefits, and guaranteed ride home programs.
different economic situations and different housing needs would live in mixed housing neighborhoods and be more likely to walk. I expect the coefficient to be positive.

**COMMGARDEN**: This variable is the number of community gardens in a neighborhood. It is a continuous variable provided by the Baltimore Neighborhood Indicators Alliance. The coefficient should be positive, indicating that neighborhoods with a sense of community and the level of cooperation necessary to create and maintain community gardens are more likely to be communities in which parents and children feel safe allowing children walk to school. Neighborhoods with community gardens may also be more interested in sustainable lifestyles, including using active modes of transportation.

**MVOLUN**: This variable is an indicator variable that a child’s mother volunteers regularly. Fathers were not included because so few of them reported participation in volunteer activities. The variable equals 0 if the child’s mother does not volunteer regularly, and it equals 1 if the mother does volunteer on a regular basis. The variable comes from the Household Travel Survey. The coefficient should be positive, indicating that when a household is actively engaged in the community, its members share a sense of community. This result may indicate that families involved in their communities feel that their neighborhoods are safe and let children walk to school.


**DATA AND DESCRIPTIVE STATISTICS**

The research uses a primary set of data, the Household Travel Survey. Supplemental data sources provide additional geographic and social variables. Descriptive statistics for the variables in the model are in Table 2. The combined dataset is cross sectional with 430 observations, but only 413 observations were sufficiently complete to include in the estimated equations.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean*</th>
<th>Min</th>
<th>Max</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>430</td>
<td>10.86</td>
<td>0</td>
<td>17</td>
<td>3.98</td>
</tr>
<tr>
<td>Cars</td>
<td>430</td>
<td>1.3</td>
<td>0</td>
<td>4</td>
<td>1.01</td>
</tr>
<tr>
<td>CommGarden</td>
<td>430</td>
<td>1.45</td>
<td>0</td>
<td>9</td>
<td>1.68</td>
</tr>
<tr>
<td>Dirty</td>
<td>430</td>
<td>74.97</td>
<td>1.14</td>
<td>388.96</td>
<td>68.69</td>
</tr>
<tr>
<td>Econdiverse</td>
<td>430</td>
<td>71.28</td>
<td>46.06</td>
<td>79.25</td>
<td>7.04</td>
</tr>
<tr>
<td>FreeParking*</td>
<td>430</td>
<td>168</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Income†</td>
<td>430</td>
<td>5.12</td>
<td>1</td>
<td>12</td>
<td>3.16</td>
</tr>
<tr>
<td>Mile*</td>
<td>430</td>
<td>251</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>MVolun*</td>
<td>413</td>
<td>100</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>NonWhite*</td>
<td>430</td>
<td>296</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Trees</td>
<td>430</td>
<td>22</td>
<td>.072</td>
<td>65.34</td>
<td>14.56</td>
</tr>
<tr>
<td>WalkScore</td>
<td>430</td>
<td>56.43</td>
<td>3</td>
<td>99</td>
<td>21.42</td>
</tr>
</tbody>
</table>

* For binary variables, the number in the mean column is the number of observations equal to 1.
† The min value of 1 indicates that a household’s annual income was less than $10,000. The max value of 12 indicates that a household’s annual income was $200,000 or more.

The primary data come from a Household Travel Survey of the Baltimore, MD and Washington DC metropolitan region, which was conducted by the Metropolitan Washington Council of Governments. The survey gathered information on travel patterns, types of transportation, and other types of information that will be used to “guide future transportation planning as the area continues to grow and assist local governments in figuring out which transportation improvements will benefit their citizens the most” (MWCOG). The survey was conducted throughout 2007 and the first half of 2008 and surveyed over 10,000 households. The
sample is cross-sectional and designed to be representative of the Washington DC and Baltimore, MD metropolitan areas. The data came in three sets of data: one for households, one for individuals in the household, and one for each trip for each person on the survey day.

Supplementary data provide additional information on the built environment and social factors. Supplementary data include a set of data compiled by the Baltimore Neighborhood Indicators Alliance (BNIA). The BNIA publishes data about Baltimore neighborhoods on a yearly basis that "'take the pulse' of Baltimore neighborhoods by measuring progress toward a shared vision and desired results for strong neighborhoods, good quality of life, and a thriving, vital city over time.” The data include 40 different measures of progress such as percentage of students performing at grade level and juvenile crime rates. These data were matched to the Household Travel Survey data by geographic area.

In addition I used the WalkScore.com web app to calculate the WALKSCORE for each Census tract. WalkScores are a proxy for how easy or difficult it is to travel by foot in a given location. I used the “Smart Street” version of the WalkScore algorithm that acts as a proxy for measuring the built environment because, according to WalkScore’s website, it includes intersection density, block length, and other variables (WalkScore, 2011). The company granted me permission to use their web application for this thesis.

It should be noted that the sample used in this study may have bias. The sample was selected to be representative of people in the Baltimore, MD and Washington, DC area, but the Baltimore-Washington metropolitan area is unique in several respects. For example, in 2007 when the Household Travel Survey was conducted, Washington DC had the fourth worst traffic in the country and Baltimore had the 19th worst traffic; since then Baltimore traffic congestion
has increased (INRIX, 2010). The region includes several of the richest counties in America (Sherfinski, 2010). But at the same time, the city centers have high poverty rates; in Baltimore the poverty rate is over 19% while in Washington DC it is almost 17%. The proportion of blacks to whites in the region is significantly higher than the national average. As a result of these regional characteristics, the households in the sample reflect similarities by nature of their shared Baltimore-Washington metropolitan experience, but those similarities are not reflective of other regions, even other metropolitan regions, in the country. Additionally, this thesis included only Baltimore City residents. Suburban and rural areas surrounding Baltimore City were excluded from the analysis as was Washington DC. Only Baltimore City was included because Baltimore collects and publishes a variety of social and economic indicators that were unavailable for other areas. Because of the unique demographic, social, and economic characteristics of Baltimore City, the results may only be relevant in similar urban areas. (Census, 2010)
RESULTS

Coefficients and Odds Ratios

The results of the analysis are presented in Table 3. The binomial logit model tests the relationship between the independent variables and children choosing to walk to school. Overall, the model is significant at the 99 percent level, and the Pseudo R-squared indicates that the model explains 48% percent of the variation in choices to walk or not walk to school, at least among school-aged children in Baltimore, MD. To put the relatively large Pseudo R-squared value in perspective, the single variable MILE explains 23% of variation in mode choice. The other variables combined explain an additional 25% of variation. The results support the hypothesis that demographic and social factors play a significant role in explaining children’s mode choice.

One feature of logistic regression is that the magnitude of the coefficient cannot be evaluated directly; the coefficients must be transformed into odds ratios or used to find predicted probabilities. While I will focus on predicted probabilities, Table 3 includes the coefficients and odds ratios for each variable. Odds ratios are a way to compare the odds across groups, such as the odds of walking to school for white children and non-white children. The odds ratio for NON_WHITE is 0.280, which means that non-white children have odds of walking to school 0.28 times lower than the odds of white children walking to school. To provide another example, the odds ratio for COMMUNITYGARDEN is 1.921. This means that for each additional community garden in a child’s neighborhood, we expect a 92% increase in the odds that the child walks to school. Importantly, this is not the same thing as saying that adding a community garden increases the probability of walking by 92%. Lastly, it should be noted that the
interpretation for each coefficient is for a one unit increase in the variable while holding all other variables constant.

Table 3: Model Coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio</th>
<th>Coefficient</th>
<th>Robust S.E.</th>
<th>Z</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mile</td>
<td>0.029</td>
<td>-3.541***</td>
<td>0.504</td>
<td>-7.02</td>
<td>0.000</td>
</tr>
<tr>
<td>WalkScore</td>
<td>0.983</td>
<td>-0.018*</td>
<td>0.010</td>
<td>-1.78</td>
<td>0.075</td>
</tr>
<tr>
<td>Trees</td>
<td>0.939</td>
<td>-0.063***</td>
<td>0.020</td>
<td>-3.11</td>
<td>0.002</td>
</tr>
<tr>
<td>Dirty</td>
<td>0.982</td>
<td>-0.019***</td>
<td>0.005</td>
<td>-3.62</td>
<td>0.000</td>
</tr>
<tr>
<td>FreeParking</td>
<td>0.149</td>
<td>-1.904***</td>
<td>0.496</td>
<td>-3.84</td>
<td>0.000</td>
</tr>
<tr>
<td>EconDiverse</td>
<td>0.923</td>
<td>-0.080***</td>
<td>0.030</td>
<td>-2.68</td>
<td>0.007</td>
</tr>
<tr>
<td>CommGarden</td>
<td>1.921</td>
<td>0.653***</td>
<td>0.170</td>
<td>3.83</td>
<td>0.000</td>
</tr>
<tr>
<td>MVolun</td>
<td>0.212</td>
<td>-1.552***</td>
<td>0.454</td>
<td>-3.42</td>
<td>0.001</td>
</tr>
<tr>
<td>Age</td>
<td>1.806</td>
<td>0.591**</td>
<td>0.233</td>
<td>2.54</td>
<td>0.011</td>
</tr>
<tr>
<td>AgeSq</td>
<td>0.980</td>
<td>-0.031***</td>
<td>0.011</td>
<td>-2.75</td>
<td>0.006</td>
</tr>
<tr>
<td>NonWhite</td>
<td>0.280</td>
<td>-1.274*</td>
<td>0.653</td>
<td>-1.95</td>
<td>0.051</td>
</tr>
<tr>
<td>Income</td>
<td>0.575</td>
<td>-0.554***</td>
<td>0.211</td>
<td>-2.62</td>
<td>0.009</td>
</tr>
<tr>
<td>IncomeSq</td>
<td>1.051</td>
<td>0.050***</td>
<td>0.017</td>
<td>2.95</td>
<td>0.003</td>
</tr>
<tr>
<td>Cars</td>
<td>0.640</td>
<td>-0.447</td>
<td>0.289</td>
<td>-1.54</td>
<td>0.123</td>
</tr>
<tr>
<td>Constant</td>
<td>9.789***</td>
<td>2.777</td>
<td>3.52</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Pseudo R-squared</th>
<th>Wald Chi-squared</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>413</td>
<td>0.4813</td>
<td>92.48***</td>
</tr>
</tbody>
</table>

* Statistically Significant at the 90% Level
** Statistically Significant at the 95% Level
*** Statistically Significant at the 99% Level

As expected, distances greater than one mile between home and school were negatively associated with walking to school. The coefficient of MILE has a negative sign, and the coefficient is significant at the 99 percent level. This finding is consistent with the literature on children’s mode choice.

The coefficient on WALKSCORE is statistically significant only at the 90% level. A possible interpretation of the lower significance score is that the built environment is not an important factor. A better interpretation might be that the variable fails to capture one or more

---

\[d\] In order to correct for heteroskedacity, the logit model in this study was run with robust standard errors.
important aspects of the built environment. Since WALKSCORE is a composite of several
variables in the built environment, it is plausible that an important variable is missing in the
composite score. The negative sign for the coefficient of WALKSCORE is initially surprising
given the expectation that “walkability” will encourage walking. However, the WALKSCORE
measures both ease of walking and proximity to amenities such as retail and restaurants. The
negative sign of the coefficient may reflect the fact that areas with many shops and restaurants
cater to adults and are often located in business districts rather than in school zones.

In contrast to some literature and also to my expectations, TREES are a negative
predictor that children will walk to school. The negative coefficient may be explained by
considering that trees are more often found in suburban neighborhoods with larger parcels of
land than in more dense and urban development. In this thesis TREES may have acted as a
proxy for population density. A more detailed approach that measures the impact of having or
not having trees in equally dense areas may be a better way to measure the effect of trees on
people’s choices to walk or drive. The coefficient on TREES is highly statistically significant, at
the 99 percent level.

The coefficient on DIRTY is negative and highly statistically significant, indicating that
the perception that streets are dirty is associated with a lower likelihood of using active
transportation modes. This result implies that the cleanliness or appearance of the built
environment matters in addition to its physical form. This result is notable because previous
research has not included a measure of cleanliness in an empirical model.

As expected, FREEPARKING is a significant, negative predictor of children’s active
transportation. When a parent’s employer provides free parking, the parent has incentive to
drive. Possibly, parents drop children off at school on the way to work. While this research does not explore the exact nature of this phenomenon, it is clear that free parking at work is associated with lower probability that children walk to school. This variable, and indeed the whole idea of looking at the impact of employer-created incentives for parents on children’s behavior, is original to this thesis.

Social factors that could be considered measures of a neighborhood’s sense of community also had impacts on children’s mode choice. Contrary to my expectations, the sign of the coefficient for ECONDIVERSE is negative; the coefficient is significant at the 99 percent level. Mixed housing may be a beneficial and attractive prospect, but economic diversity is a complex phenomenon linked to racial and class diversity. Based on the research of economic geographers, who have studied the patterns of housing diversity and segregation for decades, it is clear that diversity is an artifact of social, political, and historical influences rather than the result of housing type (Glasmeier & Farrigan, 2007). While it is still likely that income helps determine housing type, there is evidence that smart growth policies, intended to encourage mixed use development rather than suburban sprawl, result in greater income segregation (Pendall & Carruthers, 2003). In light of this result, ECONDIVERSE may be negatively associated with sense of community or may not be a good measure of it.

Among several variables used to measure community organizations in preliminary models, community gardens was the only variable that was consistently significant. For this reason, COMMGARDEN is the only variable retained in the final model. It is significant at the 99 percent level. The sign of the coefficient is positive, indicating that as the number of community gardens in a neighborhood increase, children are more likely to walk to school. As
previously described, the attempt to measure the sense of community in a neighborhood is an original contribution of this thesis to the literature on children’s mode choice.

Surprisingly, mothers who volunteer regularly are negatively associated with children using an active mode of transportation. MVOLUN was intended as a proxy for sense of community and, specifically, the household’s sense of community. My assumption was that families in which the mother volunteers will have a greater sense of community. The results may indicate that the increased time pressures created by additional commitments outside the home may actually reduce the probability that children walk to school. MVOLUN may not actually measure sense of community in the way I intended.

Consistent with the literature, AGE and AGESQ are significant, positive predictors of using active transportation modes. The coefficients of AGE and AGESQ describe a phenomenon in which children are more likely to walk to and from school as they get older and more capable of independent travel outside the home. But, the magnitude of the effect of age on likelihood to walk diminishes as age increases. A difference of a year in age has a larger impact when a child is young than when a child reaches the teenage years. For this reason, the quadratic form is appropriate.

The coefficient of NONWHITE is statistically significant at 90%, barely missing the cut-off for significance at 95%. The sign of the coefficient is negative. While much previous literature has ignored race and ethnicity, some literature found that Hispanic ethnicity was associated with a higher probability of walking and that non-U.S. born children were also more likely to walk to school. The findings of this thesis are, therefore, somewhat surprising because nonwhite children were less likely to walk to school than white children. In Baltimore, MD the
The majority of non-white children are African American, not Hispanic, and the results from this research are quite different from previous findings.

The results for INCOME and INCOMESQ are as expected and consistent with previous research findings. The sign of the coefficient for INCOME is negative, and the sign of the coefficient for INCOMESQ is positive so that the probability of walking declines with income, but at a diminishing rate. INCOME and INCOMESQ should be interpreted to mean that as household income increases, the effect of income is diminishing. For example, the difference in probability of walking is large when comparing families with $10,000 in income to those with $30,000 in income. But, the difference in probability of walking changes little between families with $70,000 in income and those with $100,000 in income. Because of the diminishing effect, the quadratic form is appropriate. Both INCOME and INCOMESQ are significant at the 99 percent level.

Most models of children’s mode choice for trips to school include a variable to account for the number of cars owned by a household. This thesis included CARS in the model, but found that the coefficient was not statistically significant. Car ownership is generally considered to be associated with income, and the impact of cars may simply be a function of income rather than an independent predictor of mode choice. In any case, the number of cars owned by a household had no predictive power in my model.
Predicted Probabilities of Walking to School

Using the results of the logit model, I calculated the probability a child will walk to school given a set of specific characteristics. Table 4 shows the predicted probabilities for several variables of interest. All of the variables were statistically significant except the indicator for Non-White and the measure of walkability, both of which were significant only at the 90% level.

Table 4: Predicted Probabilities of Walking to School

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Predicted Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance &gt; Mile</td>
<td>2.724</td>
</tr>
<tr>
<td>Distance =&lt; Mile</td>
<td>49.123</td>
</tr>
<tr>
<td>Free parking at parent’s job</td>
<td>3.76</td>
</tr>
<tr>
<td>No free parking at parent’s job</td>
<td>20.79</td>
</tr>
<tr>
<td>Mother volunteers</td>
<td>3.727</td>
</tr>
<tr>
<td>Mother does not volunteer</td>
<td>15.45</td>
</tr>
<tr>
<td>Age = 5 years old</td>
<td>0.22</td>
</tr>
<tr>
<td>Age = 14 years old (highest predicted prob)</td>
<td>13.86</td>
</tr>
<tr>
<td>Age = 17 years old</td>
<td>8.0</td>
</tr>
<tr>
<td>Non-White</td>
<td>7.774</td>
</tr>
<tr>
<td>White</td>
<td>23.166</td>
</tr>
<tr>
<td>Income = Less than $10,000</td>
<td>12.41</td>
</tr>
<tr>
<td>Income = $10,000 - $14,999 (most common)</td>
<td>12.31</td>
</tr>
<tr>
<td>Income = $40,000 - $49,999 (2nd most common)</td>
<td>5.42</td>
</tr>
<tr>
<td>Income = $200,000 or More</td>
<td>0.14</td>
</tr>
<tr>
<td>Number of Community Gardens = 0</td>
<td>4.64</td>
</tr>
<tr>
<td>Number of Community Gardens = 1</td>
<td>8.55</td>
</tr>
<tr>
<td>Number of Community Gardens = 9</td>
<td>94.56</td>
</tr>
<tr>
<td>Least Economic Diversity</td>
<td>49.08</td>
</tr>
<tr>
<td>Most Common Level of Economic Diversity</td>
<td>18.26</td>
</tr>
<tr>
<td>Most Economic Diversity</td>
<td>6.4</td>
</tr>
<tr>
<td>Least Walkable</td>
<td>24.07</td>
</tr>
<tr>
<td>Most Common Level of Walkability</td>
<td>13.36</td>
</tr>
<tr>
<td>Most Walkable</td>
<td>5.54</td>
</tr>
</tbody>
</table>

As Table 4 shows, the probability of a child walking to school when the school is a mile or less from the child’s home is 46.4 percentage points greater than the probability that a child
will walk when the school is farther than one mile from home. Consistent with the model and previous research, distance is of primary importance when families decide whether children will walk to school.

Children whose parent has free parking at work are 17.03 percentage points less likely to walk to school than children whose parent does not have free parking at work. This relationship indicates a relationship between transportation decisions of parents and children. I hypothesized in this thesis that transportation choices are made by families as a whole, not individuals, especially for children’s mode choice. While other studies also express this belief, few studies have included variables that could measure interaction between parents and children. The fact that parents’ incentives do affect children’s mode choice validates the belief that decisions about transportation balance the needs and influences on all family members.

Children whose mothers volunteer regularly are 11.72 percentage points less likely to walk to school. As noted above, volunteering may increase time pressures in a family, and the convenience and time-savings of driving may be a greater incentive for driving than the incentive for walking created by community participation.

The age at which children are most likely to walk to school is 14 years old. Elementary school aged children are very unlikely to walk, possibly out of concern for their safety and ability to travel alone. Only once children reach the teenage years does the predicted probability reach double digits. But, as soon as children can drive, the probability that they will walk decreases again.

White children are 15.39 percentage points more likely to walk to school than Non-White children. It is not immediately clear what accounts for the difference. The reason could be
differences in some socio-economic measure, although income was held constant in the model. Preliminary models that included indicators for single-parent households and dual-income families found no significance in those variables. The difference may be due to differences in attitudes about walking or how families make decisions about transportation.

As family income increases, children are less likely to walk to school. There is a steady decline in walking associated with increased income. The difference between the highest income group (families with income $200,000 or more) and the lowest income group (families with less than $10,000 income) is 12.27 percentage points. Table 4 also includes the predicted probabilities for the two most frequent income levels, which is interesting in itself. The fact that the most common incomes levels in Baltimore are clustered near the poverty threshold may be imply that these results are most salient to cities with similar economic conditions. The dynamics in more affluent cities could be quite different.

One of the most interesting results of this thesis was the predictive power of community gardens. In neighborhoods with many community gardens, children are very likely to walk to school. As shown in Table 5, all children who lived in neighborhoods with more than 5 community gardens walked to school. However, there were few observations of children who live in communities with more than five community gardens, and so, this result deserves additional research.

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"The poverty threshold is defined by the federal government each year. In 2007 the poverty threshold for a two-person family was $13,690. For a three-person family, it was $17,170. And for a four-person family, the threshold was $20,650." (Federal Register, 2007)
<table>
<thead>
<tr>
<th>Commgarden</th>
<th># Children Not Walking to School</th>
<th># Children Walking to School</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>125</td>
<td>37</td>
</tr>
<tr>
<td>1</td>
<td>86</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>52</td>
<td>24</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>37</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

Children who live in a neighborhood with greater economic diversity are less likely to walk to school. The predicted probability of walking for children who live in the least economically diverse neighborhoods is almost 50 percent. Children in the most economically diverse neighborhoods are predicted to walk with only a 6.4 percent probability. In the vast majority of Baltimore neighborhoods, the probability is greater than 50 percent that two randomly-chosen households’ incomes will be in different income groups. Most commonly, the probability that any two households are likely to be in different income groups is 64%. At this most common level of economic diversity, the probability that a child will walk to school is 18.26%. As previously noted, my expectation for this variable was proved wrong. Economic diversity led to less walking, which probably indicates less active lifestyles overall. This is an important point because it indicates that the assumptions made by many architects and urban planners about the benefits of mixed housing for creating sustainable lifestyles may be more complex than anticipated. Further research could determine if the effect of economic diversity is similar in all neighborhoods or if it differs in mid-to-high income environments versus low-to-middle income environments.
Finally, the walkability of a neighborhood also presents a complex picture for policy makers and urban planners who want to create cities that promote sustainable lifestyles. Often, the ease of walking and proximity to amenities is associated with increased active transportation, but these previous results are for adults (Cervero & Radisch, 1996). As noted in the coefficients section, walkability as measured by the WalkScore, was a negative predictor of children walking to school. In the neighborhoods considered least walkable, the probability that a child will walk to school is 24.07 percent. In the neighborhoods considered most walkable, the probability that a child will walk to school is only 5.54 percent. At the most common level of walkability in Baltimore, the probability that a child will walk to school is 13.36 percent. The paradoxical results for walkability indicate the need to ask “Walkable for whom?” when thinking about neighborhood design. The least walkable neighborhoods tend to be residential. It may be that children are more likely to walk to a school located in the middle of a residential neighborhood than a school in a mixed-use environment, where safety may be more of a concern.
CONCLUSIONS AND POLICY IMPLICATIONS

This thesis proposed that children’s mode choices are unique from adults’ choices but still tied to them because families make decisions together to meet their collective needs. The model in this thesis estimates the probability that a child will walk to school rather than using more passive transportation modes. I identified broad categories of influence that may determine the decision families make about whether children walk to school. These categories were characteristics of the trip to school, built environment, neighborhood, family’s socioeconomic status, and parents’ commuting incentives. The empirical model used twelve specific variables to measure these characteristics.

The results of the model confirm some results of previous research and provide new insights. Variables that are negatively associated with walking are 1) distances greater than a mile, 2) a higher percentage of tree cover, 3) dirty streets, 4) higher WalkScore, 5) free parking at parent’s workplace, 6) greater economic diversity, 7) mothers who volunteer regularly, 8) being non-white, and 9) higher family income. The variables that are positively associated with walking are child’s age and the number of community gardens in a neighborhood. The number of cars owned by a family was not significant.

Putting this research in context, walking to school is only one recommendation among many to improve the health and sustainability of our society. This thesis contributes to an understanding of what matters when families decide if children will walk to school. The results of this thesis have several policy implications. I focus on the following policy areas: analyzing and implementing ideals of sustainable urban design, implications for neighborhood schools,
evaluating programs meant to increase the number of children who walk to school, and finally, assessing the costs and benefits of sustainable lifestyle choices.

Analyzing and Implementing Sustainable Urban Design

Physical activity has been in steady decline for several decades. This phenomenon is not unique to America, but the effects for Americans’ health have been particularly notable as obesity and related health problems have increased dramatically in recent years. The current environment encourages driving and leads to obesity and other health concerns such as air pollution. Proponents of new sustainable design ideals envision a changed environment that would encourage walking, biking, and mass transit in order to reduce obesity, air pollution, and other health and environmental problems.

New design ideals are meant to create a sustainable society in terms of human and environmental health. Sustainability will mean changes in how people live so that each person uses fewer resources and less energy. People who live in urban areas tend to live in smaller homes and travel shorter distances, thereby using less energy. For this reason, many planners, architects, and policymakers advocate an urban lifestyle. The important element of the urban lifestyle is thought to be the increased density that fits more people into a smaller area. Density is a positive aspect of the urban lifestyle because it reduces transaction costs between people and so increases wealth. Living smaller and closer also conserves energy and other resources. Mass transit needs a dense population to make it cost efficient. But at the same time, cities are expensive, loud, have more crime, etc. Interestingly, density was not statistically significant, either by itself or in combination with other variables, in this thesis. While some studies have
found density to be significant, it may be that it is not density that matters but that there is an 
omitted variable acting through density. There are enough negative consequences of high 
density living and a lack of evidence to support the significance of density to question whether 
density should really be the ideal for the future.

In terms of this thesis, I was only able to do research on an urban center because the 
surrounding suburban and rural areas do not collect and publish the data needed for analysis. 
Research done using urban samples probably does not describe the dynamics in suburban or rural 
areas, but those areas typically do not make data available. As long as suburban and rural areas 
lag in providing data, policies and decisions will be made based on the urban experience. That 
should be a concern for communities where different constraints and dynamics influence how 
people travel.

Another ideal of sustainable planning is the mixed-use neighborhood. As noted, decades 
of research indicate that mixed-use neighborhoods promote walking, biking, and use of mass 
transit by adults. Mixed-use neighborhoods often require changes to prevalent zoning and 
planning habits. Neighborhoods have to be zoned for a mix of residential, retail, and commercial 
space. Changes to zoning require additional thinking to make rules that work for the different 
types of activities that take place in a mixed-use neighborhood. Additionally, roads often need to 
be designed with bike lanes and wider sidewalks. Cities need to remove requirements for 
businesses to provide large parking areas. (Farr, 2007)

In this thesis, I could not directly measure mixed-use neighborhoods. As a proxy, I used 
WalkScores which, among other things, measure access to amenities in the area. As noted in the 
results, children were less likely to walk to school when WalkScores were high, ostensibly
indicating ease of walking. Children were much more likely to walk to school when there were fewer amenities nearby, possibly because less walkable neighborhoods were residential ones in which children attended neighborhood schools. It appears that mixed-use neighborhoods do impact children differently from adults. The impact of mixed-use neighborhoods on families may also be different from adults on average. This possibility merits further study.

Another way in which this thesis can inform thinking about the ideal of mixed-use zoning is the impact of employer provided parking for parents of school children. When employers provide free parking, the children of employees are less likely to walk to school. Logically, if employees could get to work via walking, biking, or mass transit, many would choose to do so. When employees pay for parking, the cost of using transit relative to driving declines. Transit may even be the cheaper alternative. Similarly, some employees might choose to bike or walk to work. Mixed-use zoning may bring jobs closer to homes so that walking or biking becomes a possibility. Employer-provided incentives could change behavior so that employees prefer active transportation or public transit. If parents are not driving to work, the children are probably less likely to be driven to school.

The Household Travel Survey used in this thesis included variables for other types of employer-provided commuter incentives, but so few survey respondents reported that employers provided the various commuter incentives that those variables were of little use. However, this thesis found that free parking reduces the probability that children walk to school. More broadly, this result means that incentives matter as families choose how to travel. The point of mixed-use zoning is to change the constraints and incentives people face. In light of this thesis, mixed-use
zoning may be an ideal worth pursuing. Particularly, mixed-use zoning may be a better standard for designing where people work and how they get there.

A twin ideal of mixed-use zoning is mixed-housing neighborhoods. A mixed-housing neighborhood includes houses of different sizes and price points. Often it includes apartments, townhouses, small single family houses, and larger houses. The ideal is that families can maintain strong relationships in their community by simply moving from house to house as their needs change. Rather than moving from the city to suburbia when a couple has children, they could simply move into a different sized house in the same neighborhood. (Farr, 2007)

While appealing, this ideal seems to ignore obvious economic constraints. One way people organize society is through our spatial order – where people can and cannot go, how much space people can have, how spaces are connected to each other, and so forth. Because size of space is associated with social status and wealth, it is naïve to think that families can afford larger homes simply because they have larger households. While some families will be able to increase income ahead of the dual costs of raising children and purchasing a larger home, many will not.

In addition to this criticism, the ideal of mixed-housing as a sustainable lifestyle choice was not supported by the impact of economic diversity on children’s probability of walking to school. As economic diversity increased, children were less likely to walk to school. Economic diversity may make it more difficult to develop a sense of community in a neighborhood. People may feel too different from each other, or lower-income households may be too busy working to devote time to community activities. Whatever the reason, mixed-housing as initially idealized may not be realistic. Still, the ideal has appeal and one sees an increase in mixed-housing
development in the Baltimore-Washington area, so some version of the mixed-housing ideal may be possible.

The final sustainable design ideal I will discuss is the importance of preserving and creating public spaces, usually public green spaces. The results of this thesis highlight several important features of public spaces. First, public spaces need to be clean if they are to be used. Children were less likely to walk to school when their neighborhood streets were dirty. Second, public spaces that provide a sense of community promote walking.

Despite the difficulty in measuring sense of community, the variable of community gardens as a measure of community was one of the most significant variables in this thesis. Having several community gardens in a neighborhood guaranteed that children walked to school. Clearly it is not the gardens themselves that convince children to walk to school. Something about communities with gardens makes it more likely that children will walk to school. It seems likely that communities that can cooperate to maintain a common area, and avoid the tragedy of the commons described by economist Garrett Hardin, do a better job of being a sustainable society in other ways, too (Hardin, 1968). This would be an interesting question for further research.

Lastly, as discussed in the results section, additional research on tree coverage would be useful for understanding what sort of public spaces encourage sustainable lifestyles. Typically, parks and tree-lined streets are considered good environments for encouraging walking. This thesis found that having more trees predicted that children would be less likely to walk. The reason for this result is not clear. One possibility is that more residential neighborhoods might
have more trees but fewer sidewalks for children to walk on. Perhaps neighborhoods with some trees are friendlier but those with too many trees are not.

In summary, new ideals for sustainable societies envision real changes in the spatial distribution of homes, jobs, shopping, and recreation. Among these ideals are urban density, mixed-use zoning, mixed-housing, public spaces, and reclamation rather than expansion. This last ideal is the topic of the following section on neighborhood schools, by which I mean schools located in the midst of the neighborhoods they serve.

**Neighborhood Schools**

Understanding children’s behavior when traveling to and from school can guide decisions about where and how schools are situated in relation to the neighborhoods they serve. In other studies on children’s mode choice, researchers note that old schools in residential neighborhoods are often abandoned while new schools are constructed on the outskirts of town. This decision has an obvious, negative effect on walking to school. Because this thesis and all other studies find that distance is the single most important factor in determining whether children walk to school, moving schools out of neighborhoods discourages walking. The EPA describes neighborhood schools as “[s]chools built close to students, in walkable neighborhoods” (EPA, 2003). If we as a society want children to be more active, we need to make it easier to be active – easier both physically and socially – and that means neighborhood schools.

Making it possible for children to walk to school may mean renovating or replacing old schools in their original location rather than building new ones on the edge of town. A walkable school is built in the neighborhood that it serves. In the first study of children’s mode choice, the
EPA concluded that “decisions about the construction and renovation of these schools will have important implications for their adjoining communities . . . Citizens, school administrators, and parents are recognizing that schools do more than house children for the day. They affect home-buying decisions and traffic patterns. They present opportunities to create neighborhood centers for education and civic life.” (EPA, 2003). At their best schools are an integral part of a neighborhood and community. The implication is that communities should make policy decisions that consider the impacts of school siting decisions.

An obvious implication of school siting decisions is the resulting traffic pattern. The problem of traffic congestion at schools is one school administrators know well – one that they attribute to the larger area from which their students come, usually by car or bus. For example, the principal at a New Jersey elementary school recently sent a letter to parents introducing a new incentive program for walkers and carpoolers. The principal explained:

In the 1950s, the Bertrand Franklin Gibbs Elementary School housed 200 students in eight classrooms, and most of those children walked to school! Sixty years later, the building has more than tripled in size, and 510 children come through our doors each morning. However, while the roads around the neighborhood have not changed much, today, most of our students arrive by car, leaving us with lots of congested streets in the morning. (Montgomery, 2011)

In a neighborhood school, in other words, many children simply walked to school. In this case the school was not relocated, but the area served and the number of children attending more than doubled. The result was that many parents drove their children to school.

Another implication of school siting decisions is the impact on children’s overall physical activity. One reason communities might site schools on the edge of town is to increase the space available for official sports (Vincent, 2006). Sports fields provide space for physical activity;
however, it is a contradiction to create space for official sports while creating a barrier to active lifestyles by locating schools far from residential areas. The results of this thesis indicate that when schools are within walkable distance from children’s homes, children are more likely to walk to school. The decision to build a school far from homes so that the school can have sports fields is probably not best for children’s overall physical activity. Communities can probably find creative ways to incorporate sports facilities into school grounds without requiring large pieces of land that force schools to the edge of town.

Schools siting decisions made to encourage official sports also have regressive impacts because low income students are less able to participate in official sports. Data show that low income children have higher rates of obesity than higher-income children, who are more able to afford official sports (Müller, 1999). The policy implications are that school siting can make active lifestyles harder and that the results may impact low income children disproportionately.

The results of this thesis are consistent with the thinking on neighborhood schools in that distance was the main determinant of walking behavior. However, additional research could further investigate the impact of neighborhood schools on children’s walking. Looking at a map of school locations in Baltimore City, one can see that the schools are sprinkled throughout the city rather than sited along the periphery. This may be a result of history, i.e. that Baltimore is an old city with traditional, neighborhood schools. Alternatively, it may reflect that fact that land is scarce in a large city, and so, it may be more practical to renovate schools rather than build new ones elsewhere. This thesis did not include data about whether schools were newer or renovated older schools. While it is clear that distance to school matters, this thesis did not have available any data about the centrality of schools in a neighborhood. Data measuring how
centrally located a school is to the area it serves may not exist, but it could be collected. I would expect that a more central location would reduce distances and increase the probability that children walk to school.

Another avenue for additional research is the importance of a sense of community in promoting active transportation in children. This thesis was the first study that tried to measure sense of community. Several of the variables chosen as proxies for sense of community appeared to measure something other than sense of community. This fact highlights the difficulty in choosing proxies for a complex concept like ‘sense of community,’ and additional effort should be made to find appropriate proxies.

Despite the difficulty in measuring sense of community, one of the most notable results of this thesis was the direct association between community gardens and children’s walking to school behavior. The presence and number of community gardens were strong predictors that children would walk to school. This association may not indicate causation. Rather, both children walking to school and communities supporting community gardens may indicate a strong sense of community. But as a marker of ‘sense of community’, the number of community gardens appears to be useful. Additionally, neighbors working together to maintain community gardens could foster a greater sense of community. This result implies that policy makers and neighborhood organizations should encourage community gardening. Small neighborhood schools may not have land for sports fields, but they may have the land for a garden. Neighborhood schools could host community gardens. If not at schools, community gardens situated in odd or abandoned lots could improve the perceived cleanliness of the neighborhood, which this thesis also found to be an important predictor of children walking to school.
The results of this thesis suggest that smaller neighborhood schools are the right direction to go policy-wise. First and foremost, neighborhood schools create better conditions for active lifestyles. Walking to a neighborhood school is a physical activity available to all income groups and does not disadvantage low income children. Neighborhood schools provide a community center where sense of community can be built; specifically, community gardens can be built at schools and are shown to be highly correlated with walking. Finally, it is important to note that neighborhood schools tend to be smaller in size and have smaller numbers of students. There is evidence of social and academic benefits from smaller schools, but these benefits are beyond the scope of this thesis (Howley, 1989).

Program Evaluation

Lack of knowledge poses a problem for programs intended to increase walking, because programs are designed based on reasonable, but unstudied, assumptions. The largest program in the United States is Safe-Routes-To-School. The Centers for Disease Control and Prevention runs another program, KidsWalk to School, on a smaller scale. The Safe-Routes-To-School program is a federally funded program managed by the Department of Transportation that provides grants for both infrastructure and non-infrastructure projects. Based on the results of my thesis, the role of the built environment has some effect but, other than distance, it is not the primary factor in children’s mode choice. Further research should be done on the specific types of infrastructure projects funded through the program in order to access their impacts. As for the non-infrastructure projects, a brief look at the projects reveals them to be educational or public awareness campaigns. In my reading of literature, there has been no study of the effect of public
awareness campaigns on children’s mode choice. Public awareness education projects may be simple for schools and communities to design and implement, but there appears to be little theory to predict the expected benefits of these types of programs.

This thesis is not an analysis of Safe-Routes-To-School projects so I will simply make the general recommendation that the projects should be evaluated in terms of the effect they have. Additionally, projects should be designed based on empirical studies of what factors matter most. Based on the results of this thesis, social and community factors are important predictors of walking to school. Further research could help link the most salient community factors with the education programs used in schools. To the extent that the educational programs can increase sense of community and implement strategies to draw the community together, they may be more successful.

Assessing Costs and Benefits

Current thinking about the costs and benefits of lifestyle choices is incomplete at best. Easily quantifiable, financial costs are routinely ignored when families, communities, and policy makers evaluate competing choices. The health care costs of obesity and chronic disease are often seen as a separate issue rather than as a cost incurred by specific lifestyle and societal choices. Often what appears to be a cheaper option is really just shifting costs to someone else. For example, if a city decides to close a neighborhood school and build a new school, the school system may save money. But, the city will have to build and maintain new roads to the new school. Children will be bussed or driven to school. Children become less active, and their health suffers. Health care costs increase. So, the school saved money while the transportation
department and health department, and probably society as a whole, suffered losses. While the city’s motivation was to be cost efficient when it built a new school, its cost-benefit analysis was too narrowly defined. This scenario may seem too convenient, but it is just this scenario that has occurred in communities across the country. Communities need to reassess the costs and benefits of choices they have made.

In reassessing the choices communities make, there is growing support for adopting a “systems-thinking” approach. Rather than considering the costs and benefits of a single investment, technology, or decision, the whole system is the focus and individual pieces are evaluated based on how they affect the function of the whole system. For example, builders now value insulation more than in the past because better insulated buildings are more efficient and allows them to use smaller HVAC systems. Regional planners implement car pool lanes, bus-only lanes, and rush hour lanes as ways to better use existing roads rather than building new ones. Mixed-use zoning can help revitalize a downtown area rather than encourage the construction of new development on the edge of town. Systems-thinking is the kind of thinking that characterizes a sustainable approach to society because it keeps the focus on the whole picture.

Recognizing the interconnection between parts is the hallmark of systems thinking. This thesis explores only one small part of society – the decisions families make about how children travel to school – but it looks at how the built and socioeconomic environment as a whole impact walking behavior. The results of this thesis show that several factors predict whether a child will walk to school. Some of the factors are within the control of families themselves, but many
influences on children’s walking come from the neighborhood, the way the city was built, employer practices, and so forth.

Additionally, looking at the system enables one to see how improvements in one area can come at the expense of another area. In this thesis, seemingly good things such as walkability for adults did not automatically mean children walked to school. In fact, the opposite was true. Similarly, mother’s volunteerism seems likely to increase a family’s ties in a community, but at the same time, the mothers’ volunteer commitments result in children who are less likely to walk to school.

The unavoidable result of looking at current ways of living from a systems approach is that distributional questions will arise. Even though it is now fairly obvious that current American lifestyles are not sustainable, the costs to change are high. It is difficult and costly to change course – rethinking how communities are designed, changing roads that are already built, and changing incentives that encourage car-dependency. More importantly, changes will also alter the balance of who pays the costs. In the example of a city that builds a new school and then must build new roads and incur future health care costs, there was a winner and there were losers. If the city took a systems approach to its investments, there is a better chance of seeing how saving money in the school budget would create greater losses in transportation and health. However, even if the fact were known, the schools would still have incentive to reduce their costs at the expense of other city services. The distribution of costs and benefits is not a problem that a systems approach can solve.

In summary, there are two problems in how costs and benefits are assessed. The first is a myopic view that is solvable, or at least able to be improved, through a systems approach. The
second is the perennial question of how resources will be distributed in society. This question is continually being asked and answered through public debate and the laws, policies, and norms we create for ourselves.
## APPENDIX A

### Income Levels per the Household Travel Survey

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<tr>
<th>Code from Household Travel Survey</th>
<th>Income Level</th>
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<tbody>
<tr>
<td>1</td>
<td>Less than $10,000</td>
</tr>
<tr>
<td>2</td>
<td>$10,000 - $14,999</td>
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<td>3</td>
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REFERENCES


