Youth Travel to School:

Community Design Relationships with Mode Choice, Vehicle Emissions, and Healthy Body Weight

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Executive Summary

This project was focused on increasing the understanding of factors that are associated with youth travel to school. An Atlanta, Georgia household travel dataset (known as SMARTRAQ) provided a unique opportunity through a large sample of youth ages 5 through 18 years, containing a wealth of information about factors that potentially influence school travel - including parental perception of neighborhood safety from crime and traffic, and revealed travel patterns of parents and youth. These factors were included in the analysis alongside detailed, objective measures of neighborhood design of home, route and school environments, air pollutants and CO_2 emissions generated from each school trip, and self-reported height and weight.

Project Aims

The results presented here are organized around three primary objectives or aims. The first aim investigates the factors that influence a student's travel mode choice for school trips. The second and third aims, respectively, examine the implications of those travel mode choices on vehicle emissions and body mass index (BMI).

Summary of Findings

Numerous factors influence how youth travel to school, and no single study could account for all possible factors. Factors such as short travel distances and pedestrian facilities encourage walking, the same as they do for adults. However, we found that the relationship between youth travel to school and aspects of residential neighborhood design were not as strong as they have been found to be for adults. It appears that while some neighborhood design characteristics such as compact residential neighborhoods and interconnected street networks are a necessary component of the choice to walk, these factors can be overwhelmed if other factors – parental preferences and perceptions of school quality, traffic safety and crime, or even other neighborhood design characteristics – are not supportive. Other factors, such as a mixed land use pattern, that have significantly impacted travel behavior in other research, do not seem to influence youth school trips. This is consistent with findings from previous studies of youth travel to school. Travel mode may be predetermined by parents or constrained by other circumstances, and it may only be under certain circumstances - such as youth located in communities safe from crime and traffic that are close to schools - where neighborhood design may influence travel mode.

Short Distances are crucial to encouraging walking to school. The probability of youth walking to school drops off quickly and dramatically as distance to school increases, going from about 25 percent of all school trips at the shortest distances to school (in our sample, the shortest trip distance was under 1/10th of a mile), to less than 5 percent of all school trips over 1 mile. The average school trip for students in the study was close to 5 ½ miles – well over the threshold of a reasonably walkable distance.

Neighborhood design is more important for short school trips and for younger children. For shorter distance school trips (0-1.5 miles), more neighborhood design factors are significant predictors, and with higher levels of significance, than for middle (1.5-3 miles) and longer distance (over 3 miles) trips. Because short trips are those most likely to be walking trips to begin with, it makes sense that urban form could make more of a difference in the choice of whether or not to walk. This same phenomenon exists for youngest age group (5-10).

Mode choice changes as students age.
Overall, the probability of walking increases between the ages of 5 and 8, then holds relatively constant until age 12. It increases again between ages 12 and 16, then finally dips once students reach age 16. The probability of riding a school bus remains constantly neutral across all ages, while the probability of driving alone increases rapidly (and predictably) once it becomes an option at age 16.

Neighborhood design and physical infrastructure is important. Of the neighborhood design characteristics we tested, more sidewalks, higher residential densities and more interconnected streets are consistently related with more walking trips to school and fewer emissions (including carbon dioxide). Interconnected street networks are also associated with lower body mass index. Intersection density, presence of sidewalks, residential density and employment density all appear to be most important for students along the route to school rather than at the home or school end of the trip. Based on the results, we were able to estimate the how association of specific changes in neighborhood design could result in changes to more physically active mode choice and reduced emissions. These estimates show that changes in the physical infrastructure and surrounding built environment can have a clear transportation and emissions (environmental) benefit. This is especially true when considering the population level impacts – that is, when the results are multiplied out to include all youth (and others) that will be impacted by the changes.

An increase in **sidewalk coverage along the route to school** from the median value (26.4 percent sidewalk coverage) to the 60^{th} percentile (36.5 percent coverage) improves the final likelihood that a child will choose to walk to school by a factor of 18.44 percent. That same change also reduces school trip distance by 4.97 percent, CO2 emissions by 5.49 percent, hydrocarbon emissions by 3.08 percent, and oxides of nitrogen by 3.97 percent, *per student, per trip*.

The same increment of increase in **intersection density along the route to school** was estimated to increase the probability of a child walking to school by a factor of 6.67 percent, decrease the average trip distance by 3.23 percent, and decrease carbon dioxide, hydrocarbons, and oxides of nitrogen by 2.34 percent, 2.25 percent and 2.65 percent, respectively, *per student, per trip*.

Increasing the median **net residential density along the route to school** to the 60^{th} percentile (from 2 du/acre to 2.54 du/acre) improves the likelihood that a child will select walking as a mode choice for school trips by a factor of 7.09 percent.

Some neighborhood design factors are associated with youth travel to school differently than other types of trips. Previous studies on factors influencing mode choice for all trips (not just school trips) consistently show a positive relationship between land use mix and walking, but that was not the case in this study, where the relationship to land use mix was less consistent. Although this finding may be an artifact of the study's location in Atlanta, mixed land use patterns are often in the form of auto-oriented commercial and office development, it may also be that youth are less influenced by the need to visit other destinations on the way to or from school. This is a reasonable conclusion to draw from these results - however, research in other urban areas would lend additional insight.

School quality is a transportation issue. Higher parental perception of neighborhood school quality has a positive association on walking as a mode, particularly for short school trips and for younger children (the most likely to be attending schools in their neighborhood). As parental perception of school quality increases, per capita carbon dioxide and oxides of nitrogen emissions also decline. This is a strong argument for the impact that school quality may be having, indirectly, on environmental outcomes – if a parent feels good about the local school, they are more likely to send their child there and because it's the neighborhood school, it will be more convenient to walk to. The degree of flexibility in school choice that parents have vary among the 15 school districts in the Atlanta region where the study was conducted. For example, the Atlanta school district has implemented some charter schools in the past 8-10 years. It can also be assumed that parents who can afford it may choose to send their children to a private school; which complicates the analysis.

Policy Implications of Findings

Complete Pedestrian Connections -- Complete sidewalks and direct connections between home and school is an important factor associated with walking to school. This study indicates that sidewalks are most closely associated with walking for trips between 0 and 1.5 miles, for elementary school students (ages 5-10) and for older high school students (ages 16-18). Funding is needed to improve and complete the pedestrian network. The Federal Safe Routes to School program funds sidewalks, but at a level that will only fill in short gaps in a network – not wholesale retrofitting as is needed in many cases. Much more funding is needed, and the national funding will probably need to be supplemented at the local, school district or state level for large amounts of change. However, this study indicates such an investment could yield more students walking to school, and lower air pollution and carbon dioxide emission rates.

School quality may have a transportation impact. Perception of neighborhood school quality emerged as consistently important in predicting the choice to walk, emissions and body mass index. Better quality neighborhood schools can generate more walking trips, as parents choose to send their children to a nearby neighborhood school rather than another school further away (such as a private or charter school).

Fund programs as well as physical infrastructure. The need for programmatic support, in addition to physical infrastructure, is evident in these results, which show that parental perceptions or other demographic factors can undermine an otherwise supportive physical environment. Educational and awareness programs, those that provide adult support for children walking to school such as "walking school buses" and crossing guard programs where they do not exist may help to increase the comfort of families who would not otherwise consider walking as a legitimate travel mode for their children. In high-traffic and higher crime areas, enforcement or other programs that help to increase traffic safety and personal security may be a priority, but ideally would take place alongside infrastructure investment in those areas that are not already pedestrian-friendly. However, in some contexts children may be walking whether or not an area has supportive facilities, and these areas should be prioritized for safety's sake.

Currently, the Safe Routes to School (SRTS) initiative has a target of 10 - 30 percent of funding for programs, which, given the vastly higher cost of physical facilities, is entirely appropriate.

Contents

Figures

Tables

Acknowledgements

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1. Introduction

Background

Despite the potential air quality and public health benefits associated with walking and biking to school, far fewer children do so today than did in the past. Concurrent with the decline in regular physical activity among children has been a growing reliance on personal automobile use to accomplish school trips. In 1969, roughly half of children traveling to school did so by either bicycling or walking (Federal Highway Administration [FHWA], 1972). By 2001, the percentage of children walking and bicycling to school dropped to roughly 15% (Bureau of Transportation Statistics [BTS], 2003). These patterns are true for not only longer-distance school trips, but shorter ones as well. In 1969, 90% of children living within one mile of school walked or biked; a number that has since declined to less than one-third (CDC).

During this time of decreasing active travel to schools the design of schools and the communities in which they are located has also changed. The trend has been to develop increasingly larger schools housing greater numbers of students, and to place them in outlying areas where land is cheaper that are oriented towards more use of school buses and personal automobiles. This is most often at the expense of accommodating non-motorized modes. Not only can urban design around a school discourage walking, but the sheer distances youth have to travel to get to school, particularly as students age, can make walking impossible. A recent report by the National Safe Routes to School Task Force reports that, according to federal transportation data, in 1969 close to 55 percent of youth school trips were over 1 mile; by 2001 this number had increased to over 75 percent (National Safe Routes to School Task Force 2008, p. 30; data cited is from Federal Highway Administration, National Household Travel Survey 2001; NHTS Brief on Travel to School, January 2008).

To address some of these concerns, Congress established the national Safe Routes to School (SRTS) program in 2005, as part of the federal transportation funding bill known as SAFETEA-LU (Safe, Accountable, Flexible, Efficient Transportation Equity Act – A Legacy for Users). The program set aside $612 million for Safe Routes to School programs in all 50 states. Funding is available for education and enforcement programs in addition to physical infrastructure improvements. The SRTS program, however, does not address the problem of school siting, which is under the purview of local school boards and municipal land use policy. Schools locate in these areas for some of the same reasons that individual consumers do – land is cheaper and it is easy to discount the cost of transportation at the time the location decision is made. Zoning requirements such as parking, and state or local requirements for minimum acreage, practice fields or other facilities may actually exclude urban areas from consideration, since large enough parcels may not exist (or, if they do, the costs may be prohibitive). Construction budgets also frequently favor new construction over renovation (Ewing et al. 2004).

A great deal of research has studied relationship between community design and non-motorized travel, finding that walkable neighborhoods with higher residential densities, a mixture of homes, shops and services within walking distance, and interconnected (e.g. gridded or modified grid street systems) street networks encourage higher rates of walking, particularly for utilitarian purposes (Cervero, 1989; Cervero and Kockleman, 1997; Dunphy and Fisher, 1996; Frank and Pivo, 1994). Walkable urban environments have also been associated with higher physical activity levels (Frank et al. 2005; 2006), lower rates of obesity (Ewing et al. 2003; Frank et al. 2004), and even some improvements in personal health (Sturm and Cohen 2005; Hoehner et. al., 2005; King et al., 2003). Still, it is evident that a great number of other factors influence the choice to walk, among them safety from traffic and personal security issues, a neighborhood's overall attractiveness, and personal preference (Cambridge Systematics, 1994; Cervero, 1996; Cervero and Gorham, 1995; Friedman, Gordon, and Peers, 1994; Handy, 1996; Kitamura, Laidet and Mokhtarian, 1997; Lund, 2003; Frank et al. 2007).

How Street Network Design Affects Walking

A high degree of street connectivity allows shorter, more direct trip routing. In both of the images below, the straight line distance between points A and B is the same – however, the actual walking distance (the yellow line) is approximately twice as long in the photo on the left.

Compared to the amount of research that has been done on adults' walking patterns (or on walking in the population as a whole), there has been comparatively little on children, particularly when just considering the trip to school. A detailed study of school-aged children in Gainesville, Florida found that a student's distance from school and the amount of sidewalk coverage in a neighborhood were significantly correlated with the probability that a child would walk to school (Ewing, Schroeer and Greene, 2004). The findings of this study are in part confirmed by an earlier study conducted by Kouri (1999), which found that schools built before 1983 reported four times as many walking trips to school as did schools that were developed more recently.

There are, however, still many questions about the role that other neighborhood design factors may play in determining how a child travels to school. First, children have different travel needs than adults. Youth school trips are less likely to be linked to secondary trip attractions, which may reduce the chances of an association between walking to school and mixed land uses. School trips are mandatory, and both home and school locations are fixed for the student – i.e., there is typically no possibility to substitute a more proximate destination. The school a student attends can also be determined on a basis other than strictly proximity, such as school quality. A parent (or a child/youth) may very well choose to go to a better school (a private or a magnet school, for instance) across town rather than the school across the street, which may not only preclude walking as a legitimate travel mode, but may necessitate a special driving trip. This may also make neighborhood design factors less important overall. The Ewing, et al. (2004) study cited above found results that give some support to this contention, finding no relationship between neighborhood design factors and the likelihood that a child would walk to school. This could be a function of sample size and lack of variability in neighborhood design in that study. Population density and street connectivity did emerge as correlated to rates of walking and bicycling to school in a study by Braza et al. (2004). More analysis is warranted in order to lend detail to these findings.

Secondly, youth travel choices are likely strongly influenced by their parents' perceptions and comfort with walking as an option. All of the more subjective factors that may influence the choice to walk – traffic safety, personal security, preference for one travel mode over another - are likely even more important for youth travel, and interact with the preference of the parents as well as the children. Again, when looking at youth, these factors may very well counter or outweigh the link between neighborhood design and walking that exists for travel in adults – while demographic factors such as income and ethnicity that influence adult travel patterns will likely persist. In a CDC study cited by the STRS Task Force Report, parents were asked which barriers prevented their children from walking to school (traffic, crime, distance, lack of protection from the weather, the school does not allow it, and other reasons). Traffic safety issues were one of the most common barriers reported (by close to 30 percent of respondents), second only to distance to school (reported by over 60 percent of respondents). Nearly 12 percent of respondents reported crime as a barrier, and nearly 16 percent of respondents reported that it was not difficult for their child to walk to school (CDC 2005, cited in SRTS Task Force 2008, p. 16).[1]

Lastly, youth travel patterns are likely to change a great deal as children age and become more independent. Not only will parents be more comfortable letting older children walk or take a city bus to school, but once children reach driving age they will have another travel option available – driving themselves to school. Research that has examined walking among separate age groups of youth found differences in the influence of neighborhood design – in a study by Frank et al. (2007), 12-15 year olds were the only age group that is significantly impacted by the same set of neighborhood design factors that impact adults (compactness/density, land use mix, street connectivity). This age group is old enough to be independent – but not old enough to have a drivers' license. Therefore, the ability to separate out and test different age groups is crucial.

Two primary data sets in the Atlanta region provided a unique opportunity to explore some of these questions and issues surrounding youth travel to school. The Atlanta Regional Commission's travel survey from 2001 and 2002 included youth aged 5 – 18 years old in its sample. From this 8,069 household (~19,500 people) survey the analyses reported here make use of nearly 6,000 trips made by this age group for mode choice analysis, the average trip level emissions for nearly 1,600 students, and the body mass index for slightly over 250 students (aged 16 – 18 years old). The survey information also contained unique data on parental perception of neighborhood safety from both crime and traffic, as well as a general assessment of neighborhood quality of attributes such as affordability, school quality, and access to roads, jobs, retail shops and services, and parks and

[1] Responses add up to over 100 percent because parents were allowed to choose multiple barriers.

recreation. A Georgia Institute of Technology and University of British Columbia led research project called the SMARTRAQ project[2] created detailed trip-level estimates of criteria air pollutants (Oxides of Nitrogen - NOx, and Hydrocarbons - HC) and carbon dioxide, a greenhouse gas, as well as detailed measures of neighborhood design at the 200 meter grid cell level, for the entire Atlanta region, provided a set of urban form factors potentially influencing walking in youth.

Research Questions and Aims

The aims of this research were framed by the major gaps in the research – 1) the need for a detailed study of youth school trips on a large sample, 2) the need to examine youth walking behavior among different age groups, and 3) the need to understand how parental perception may impact youth walking behavior. Additionally, this project looks at outcomes beyond travel behavior and walking, and examines air pollution and body mass index.

AIM 1. Mode Choice

The first objective of this research was to more precisely understand how specific urban form characteristics and parental perceptions shape the choice to travel to school by one travel mode vs. another, while controlling for demographic and other household characteristics. Our specific hypotheses surrounding this aim were as follows:

- The likelihood of walking *to* school increases with age (until age 16), positive parental perceptions of neighborhood safety from traffic and personal security, more sidewalks, and more interconnected street networks.

- The likelihood of walking *to* school decreases as household and neighborhood income, household vehicle ownership, distances to school and the availability of convenient busing increase, and once a student reaches age 16.

- The likelihood of being driven *to* school decreases as age, parental perceptions of neighborhood traffic safety and personal security, sidewalk availability, and intersection density decreases.

- The likelihood of being driven *to* school increases with household and neighborhood income and household vehicle ownership, longer distances to school, and the availability of convenient busing.

- The likelihood of walking home *from* school increases with the presence of open space in more affluent neighborhoods, and decreases with the presence of open space in less affluent neighborhoods.

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[2] A team of researchers were involved in the SMARTRAQ project at Georgia Tech and the University of British Columbia. The researchers included Dr. Lawrence Frank (PI), Mr. James Chapman (Co-PI), Dr. Simon Washington (Co-PI), Dr. Steven French, and Dr. William Bachman. It was funded by the Georgia Department of Transportation, Federal Highway Administration, US Environmental Protection Agency, Turner Foundation, Centers for Disease Control and Prevention, and the Georgia Regional Transportation Authority) and led by an oversight panel of experts, including Expert panel members included: Mr. T. Keith Lawton, Dr. Anne Moudon, Dr. Kay Auxhausen, Mr. Greg Logan, Dr. Martin Lee-Gosselin, Dr. Elaine Murakami, and Dr. John Douglas Hunt.

- For youth 12 and older, the likelihood of walking *to* school is increases as the mix of land uses in a neighborhood increases.

AIM 2. Vehicle Emissions

In the second objective, we wanted to evaluate how household vehicle emissions (CO2, NOx and HC) are shaped by home, school and home-to-school urban form characteristics and parental perceptions. The hypotheses in Aim 2 were that:

- As intersection density, land use mix, and positive parental perceptions of neighborhood traffic safety and personal security increases, vehicle emissions from school travel decreases.
- Vehicle emissions resulting from school travel increase with household and neighborhood income, distance to school, and number of vehicles in a household.

AIM 3. Body Mass Index

Finally, we examined the relationship between body weight, demographics and home, school and home-to-school urban form characteristics. The hypotheses were that:

- The likelihood of being overweight or obese is inversely associated with the proportion of walking school trips, individual and neighborhood income level, and percent white in neighborhood.
- The likelihood of being overweight or obese is positively associated with distance between home and school and the proportion of auto based school trips.

The three research aims for this project tie directly into several of the stated goals of the national SRTS program. By identifying those factors which support the program's stated goals of encouraging non-motorized trips to school, encouraging active lifestyles, and reducing traffic and air pollution around schools, this project can potentially inform which strategies may work best in this regard. However, the focus of SRTS program is on infrastructure and programs, while the purpose of this research is broader – on both infrastructure characteristics such as sidewalks and street network design (which are subject to SRTS funding) and land use characteristics, such as residential density and land use mix (which are not). By looking at parental perception of traffic safety and personal security from crime, this research may also lend insight

Goals of the Safe Routes to School Program

(1) To enable and encourage children, including those with disabilities, to walk and bicycle to school;

(2) To make bicycling and walking to school a safer and more appealing transportation alternative, thereby encouraging a healthy and active lifestyle from an early age;

(3) To facilitate the planning, development, and implementation of projects and activities that will improve safety and reduce traffic, fuel consumption, and air pollution in the vicinity of schools.

Section 1404, SAFETEA-LU Act

regarding the need for programmatic or enforcement approaches, which can be funded through SRTS program.

2. Approach

The analysis used two primary data sources. A spatially defined geographic information system (GIS) database, built from tax assessor parcel data and the road network, contained the neighborhood design information for the Atlanta region (the independent variable of interest in the analysis). Information on travel, demographics, parental perception, vehicle emissions and body mass index were taken directly from, or in the case of vehicle emissions developed based on a travel survey conducted by the Atlanta Regional Commission in 2001 and 2002. This survey provides a two-day snapshot of travel patterns across the Atlanta region for over 8000 households with more than 19,500 people living in a range of different land use types, household sizes, and incomes.

Built Environment Measures

For each school trip built environment variables were calculated using parcel, road network and Census data for three different geographic areas: 1) around the home location of each student in the dataset, 2) around each school in the dataset and 3) for the area along the route between home and school.[3] Measures calculated included land use mix, net residential density, intersection density and sidewalk availability. A full discussion of how each of those variables, and others used in the presented models, were calculated can be found in Appendix 1.

These variables were calculated for a 200 meter grid system covering the 13 county Atlanta region. This grid surface was used by the Atlanta Regional Commission and augmented through the SMARTRAQ study with built environment measures. The 200m grids containing the participant's home and the school attended, as well as all the grids intersected by the trip route from home to school were determined. These grids provide for a consistent scale to measure urban form at both the trip ends and along the route.

Given the relatively small size of an individual grid the urban form measure values assigned to each are based on an enlarged or buffered area. Figure 1shows the buffered area used to determine the values for each cell. A total of 49 cells, covering an area of nearly two square kilometers, make up the buffered area for each individual cell. The cell is buffered by three cells around it. Measures include land use mix, density, street connectivity, and an index of walkability. Each grid was assigned the average value of the built environment measures for the set of grids making up its buffered area (n_grids_buffered_area = 49, 48 surrounding one at the center) was assigned to it (the center grid of the block of 49).

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[3] The actual path of each trip taken by the survey participant was not reported; paths along the road network were created between the ends of each trip using GIS analysis. Shortest *distance* paths were created for walking trips. Shortest *time* paths (based on posted speed limits and congestion) were created for motorized modes. It is likely the actual path for school bus and regional transit is not the shortest time path between trip ends; however, actual school bus routes were not available.
For each trip, we overlaid the created path with the 200 meter grids cells and Census block groups it intersected, and created descriptive statistics for various attributes for these sets of grid cells and block groups. Therefore, the urban form and demographic attributes for longer trips will be based on values associated with more grid cells and block groups than shorter trips.

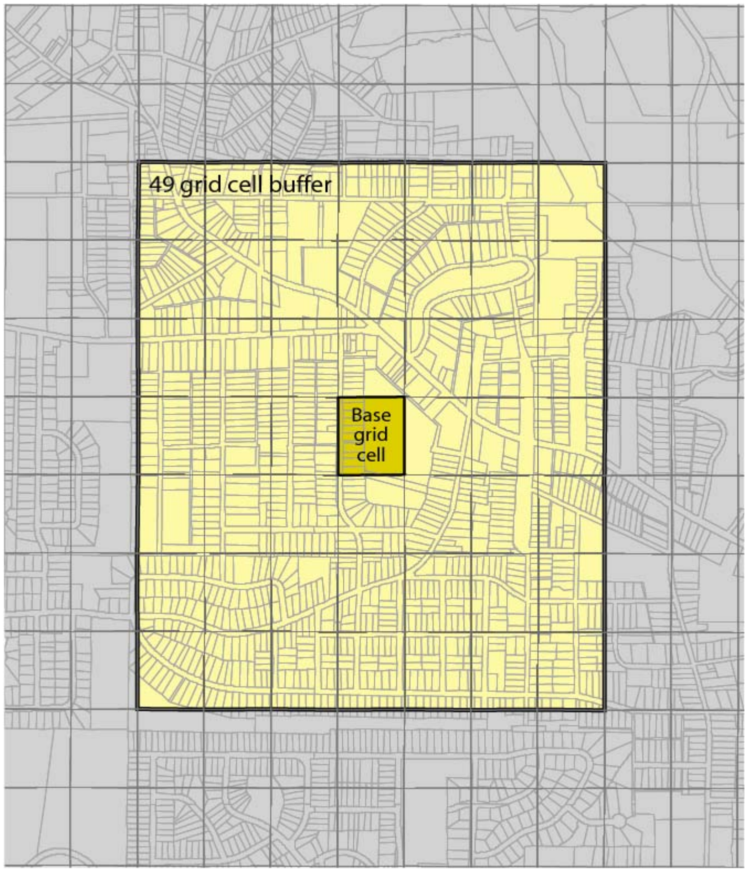

Figure 1: 200 Meter Walkability Surface

Travel Survey Data

Information on travel, demographics, parental perception, vehicle emissions and body mass index were taken directly from, or in the case of vehicle emissions developed based on a travel survey conducted by the Atlanta Regional Commission in 2001 and 2002.

The Atlanta Regional Commission's two day household travel survey was collected in the spring and fall of 2001 and spring 2002. The self-reported data collected through this survey provides the basis for analyzing the aims of this project. The survey provides demographic, travel behavior (trips made, mode used, trip end locations, activities at the destinations, etc) and neighborhood perception data. Over 8,000 households with more than 19,500 people were recruited from a thirteen county region[4]. The data associated with these participants (ages 5 years and older) and their households include travel patterns, perceptions, and body mass index. The survey was conducted by NuStats under contract to the Atlanta Regional Commission and led by a team of researchers constituting the SMARTRAQ project at Georgia Tech and the University of British Columbia. The researchers included Dr. Lawrence Frank (PI), Mr. James Chapman (Co-PI), Dr. Simon Washington (Co-PI), Dr. Steven French, and Dr. William Bachman. It was

[4] Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Paulding, Rockdale Counties

funded by the Georgia Department of Transportation, Federal Highway Administration, US Environmental Protection Agency, Turner Foundation, Centers for Disease Control and Prevention, and the Georgia Regional Transportation Authority) and led by an oversight panel of experts[5].

The travel survey response rate was calculated for recruitment and retrieval of data. Travel and activity patterns over a two day period were reported for all household members age five and up for each household in the study. Weekdays and weekends were included in the survey period. The overall response rate for the survey was determined by multiplying the two resultant rates. The recruitment rate was 44.8% and the retrieval rate was 67.8%, for an overall rate of 30.4%. Response rates were lower in higher density, lower income areas.

Household recruitment was stratified by income ($0-$20,000, $20,000-$50,000, $50,000-$80,000, $80,000 and up), household size (1, 2, 3, 4+ persons per household), and net residential density (0-2, 2-4, 4-6, 6-8, 8 + households per residential acre), The stratification of households across net residential density provides increased variability in urban form from which youth were drawn supporting the ability to study differences in youth travel patterns within a range of urban form contexts[6]. This stratification represents an innovation supporting the ability to test urban form – travel behavior relationships and elevates the importance of urban form within the travel data collection process.

Neighborhood Perception

The travel survey contained a series of questions asking people to rate the quality of various neighborhood attributes, and to rate level of influence different factors have on their willingness to walk in their neighborhood. These questions are used in the analyses reported below. The questions are "On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood:

- Affordability (low cost, taxes).
- Closeness to job.
- Ease of walking.
- Low crime.
- Near major roads and interstates.
- Near outdoor recreation (e.g. parks).
- Near to public transit.
- Quality of schools.
- Near shops and services.

[5] Expert panel members included: Mr. T. Keith Lawton, Dr. Anne Moudon, Dr. Kay Auxhausen, Mr. Greg Logan, Dr. Martin Lee- Gosselin, Dr. Elaine Murakami, and Dr. John Douglas Hunt.

[6] The 2000 U.S. Census and land use data from the Atlanta Regional Commission was used in a geographic information system (GIS) to measure net residential density using a region wide surface of one kilometer square grids.

For analysis purposes the original scale was modified. When the question was originally posed to the participant the scale was reversed from what is written above, with 1=excellent and 5= poor. This question was asked of a random adult for each household. It was treated as a household level variable in the analysis.

The questions regarding willingness to walk are "On a scale of 1 to 5, with 1 being "not at all" and 5 being "very much", please tell me how much the following factor influences your willingness to walk in your neighborhood:"

- Crime.
- Availability of sidewalks.
- Traffic.

Again, for analysis purposes the original scale was modified. When the original question was posed to the participant the scale was reversed from what is written above, with 1being very much and 5 being not at all. This question was asked of people 16 years or older. The response for the participant was used unless they were younger than 16. In that case the household's main respondent was used. If the main respondent did not answer the question then the answer from next person (in the order recruited) was used.

Air Pollution

As part of the SMARTRAQ project, vehicle emissions estimates (oxides of nitrogen, NOx, and hydrocarbons, HC) provided the basis for the Aim 2 modeling of the relationship between school travel, land use patterns, and regional air quality. Vehicle emissions estimates were produced for each link of each travel survey trip, as illustrated in the diagram in Figure 2, and accounted for travel time and distance, whether the trip was a hot or cold start, vehicle type and occupancy. The methods used to estimate CO2 and air pollution emissions are based on methodologies developed in earlier research (Frank and Stone, 1998; Frank et al., 2000) and are discussed in more detail in Appendix 2.

Figure 2: Hypothetical sequence of trip links for respondent.
Emissions are measured for each link, based on the facility type (arterial, local street, etc.) and time of day.

Data Limitations

Weather Conditions

Weather conditions were not reported by participants during their travel days. It is possible to obtain historical climatological data; but this was not included in the current study and could be included in follow up analyses. It is recognized that weather can be a factor in mode choice. Foul weather may, for example, make a motorized trip (where available) more likely than a walk trip.

School Bus Emissions

School bus emissions were calculated based on a shortest time path in the regional travel model. This approach, because it does not consider the bus's actual route, is likely to underestimate the travel distance and therefore emissions. The actual routes used by the bus for each child were not available. Also, travel speeds for buses were assumed to be the same as the modeled link average speed. In reality, bus travel speeds are likely below average. The effect of assuming an average travel speed could elevate NOx emissions estimates for school buses.

School Bus Availability

District wide policies were used to determine whether or not students had a school bus available to them. However, individual exceptions are possible (the practice of "hazard busing"), and were present in the data (some participants took the bus who did not meet district distance requirements).

School Bus Occupancy

Data was not available on the actual bus occupancy when the child rode it. For the emissions estimates we assumed 20 people on the bus. Total bus emissions for the trip were divided by this number to account for vehicle occupancy.

Pedestrian Environment

While presence of sidewalk data were used for this project, more refined micro-scale data such as sidewalk condition, obstacles, curb-cuts at intersections, whether intersections have crosswalks, vehicular traffic signals or pedestrian crossing signals (requiring pedestrian actuation) were not available for inclusion in the analyses. There was no information on the presence of school crossing guards.

Future analyses of school trips can be improved by collecting trip level data which capture actual routes used, school bus occupancy counts, whether a school bus is an available option. The addition of environment data (e.g. weather and pedestrian environment) relevant to the actual trip made will also provide important attributes for analysis.

Bicycling and Regional Transit Trips

Due to insufficient observations it was necessary to exclude bicycle trips, and trips where youth used regional transit systems, from the dataset. Out of the total trips in the Atlanta dataset, only 4 were bicycle trips and 40 were regional transit trips.

3. Aim 1 Results – Mode Choice

Sample Selection

The Aim 1 mode choice models are at the trip level. Trips included in the Aim 1 analysis set were made by participants 5 to 18 years old, which went directly from home to school or the reverse and were made by walking, school bus, as a passenger in a motor vehicle or as the driver of a motor vehicle (as discussed in the previous chapter, bicycling and regional transit trips were eliminated from consideration due to insufficient observations in the final dataset). School locations were identified through the reported activity at the location and the location name.

Simple tour-based modeling is used for the mode choice analysis. Home-to-home tours were considered for analysis but were rejected instead for home-to-school or school-to-home tours. Doing so allows the separate consideration of the mode used to arrive at school (typically in the morning) and the one used to return home (typically in the afternoon). If home-to-home tours were used a primary mode would need to be assigned to the tour even if different modes were used in the morning versus the afternoon.

The sample was stratified based on age groupings of the students (ages 5-10, ages 11-15, and ages 16-18) and distance traveled to school (0-1.5 miles, 1.5-3 miles, and over 3 miles). This was done for two reasons: 1) to explore the potential for differential magnitudes of impact and/or differentially signed relationships among subgroups of students; and 2) to constrain available alternatives - with the "car driver" mode only available as a mode choice for ages 16 years and older, and the walk mode only available when the distance to school was less than three miles. The age ranges chosen generally coincide with student ages in elementary, middle and high schools.

As illustrated below, the vast majority of students in the sample use a motorized mode to school: school bus, driving (for those 16-18 years old), driven to school (shared ride), regardless of whether they have school bus service available. As distances increase, the share of walking trips drops off precipitously. School bus share also decreases, while the proportion of shared ride trips increases, as distance to school increases. As might be expected, total distances traveled to school, regardless of mode, also increase with student age, with older students traveling furthest. Youth ages 5 to 10 years old are estimated to travel on average about 4.6 miles per trip on average, while 16-18 year olds average 6.6 miles per trip.

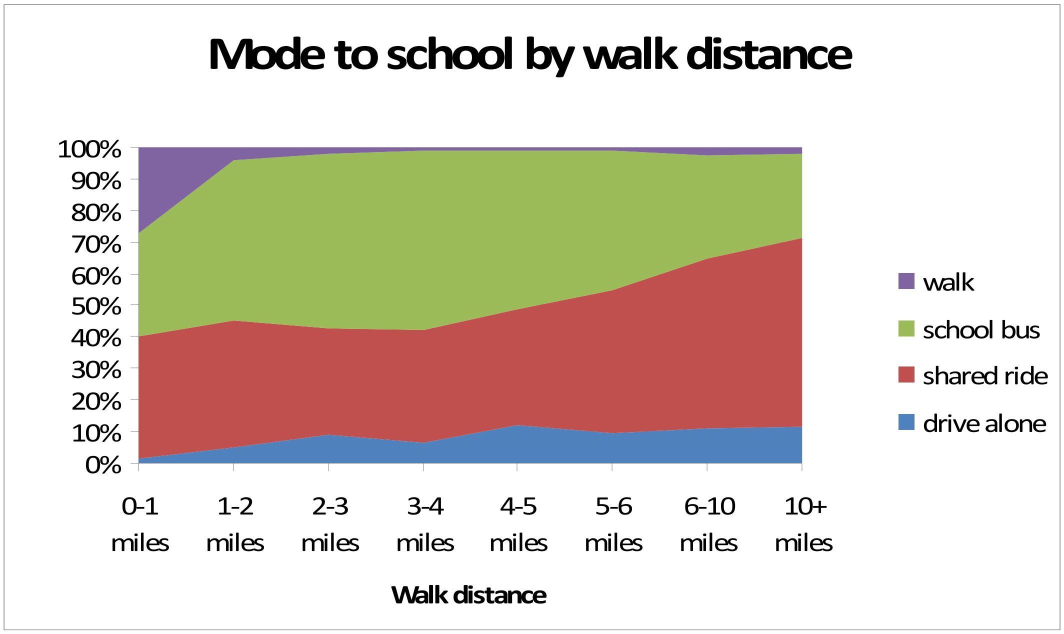

Figure 3: Travel Mode to School and School Trip Distance

Mode choice also changes as students age, as shown in Figure 4**Error! Reference source not found.**. While the proportion of walking trips remains relatively small, and somewhat constant across age groups, a large jump in shared ride and drive alone trips can be seen once students reach age 15, accompanied by a concurrent decrease in school bus trips.

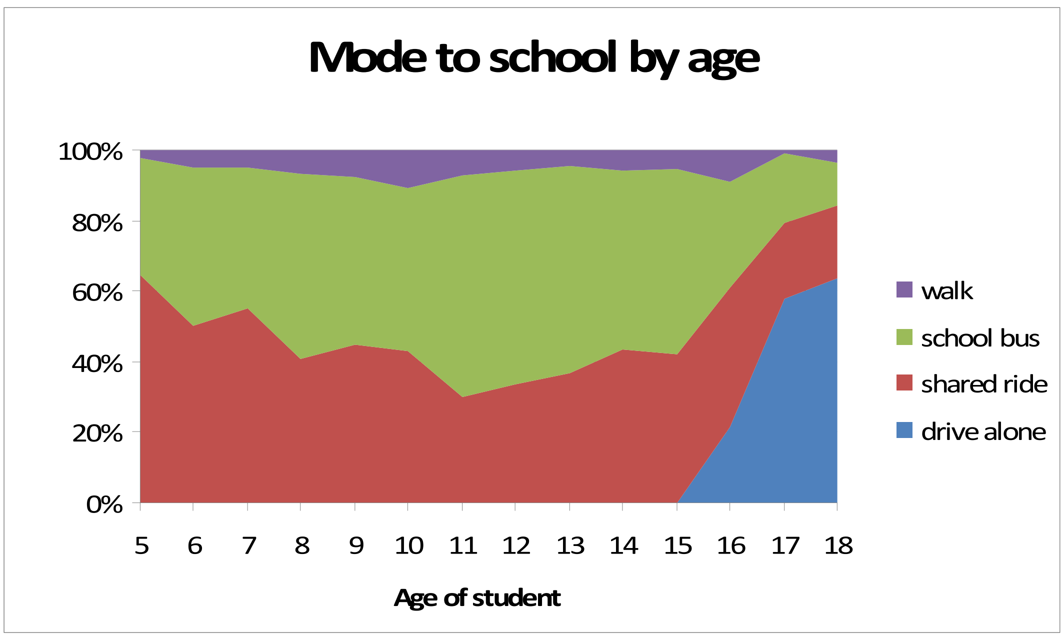

Figure 4: Travel Mode to School and Student Age

Modeling

The discrete nature of transportation mode choice decisions are typically analyzed using multinomial logit (MNL) models, and formulaic extensions like the nested logit model (where interactions between certain alternatives in an overall model are expressed).[7] These "random utility models" are an application of microeconomic decision choice theory, which stipulates that people make choices among alternatives to maximize their perceived utility based on a number of factors. The probability of each alternative being chosen depends on its utility, relative to the utility of other alternatives. The mode with the greatest utility has the highest probability of being chosen.

The results discussed below all reflect consideration of personal and household demographics such as age and gender, vehicle availability, income and ethnicity. The theoretical model employed is summarized as:

> $Pr_{car,\ bus,\ walk}$ = *f(mode availability/costs, school trip distance, child's age, parental perceptions of neighborhood attributes, stated factors influencing the parent's choice to walk, household demographics, macro neighborhood design around home and school, home to school route environment, school characteristics)*[8]

We made use of both MNL and nested logit approaches in this analysis. A fully disaggregate nested logit model was used to test mode choice relationships to the neighborhood design, demographic and perception variables on the sample as a whole. Nested logit models anticipate some form of grouping structure (i.e., clustering) among final outcomes, with a hierarchical ordering process imposed to help "simplify" the outcome process for the decision maker. In the case presented here, the decision is first made to select a motorized or non-motorized mode, and then final mode options are selected from within those groups.

Figure 5 shows the decision making process.

One of the most useful attributes of a nested logit modeling framework is that independent variables can be applied at different levels of the decision making process. In this investigation, the theory was that land use characteristics of trip origins and destinations such as residential density, land use mix, and street connectivity impact the costs of travel in terms of time and out of pocket costs for specific modes of travel (for example, low levels of density, mix, or connectivity increase the time requirements for all modes, but does so disproportionately for walking, because walking is such a slower mode of travel). Therefore, land use measures were applied at the "higher" level of the mode choice modeling process (i.e., motorized vs. non-motorized mode choices).

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[7]This section was adapted from previous work developed by the authors for the Georgia Department of Transportation. Although significantly altered, a document making some related arguments exists in the final report for the SMARTRAQ project from the Georgia Institute of Technology and the Universtity of British Columbia.

[8] This is read as the probability of choosing a mode (Prcar, bus, walk) is a function (f) of many factors.

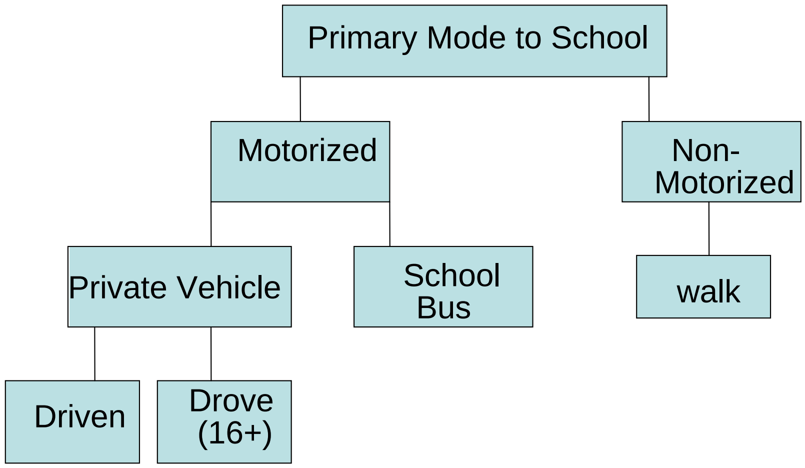

Figure 5: Nested Logit Model Structure

We present results for both the multinomial logit (i.e., the non-heirarchical) mode choice model, and the nested logit model depicted above. Based on the significance of the nesting parameter for the various models, we found that the nesting structure was significant in the overall model (N = 5890), for students ages 5 – 10 (N=2,478), and for students living 0 – 1.5 miles to school (N=1,738). However, there were insufficient observations to support testing nested structures for all age and distance sub-categories, and the neighborhood design variables were not significant for walking in the overall model once the nesting structures were applied. Since reduced sample size increases the likelihood that important effects will not be detected, we therefore relied upon multinomial logit models for the subsequent analyses. The rest of the discussion in this section is therefore based on the multinomial logit models.

When reviewing the results of the mode choice analysis, keep in mind that the outcome of the models is the "utility", or probability / usefulness of each mode. Utility of one travel mode is not constrained by changes in utility of the other travel modes – the utility of all modes can increase simultaneously. While the models presented here do contain some insignificant explanatory variables, and the models for each mode do not contain the identical combinations of explanatory variables, when taken *collectively* they provide the best combination of methods for explaining systematic variations in mode choice for children's trips to school.

Sociodemographic Variables

When the results of the models are examined across sociodemographic variables, the expected patterns generally emerge. Boys have a lower likelihood for driving than girls within 1.5 miles, Concurrently, boys, white respondents, those from lower income households, and those whose parents are homeowners all have a higher likelihood of walking, particularly for younger children and at distances under 3 miles.

Students from lower income households and households with fewer cars than drivers are less likely to drive than to walk. This effect is concentrated in the two younger age groups and at distances under 3 miles. Children under age 10 were significantly less likely to choose walking as a mode, but those between ages 11 and 15 were significantly more likely to walk.

How the mode utility changes among different age students is shown below in Figure 6.[9] Overall, the derived benefit or utility of walking increases from a negative for young children, in older children, increases above 0 around age 12, and then dips again once students reach age 16. The utility of the school bus mode remains constant because school bus was established as a reference group against which the utility of all other options are measured.[10]

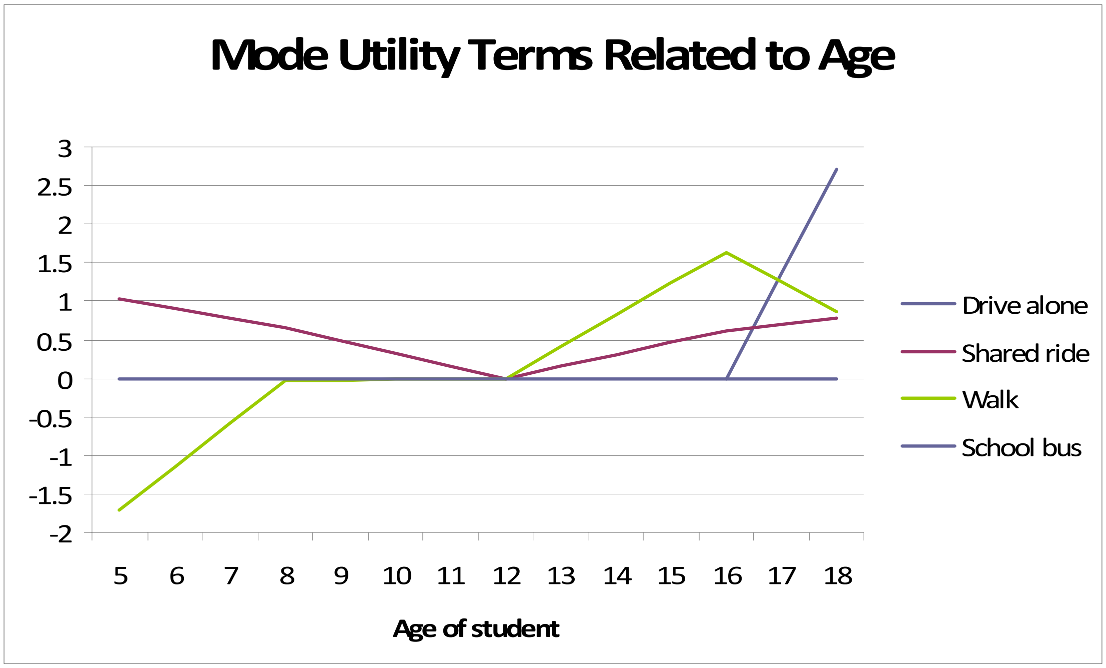

Figure 6: Mode Utility by Age

Viewing derived benefit or mode utility across distances is also instructive. Walking is the only mode that changes substantially in utility as distance to school increases. As would be expected, it drops rapidly as distances increases. Figure 7 below illustrates this phenomenon.

[9] As opposed to the descriptive charts in Fig. 4 and 5, which display the characteristics of the actual study sample, the charts in Fig. 6 and 7 show the utility of the different modes as distance/age increases. Utility is a theoretical modeling instrument for measuring the final probability of selecting a travel mode. As opposed to the descriptive data shown in the previous chapter, where a percentage increase in walking trips, for example, must be accompanied by a percentage decrease in other trip types, utility of one travel mode is not constrained by changes in utility of the other travel modes – all can increase or decrease simultaneously. In cases where simultaneous increases / decreases happen, that means the probability of usage for all modes also increases/decreases. It is the amount of change in likelihood for each mode that "breaks the tie" to determine which mode benefits the most from a change in a particular variable.

[10] The choice of a reference group is arbitrary, but mechanically necessary in order for multinomial logit models to successfully converge. For a detailed discussion on this point, see Greene, W. (2008) Econometric Analysis-6th Ed. (Prentice Hall, NJ), Ch. 23, pg. 843-845.

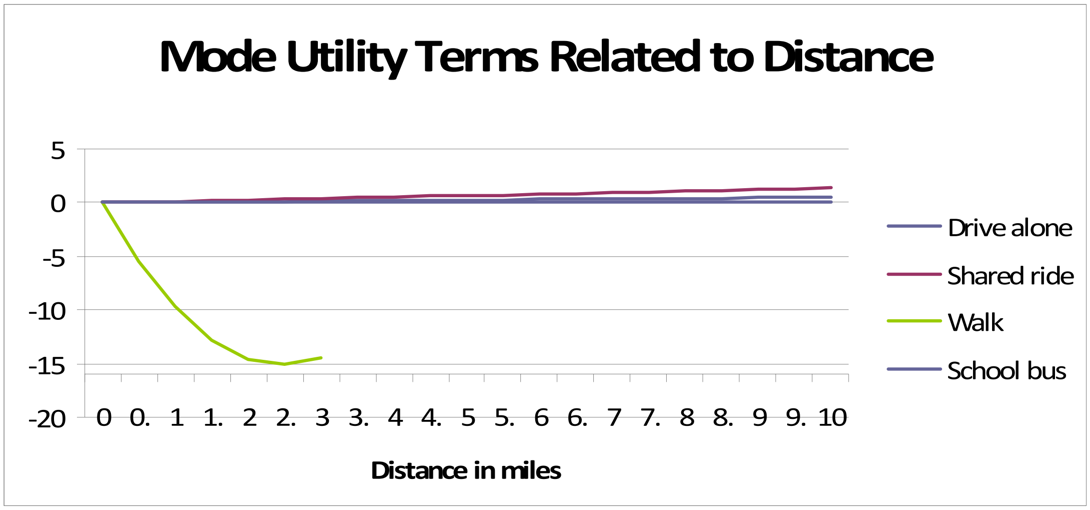

Figure 7: Mode Utility by Distance

Perception Variables

While a primary focus of this report is on the ability of objective neighborhood design measures to influence travel mode choice, personal emissions and health outcomes for students, it was also deemed necessary to account for how the environment is understood or perceived. Regardless of how efficient or accommodating an urban environment actually is with respect to non-motorized travel or public transit, if it is not *perceived* in that way, the intended benefits are not likely to manifest.

In order to account for this issue of perception, we included measures of neighborhood quality and influences on willingness to walk. In Aim 1, the variables were incorporated directly into the modeling process, being manually entered into the walking mode choice model (see Appendix 3). For Aims 2 and 3, the modeling process was varied slightly; emissions and BMI models were run with and without the perception variables. In this way, it was possible to observe and account for what happened to the relevance (i.e., statistical significance) of objective urban form when measures of perception were included. It is logical that perceived and objectively derived measures of the built environment would be very correlated.

Lastly, it should be noted that the perception variables incorporated are, in most cases, for the parents, rather than the children actually making the trip (the exception being for the willingness to walk questions, which were available to be answered by any household member over age 16. See Appendix 3 for a detailed discussion of how these questions were asked and of whom). While children may state a preference/dislike for a mode, parents typically, especially for younger children, exercise final authority over which modes of travel to school will be adopted. It is therefore reasonable to expect that parental perceptions of urban environment will influence children's mode choices.

Neighborhood Quality

As part of the process to establish models with the highest total explanatory power, perception variables were only included in the models analyzing walking mode choice. While the influence of perception of urban environment on selection of modes is well understood in the general travel behavior literature, their influence on trips for the specific purpose addressed here is less well understood. Since the focus of this investigation is on promoting physically active/non-polluting travel mode choices, we focus our discussion on influence of perceptions of urban form on that subset of mode choices.

The **perceived quality of neighborhood schools** was significantly associated with increases in likelihood of walking for younger students (age 5-10) and for students living within 1.5 miles of school. Perceived neighborhood school quality was significantly associated with reduced probability for walking for students that live further away (1.5 – 3 miles) from school. This is a strong indication that school quality may be having an influence on parental choice of neighborhood, particularly for elementary schools, as they are more likely to be located close by than middle or high schools. If a family is located in a neighborhood with better schools, then their children will be more likely to be attending the neighborhood school, and because they are closer to school, will be more likely to walk.

As the **perceived proximity to parks and recreational facilities**[11] increases, the probability of walking increases significantly overall, but not for any specific age/distance group. Parks may therefore be an asset overall, but the significance level and lack of findings in subgroups indicates that they are not a deal maker / breaker in the choice to walk.

As **perceived accessibility to shops and services** increases, walk probability decreases significantly for distance groups (under 1.5 miles, 1.5 - 3 miles), as well as for ages 16 – 18. This finding is consistent with a number of other findings related to commercial development (including objective measures of land use mix), where associations with walking are inverse for specific age groups. This could be for several reasons, the first being that commercial development in Atlanta is typically not pedestrian-friendly and it attracts vehicle trips. Also, since only simple home-to-school and school-to-home trips were examined, this finding does not reflect any trip chaining behavior or multiple destination trips, which would be expected to be more impacted by mixed use development.

Two findings emerged that were contrary to expectations. As parental **perceptions of ease of walking increase**, probability of walking was found to decrease significantly, primarily at shorter distances (0 – 1.5 miles) and to some degree for students age 16-18. This finding may be due to how the survey question was asked. A random adult from each household in the travel survey answered the question, which was "On a scale of 1 to 5, with 1 being "poor" and 5 being "excellent", please rate the quality of the following attribute of your neighborhood -- Ease of walking." Interpreting results are challenging due to the undefined term "ease of" in the question. It is not possible to be certain what factors any individual used to subjectively evaluate their neighborhood. It is also likely that the adult respondents may not have specifically considered the perspective of child walking to school in their answer. It also may be that although the

[11] We also model an open space variable in this study, which is objectively measured using county tax assessor land use codes and therefore not comparable to this one, which was a survey question. The phrase "parks and recreation facilities" was the specific question asked of survey respondents, and because we have no further information about how respondents defined "parks and recreation facilities" it is not really comparable to the objectively measured open space variable.

physical infrastructure is present and supportive of walking, other obstacles may be present. For example, while sidewalks may be present concerns about crime may discourage walking.

The **perception of less crime** was positively and significantly associated with walking for ages 16 – 18, as would be expected. However, as perceptions of crime improve (e.g. less perceived crime) walk probability decreases significantly for students age 5 – 10 and age 11 – 15, and for short (0 – 1.5 miles) school trips. This may be associated with the fact that more urbanized areas that have higher crime are also the most walkable areas in the Atlanta region where the study was located. These older areas are also where school districts are geographically smaller and distances to school are shorter. The reverse is also possible; the perception of crime may be less in areas without an otherwise conducive environment for walking. .

Influence on Willingness to Walk

As **influence of traffic on willingness to walk** becomes more important to parents and 16-18 year olds (who also answered this question directly) in the choice to walk, students are significantly less likely to walk, particularly those within walking distance of school (i.e., trips 0 – 1.5 miles; students living within 1.5 miles of school are also the segment of students that not automatically given school bus service). This finding is strongly indicative of a physical safety concern on the part of the parents.

As **influence of crime on willingness to walk** becomes more important in the choice to walk, the probability of walking is reduced for youth age 16 – 18, but increased for distance 1.5 – 3 miles. As with the question regarding perception of neighborhood walkability in the previous section, it is possible (even likely) that the respondents focused their answers on how crime influenced their own walking, and did not specifically consider the perspective of their child.[12] It is also possible that an intervening factor, potentially related to neighborhood crime or income level, is confusing this relationship.

The response to rate the **influence of sidewalks on willingness to walk** had no significant effect on the choice to walk in the overall model, a negative effect on walking for youth age 5 – 10, and a positive effect on walking for distances between 1.5 – 3 miles. Because this variable is not collinear with the objective measure of route level sidewalk coverage, which *was* significant in explaining the choice to walk, **s**idewalks appear to be a necessary, but not sufficient condition to get kids to walk. Although sidewalks are important, like some of the neighborhood design variables, it appears their influence can be overwhelmed by other factors such as sociodemographics or individual preferences/perception.

Non-respondents to the willingness to walk questions were positively associated with walking for younger students (age 5 – 10) and closest distances, and negatively associated with walking for mid-distance trips (1.5 – 3 miles). Non-respondents appear to be more likely to have young children walking over short distances. The lack of preference data among distances where youth are likely to be walking may further indicate the presence of other factors, such as crime or income, that are not completely accounted for in the analysis.

[12] 16-18 year olds were also able to answer this question directly , in addition to adults.

Neighborhood Design Variables

Neighborhood Design Around Home and School

Few of the neighborhood design measures around home and school were significantly related to walking (although several of the route level measures, which will be discussed in a subsequent section, were significant in predicting walking). A number of neighborhood design measures were significant in terms of explaining auto and school bus modes.

Population density around the home location was positively and significantly associated with the probability of taking a school bus. This effect was consistent across lowest two age ranges and all distance ranges. **Population density around the school** was positively associated with the probability of both walking and school bus mode choice, with the effect primarily concentrated in the two younger age groups (5-10 and 11-15). A higher population density means destinations are closer to home locations. This will shorten walking distances, as well as bus travel times. This finding is generally consistent with the finding for the route level measures.

The **presence of open space**[13] **around home** had no significant effect on mode choice, except for households within 1.5 miles of school, where open space drives up the likelihood of the school bus mode. The **presence of open space around school** was positively associated with school bus use generally (the only sub-groups where this variable was not significant in predicting school bus use were kids 16-18 and for trips between 1.5 and 3 miles). Because very few locations in the sample had any open space nearby, these results may reveal a censoring effect on the variable's relationship to mode choice.

For **land use mix**, findings were unclear and pulled in different directions. As **land use mix around the home location** increased, probability of school bus mode choice increased significantly, with effects concentrated in the oldest age group and for kids taking longest trips to school. However, increases in **land use mix around *school*** reduced school bus mode choice selection, both for the sample as a whole and across all age and distance groupings, with the exception of short (0 - 1.5 miles) trips. Findings were similarly inconclusive for amount of retail employment around home and school. **Higher retail employment around the home location** had a significant positive association with walking; this effect was concentrated in the youngest and oldest age groups, and in middle distances (1.5 - 3 miles). **Higher retail employment around *school*** was *negatively* associated with walking, concentrated primarily in the youngest age and shortest distance groups.

There are several explanations for this finding, the first being simply that having a mix of land uses nearby may not be a clear benefit to youth, particularly in Atlanta, which is dominated by a auto-oriented commercial development pattern not conducive to walking. A mixed land use pattern, in regard to trips to school, could also be consolidating additional trips related to the school journey near home or school trip ends. Since a school bus operates on a fixed

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[13] The open space variable consists of public parks, open space and cemeteries. These land uses were defined by tax assessors in datasets for each of the 13 counties in the Atlanta region, and combined into the single dataset used in this study.

route/schedule, a mixed use land use pattern may help to adopt the school bus mode when completing tasks before school, but hinders its use as a mode choice when bus conflicts preclude completing tasks after school (e.g., "If walking to the video store/coffee shop, etc. is more time efficient after school, but that means missing the bus home and/or staying at school late, then the kid/parent makes other travel arrangements). Lastly, because multiple-purpose trips were excluded from the model dataset[14], this finding does not reflect any trip chaining behavior or multiple destination trips, which would be expected to be more impacted by mixed use development.

Neighborhood Design Along the Route to School

As **sidewalk coverage along the route** increased, the likelihood of both car and walking modes increased significantly Overall, the effect is much stronger for walking modes, particularly within the youngest and oldest age groups, and for the shortest trips (0-1.5 miles). All else equal, increased sidewalk coverage along a route is more likely to result in the choice of walking for the trip to school.

Higher residential density along the route significantly increases the probability of both motorized and walking modes, with a consistently stronger effect on walking. For the motorized modes, the effect seems to be concentrated in ages 5-10 and ages 11-15, and for school trips between 1.5 and 3.0 miles in length. For walking, the effects are concentrated in the youngest age group and closest distance category (0 – 1.5 miles). These results suggest that higher residential densities can increase the overall likelihood of walking, but this effect can be overwhelmed if other urban form/trip distance elements do not also support walking. These findings are consistent with those related to population density around home and school.

Employment density along the route had a weakly significant (at the 90% level) positive overall effect on walk mode selection. This effect seems to be capitalized on distance to school, with the strongest effect observed for walking trips 1.5-3 miles in length. This is an indication that employment density plays a minor supportive role in the choice to walk, but like residential density, it can be overwhelmed if other urban form/sociodemographic elements are not also supportive.

Overall probability of walking for journey to school was not significantly affected by **intersection density along the route**. However, once the sample was broken out by age, intersection density along the route was positively related to walking for the youngest age group (age 5-10). The **number of arterials crossed per route mile** had a positive effect on walking, concentrated in the youngest age group and shortest distance bracket (a negative effect was found for trips 1.5 – 3 miles in length). Although the arterial crossings variable impacted all modes positively, its effect was actually stronger for walking. This is contrary to what one might expect, which is that arterials act as a barrier for walking overall. However, there is a wide variety in the design, traffic speeds and volumes on roads classified as arterials, and some may be more navigable than others. Additionally, these two variables are likely related, with the

[14] The majority of the trips in the original dataset – about 85% - were simple trips from home to school or back again. With only a small sample of complex trips, a focus on urban form association at the home and school trip ends with mode choice, and not wanting to confound the analysis with the effect of intermediate stops (on mode choice) the analysis used the trips which went directly from home to school or the reverse.

results of the arterial crossings variable possibly masking the effects of intersection density measure. The strong effect of arterial crossings on non-motorized mode choice, in the theoretically correct direction, support this assessment.

Increases in **land use mix along the route** significantly decreased the likelihood for all travel modes. For motorized (car and school bus) modes, the effect was primarily captured by the middle age group (i.e. 11-15 years old) and for trips less than 3 miles. For walking, this effect was concentrated in the lowest age group and the mid range trip distance category (1.5-3 miles to school). Where land use mix was statistically significant in predicting walking, the effect is greater than for the motorized modes. Although this is not definitive proof, these results are consistent with those for the other variables related to land use mix (perception of shops and services, and land use mix and retail employment within buffers around home and school).

As **open space increased along the route to school**, so did the likelihood of selecting car modes, across all age and distance distinctions. The effect of open space on walking was less clear. For households making less than $30,000 per year, more open space reduced probability of walking, though when split out, its effect was seen most clearly for trips less than 1.5 miles in length, with a positive sign – indicating that open space may be a predictor of short walking trips, but not for longer trips.

For households making more than $30,000, more open space increased probability of walking overall. This effect was concentrated in the 11-15 age group, and in both distance brackets (but pulling in opposite directions; positive for 0-1.5 miles, negative for 1.5-3 miles). The overall effect , where significant in predicting walking, was stronger in magnitude for households making $30,000 or more than for motorized modes. Open space can have a positive impact on walking as a mode choice, but its effect is over a short distance and is dependent on income of household. Open space in lower-income areas may be of lower quality, may attract crime, or may be poorly policed. Finally, very few locations in the sample had any open space nearby, which may have had a censoring effect on the variable's relationship with the outcomes.

Elasticity of Neighborhood Design Influence on Walking

Using the multinomial logit model results presented above, we calculated elasticities in order to show how much influence changing a particular neighborhood design element can have on travel mode choice. Table 7 in Appendix 3 shows the elasticity of neighborhood design with respect to the likelihood of selecting walking.[15]

The associated impact of a particular change in neighborhood design depends in large part on the characteristics of the pre-existing urban fabric (for example, a 10% increase in an area supportive of walking will have less of an impact than a 10% increase in an area that is not already walkable). For the neighborhood perception data, we looked at changes from the median value

[15] In a multivariate context, elasticity is technically calculated as the marginal percentage change in the dependent variable divided by the marginal percentage change in a specific independent variable, (i.e., $(\Delta y/y_0)/(\Delta x_i/x_{i0})$ holding all *other* independent variables constant (usually at their average value). In the specific case described here, the multinomial logit model models the distribution of an underlying latent variable, so the calculation simplifies to [Δprobability of selecting walking as a mode/$e^{(\beta\Delta x i)}$], where β is the coefficient of variable x. Thus, the *new* probability of selecting walking after the change is in place equals [the original probability * $(1 + e^{(\beta\Delta x i)})$].

to the next highest ranking category (i.e. an increase from “3” to “4”); for the neighborhood design measures, discussion was based on changes from the median value to the 60th percentile.

- Increasing from the median value of **sidewalk coverage along the route to school** (26.4 percent) to the 60th percentile (36.5 percent) improves the final likelihood that a child will select walking as a mode for school trips by a factor of 18.44 percent (i.e., the probability of selecting walking *after* the increase in sidewalk coverage is 118.44% of the probability of selecting walking *before* the increase in sidewalk coverage).

- For children ages 5 -10, increasing from the median value of **intersection density along the route to school** (21 intersections/sq km) to the 60th percentile (22.8 intersections/sq km) improves the likelihood that a child in this age group will select walking as a mode choice for a school trip by a factor of 6.67 percent.

- Increasing **net residential density along the school route** from 2 du/acre to 2.54 du/acre improves the final likelihood that a child will select walking as a mode choice for school trips by a factor of 7.09 percent.

- Improving the **perception of access to outdoor recreation near the home** from a value of “4” (i.e. “good”) to “5” (i.e., “Excellent”) improves the final likelihood that a child will select walking as a mode choice for school trips by a factor of roughly 19.96 percent.

Similar relationships can be discerned from a more detailed reading of the results in Table 7 in Appendix 3.

Aim 1 Conclusions

The pattern of statistical significance is generally supportive of the Aim 1 hypotheses. Many of neighborhood design variables that are associated with promoting walking (residential and employment density, intersection density) only do so because the magnitude of their coefficients are stronger on walking, as opposed to car modes. The neighborhood design measures promote more use of pedestrian or group transport (school bus) modes, but they do not actively suppress use of personal vehicles.

Urban form helps, but it isn’t a “silver bullet” - neighborhood design that otherwise promotes non-motorized choice can be overwhelmed by parental perceptions of neighborhood elements such as ease of walking, school quality, access to amenities (e.g., park or recreation space, shops and services) and crime. This is in addition to the parents’ personal values on what influences their own willingness to walk (e.g., traffic, crime and sidewalk availability). Parents looking for an excuse to not let their children walk (e.g., traffic, inconvenience) may not need much of a “push” to put them or keep them in motorized modes, rather than let them walk. For those parents concerned about safety from traffic, the loss of significance of the neighborhood design measures moving from multinomial logit to nested logit structure, in conjunction with significant nesting parameters, indicates that some students (or more likely, their parents) may have a mode preference, some of which may be based on unobserved factors (e.g., scheduling constraints or actual crime in the neighborhood).

In terms of what “drives” mode choice, walking appears to be somewhat unique. In other words, attitudes toward other modes may be more correlated with each other than for walking, where people may have strong biases for or against it.

4. Aim 2 Results – Emissions

Sample Selection

Aim 2 was a person level analysis, where an average trip level amount of emissions (and distance) have been estimated for each youth in the sample based only on their school related travel. For example, if a person made four school trips over the two day survey period (two from home to school, and two from school to home) and the grams for emission "x" for each trip were, respectively 4, 0 (walk trip), 4, 4, then the average trip emission for pollutant x is 3g per trip. (4+0+4+4=12g total. 12g/4 trips = 3 g/trip).

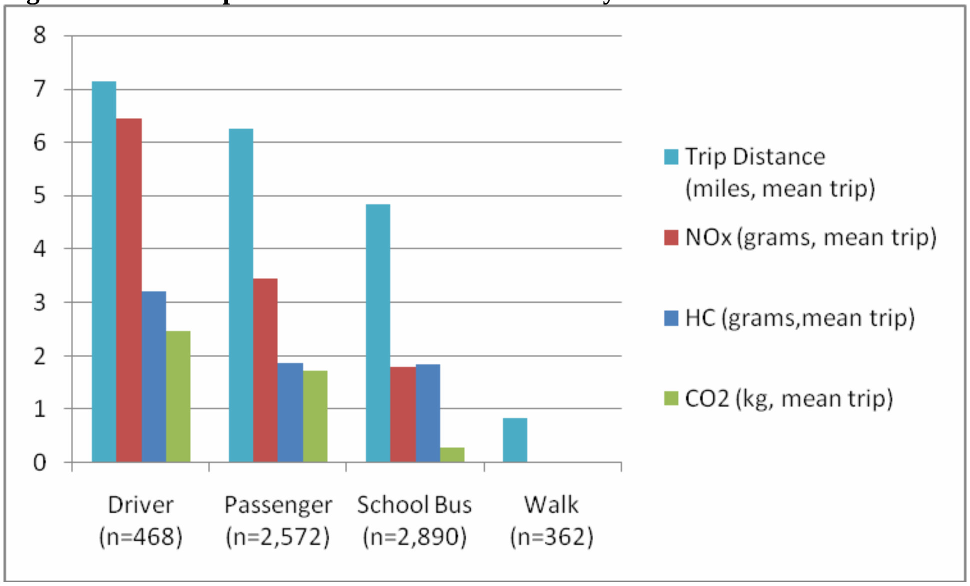
The trips used in determining average trip values of emissions generated and distance traveled were the same as for Aim 1, with the additional requirement that the trip must have a value (zero or more) for emissions and distance. Aim 2's trip requirements were therefore: made by participants 5 to 18 years old, which went directly from home to school or the reverse, were made by walking, school bus, as a passenger in a motor vehicle or as the driver of a motor vehicle, and for which emissions and distance estimates are present. Trips without emissions/distance estimates were due to an inability to locate a trip end (the school), usually due to insufficient information provided by the participant.

Figure 8 below provides descriptive of mean trip level emissions and distance by mode of travel. The drive alone mode produces the most per-trip emissions and longest distances on average, followed by passengers in private vehicles (shared ride trips), then school bus trips, with walk trips, of course, producing no emissions.

Additionally, it is possible that school bus NOx emissions are high-end estimates. This is because we assumed bus travel speeds were the same as the modeled link average speed – when in reality bus speeds are probably lower than average. However, this is balanced by the route assumed for school trips is likely less than the actual distance. The shortest time path was assumed, because the actual (in all likelihood) more circuitous path resulting from picking up passengers was not known. It is also possible that the frequent starting and stopping of school buses and resulting acceleration cycles counteracts the effect of lower speeds. All in all, the resulting NOx emissions per unit of distance traveled may actually be higher than estimated for general purpose travel.

Vehicle occupancy increases from drive alone (almost 1.2 people per vehicle trip), to passenger (about 2.5) to school bus (assumed to be 20). Vehicle occupancy for the first two modes are self-reported as part of the travel survey data. A higher occupancy results in a lower per person emission amount for the trip taken.

Figure 8: Mean Trip Level Emissions and Distance by Mode



Using the same distance ranges as in the Aim 1 analysis, Figure 9shows mean trip level emissions for each. Given the very strong association of trip distance to trip emissions, the results show that as distance increases average trip emissions increase.

Figure 9: Mean Trip Level Emissions by Estimated Distance

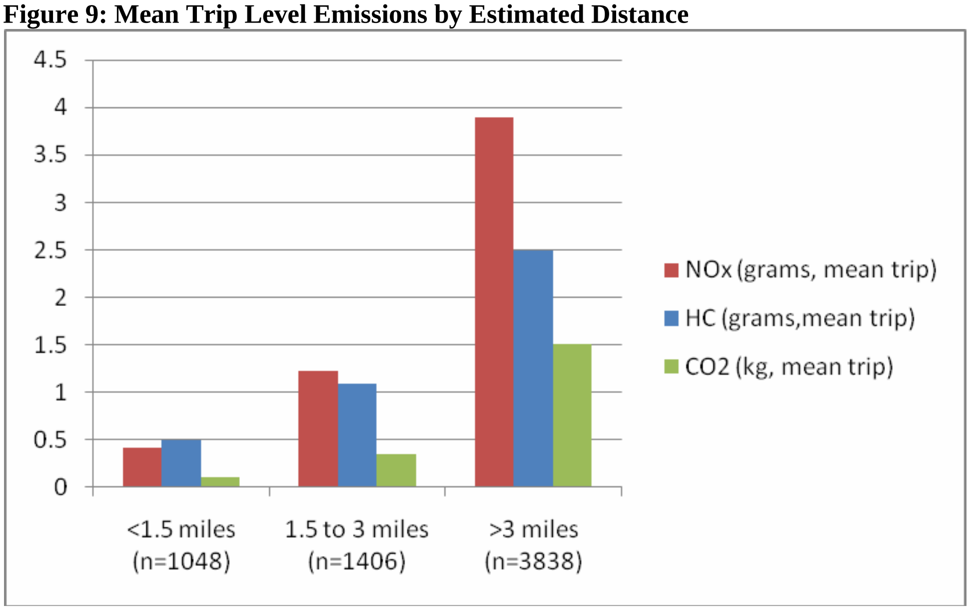


Table 1 supplements the above figures by providing a relative comparison of emissions and distance amounts for drive alone, passenger and walk to school bus. Where a difference exists, the increase in car emissions and distance (as compared to school bus trips), ranges from 47% to 775% more for the driver mode, and 29% to 520% more for the passenger mode.

Table 1: Emission/Distance Mean Trip Level Amounts Relative to School Bus

Outcome	Driver (n=468)	Passenger (n=2,572)	Reference Case: School Bus (n=2,890)	Walk (n=362)
HC (grams,mean trip)	173%	100%	100%	--
NOx (grams, mean trip)	357%	191%	100%	--
CO2 (kg, mean trip)	885%	620%	100%	--
Trip Distance (miles, mean trip)	147%	129%	100%	17%

Modeling

The influence of route to school neighborhood design measures were tested on emissions of CO_2, hydrocarbons and oxides of nitrogen. The dependent variable was average personal emissions for each trip. Emissions data generated for this analysis controlled for vehicle speed, type time of day and occupancy. The generic form of the model used was:

Estimated Vehicle Emissions $_{\text{Child's School Trips}}$ =f(macro urban form home and school, home to school pedestrian environment, school characteristics, parental perceptions of crime, traffic safety, neighborhood preference and household level socio-demographic factors)

Effects of neighborhood design around the household and school were modeled separately from effects of neighborhood design along the route to school. This is because the route level measures contain the origin and destination grids; including home and school measures in the same models with the route measures would result in double counting of the influence of the trip ends. Over short distances, it is reasonable to expect a high degree of collinearity between the home, route and school measures. Table 2 in Appendix 4 provides an abbreviated correlation matrix focusing on the neighborhood design variables used the analysis, with variable combinations with high degrees of collinearity (i.e., $|r|\geq.7000$) highlighted in red.

The route level neighborhood design measures were also dependent on the travel mode chosen for the school trip; motorized and non-motorized modes have different travel network options available to them - an automobile and/or bus can travel on a restricted access highway, whereas a pedestrian or cyclist cannot. In order to account for this difference, two different shortest path files were generated, one for motorized modes and one for non-motorized modes. The walk route was distance based and only used streets on which pedestrians are not prohibited. The motorized route was shortest time-path based (using posted speeds and road segment lengths) and includes all streets.[16] Neighborhood design and demographic measures were then calculated at the individual geographic unit and aggregated as necessary to create an average value for the entire route area for each mode. Based on the reported mode (i.e., motorized vs. non-motorized)

[16] Paths were generated between the origin and destination coordinates for school trips in the SMARTRAQ database, in conjunction with specialized scripts (written by Joyce Witebsky at University of Wisconsin-Milwaukee) for the Network Analyst extension in ArcView 3.2. The map projection applied was Universal Trans-Mercater Zone 16N, using the North American Datum, 1983 version (i.e., NAD 1983, UTM 16N).

for the trip to school, the appropriate values for the route level measures were selected into the model dataset.

In our early modeling runs, the effect of the trip distance to school variable overwhelmed any detectable effects of neighborhood design. In order to validate neighborhood design variables as a major influence on (and thus a substitute for) trip distance, we measured the effectiveness of neighborhood design in predicting average trip distance to school (based on all home / school trips for each child in the dataset).[17] A large volume of econometrics-based travel behavior literature supports the premise that urban form influences both mode choice and/or VMT generation. In the regression tables in Appendix 4, this is the first model in the column at the far left. Predictions from the distance model were then used to predict the average of emissions for these same trips, using a bivariate regression model. A comparison of the adjusted R^2 from the bivariate regression models and the regression models using urban form to predict average emissions, shows high degrees of consistency. The adjusted R2 values from those bivariate regressions are noted at the bottom of the regression tables in Appendix 4. This consistency supports the methodological premise of substituting urban form for trip distance.

Results

Household and Personal Socio-demographic Control Variables

The results of the socio-demographic controls for age, household size, income and vehicle accessibility all point in theoretically consistent directions. Student age, where significant, is positively correlated with emissions, as are households with higher incomes. Total number of vehicles in the household is a significant positive predictor of HC and NOx personal emissions per trip, for both home/school buffer and route to school models, although there is no effect for CO_2 emissions in either model. While household size is a negative predictor of personal emissions per trip for all categories, there is a positive relationship between personal emissions per trip and the number of licensed drivers; the conclusion being that larger households are more likely to engage in carpooling and/or trip chaining for trips to school, which reduces the *average* personal emissions per trip.

Perceptions of Neighborhood Quality, Traffic Crime and Safety

Neighborhood Quality Variables

Very few of the neighborhood quality measures were consistently significant in predicting personal emissions.

Improved parental perception of local school quality, however, reduced student emissions across all age and distance categories, in both sets of models (those using home/school buffer measures, and those using route level measures). This finding is consistent with the Aim 1 results that found school quality to be positively associated with the choice of walking as a mode (particularly for younger children and over shorter distances), and supports the idea that if parents are happy with their neighborhood school, their child will probably be more likely to go

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[17] The rationale for relating land use to emissions is that land use reduces trip distances, which in turn affects total vehicle operating time and/or mode choice to lower/non-polluting options (e.g., school bus and/or bike/walking).

to that school, and because it is nearby, will be more prone to walk there. As this finding shows, that relationship may also translate into emissions benefits.

For the models using home and school neighborhood design values, **improved parental perceptions of access to major roads** was positively associated with student CO_2 emissions, while negatively associated with total HC. This could be explained by the fact that vehicles emit fewer hydrocarbons per mile as they warm up, and easy freeway access could reduce the number of high-polluting 'cold starts' yet increase distance driven (and total CO2).

Improved parental perceptions of park accessibility appeared to reduce trip distance to school (but only in the home/school buffer urban form model), while **improved parental perceptions of crime (i.e. less crime)** were associated with increased trip distance to school in both the home/school buffer and route level urban form models. In neither case did the effect translate into significant influence on any of the age or distance subgroups.

Willingness to Walk Variables

With respect to the influence that traffic, crime and/or sidewalks has on parental willingness to walk, as **crime** becomes more influential in the parental decision to walk, HC emissions decrease (in the home/school buffer urban form model only), as do NOx emissions (in both the home/school buffer and route level urban form models). Influence of traffic on parental willingness to walk had no effect in any of the distance or per trip personal emissions models.

In contrast, higher importance of **sidewalks** as an influence on parental walking is associated with lower distances traveled to school, CO2 emissions (in the home/school buffer urban form model only), and HC and NOx emissions (in both the home/school buffer and route level urban form models). This variable yielded similar results in the mode choice model.

Urban Form of Home, School and Route

Intersection density within the buffered 200m grid containing the home was negatively associated with trip distance and all emissions, while **intersection density around the school** was only significantly (positively) associated with CO_2 emissions. This latter finding is contrary to expectations. However, **intersection density along the route to school** was negatively associated with trip distance and all emissions.

Land use mix at the school location and along the route was positively associated with trip distance to school, CO_2 emissions and NOx emissions. Although contrary to initial expectations, these findings are consistent with the conclusion from Aim 1 that land use mix near the home promotes school bus mode choice, while mixed use elsewhere (i.e., along the route or at either trip end) dampens the probability of selecting other travel modes, particularly walking. Commercial development in Atlanta is predominantly auto-oriented, which is one explanation for this finding - particularly for youth, auto-oriented commercial and office development would present issues of traffic safety (e.g. increased numbers of driveways cutting any available sidewalks) and potentially security, dampening the viability of walking as a travel mode. This conclusion is further supported by the positive significance of **school bus availability** on trip distance and emissions in both the home/school buffer and route level urban form models. It is also likely that, given the fact that only simple trips were included in the dataset, trips that would have supported the need for the mixed use measure were not included in the model.

Acreage of vacant space[18] around the school was positively and significantly associated with trip distance and all emissions categories. Schools with more vacant space are more likely to be located at the urban fringe. At the route level, this effect is only maintained for trip distance (not emissions). High degrees of correlation between trip end and route level measures might be masking otherwise statistically significant effects on emissions for the route level measure.

Finally, **sidewalk coverage** and **residential density along the route** were both significant in predicting both trip distance and emissions. **Sidewalk availability for the route** was negatively associated with distance and all emissions types, while **increased residential density along the route** was positively associated with trip distance and all emissions categories.

This finding for residential density may be due to high levels of correlation with another variable in the model that is masking the effects for residential density. A prime candidate in support of this conclusion would be route level intersection density. While not strictly reaching a typical standard for collinearity ($r_{xy} = \pm 0.7$), high degrees of correlation between intersection density and route level residential density[19] might be confounding the effect for residential density along the route.

Elasticity of Neighborhood Design Influence on Trip Distance and Emissions

As with Aim 1, we examined the elasticity of distance to school and/or emissions in response to particular changes in urban form. However, because the outcome is an amount, rather than a probability, the interpretation is more straightforward: for a given change in neighborhood design, how much of an associated percentage change in trip distance and/or a specific pollutant is estimated? A detailed table in Appendix 3 (Table 12) shows the complete results of this analysis. The highlights are:

- Increasing **intersection density around the home** from the median (21.4 intersections/sq km) to the 60th percentile (23.9 intersections/sq km) resulted in an estimated 2.5 percent decrease in travel distance to school, a 1.86 percent reduction in CO_2 emissions, a 1.43 reduction in hydrocarbon emissions, and a 1.38 percent reduction in NOx emissions. However, looking at **intersection density along the school route**, the same increment of change (from the median to the 60th percentile) reduces distance traveled an estimated 3.23 percent, CO2 by 2.34 percent, hydrocarbons by 2.25 percent, and NOX by 2.65 percent, *per student, per trip*. While the route level measure contains information on both the home and school ends of the trip, by comparing the results for the home buffer intersections with the route buffer it appears that smaller amounts of change along the route get bigger impacts than larger changes around the trip end.

[18] The vacant space variable includes undeveloped parcels (no buildings) that are not already part of the open space variable (which includes parks, open space and cemeteries). This land use were defined by tax assessors in datasets for each of the 13 counties in the Atlanta region, and combined into the single dataset used in this study.

[19] r(motorized route intersection density vs. motorized route residential density) = .6195,
r(non-motorized route intersection density vs. non-motorized route residential density) = .6537

- Increasing the amount of **sidewalk coverage along the route** from the median to the 60th percentile has a noticeable impact as well – resulting in a 4.07 percent reduction in trip distance to school, a 5.49 percent decrease in CO_2, a 3.08 percent decrease in hydrocarbons, and a 3.97 percent decrease in NOx, *per student, per trip*.
- Although **vacant space around the school** is statistically significant, large changes in this variable were necessary to have much of an effect on trip distances and emissions. In order to move from the median to the 60th percentile, the amount of vacant space around the school must increase from 12.04 to 24.11 acres – just over 100 percent. Assuming that change takes place, it was estimated to produce a 2.59 percent increase on travel distance to school, a 2.88 percent increase in CO_2 emissions, a 1.41 percent increase in hydrocarbon emissions, and a 1.33 percent increase in NOx emissions, *per student, per trip*.
- While these changes may seem relatively small, they are based on a per person, per trip, basis. The cumulative impact in terms of reduced emissions, which is based on the number of persons affected by any single change, can be quite substantial. For example, if several thousand students are influenced to walk to school due to sidewalk improvements similar to those described in the example used here, the total impact of the change on emissions is the percentage drop multiplied by those several thousand students, per trip.

Conclusions

Where significant, the most consistent neighborhood quality indicator influencing per capita student emissions was **parental perception of quality of local schools**; as perceived quality increased, per capita student emissions decreased. These findings are consistent with related observations and conclusions from Aim 1; by definition, kids who use non-motorized modes more frequently will have lower per capita emissions for school trips, and walking becomes more viable at shorter distances.

Out of the objective urban form measures, **increased intersection density, higher prevalence of sidewalks and reductions of vacant space along the route to school** are all associated with lower personal emissions per trip. Contrary to expectations, higher mixed use near the school and along the route increases student personal emissions per trip. Given the transportation research in linking mixed use with lower vehicle use overall, what we may be observing is that the longer the trip is the farther a student travels from their neighborhood and the more opportunities there are to pass through higher mixed use areas, and that schools with more even amounts of residential, office and commercial (higher walk index) nearby may be less neighborhood oriented/scaled and are located to facilitate drawing a larger student population from a larger service area.

5. Aim 3 Results – Body Mass Index

Sample Selection

The final Aim for the analysis was to investigate the influence of home, school and route urban form variables on body mass index (BMI) for a subset of youth in the SMARTRAQ survey, ages 16 to 18. Aim 3, like Aim 2, was a person level analysis. The dataset for this analysis is restricted to those participants with body mass index values and who are 5 to 18 years old. In this age range only 16 – 18 year old participants provided the height and weight data needed to create the BMI value. Weight and height were self-reported by the participants. Each person's BMI was calculated using this formula: Weight [in pounds] x 704.5 / (Height* Height [in inches]). Due to the inclusion of school based urban form measures the analysis set also required that participants had at least one trip to school.

In total, there were 289 children ages 16 through 18 who were identified as students in the SMARTRAQ data set. Of those, 16 reported no trips to school during the travel survey period for their household, and an additional 15 did not list the same school as their destination on both days of the travel diary. That left 258 valid cases to test the relationship between school trip related urban form and BMI.

Modeling

The influence of home, school and route urban form variables on body mass index (BMI) for a subset of youth in the SMARTRAQ survey, ages 16 to 18 was investigated using a regression model. The hypothesized relationships were operationalized as follows:

- Body Mass Index $_{\text{Youth 16-18}}$ = f(mode of travel to school, macro urban form home and school, home to school pedestrian environment, school characteristics, parental perceptions of crime, traffic safety, neighborhood preference and household level socio-demographic factors.)
- Pr $_{\text{obese, overweight, healthy weight}}$ = f(mode of travel to school, macro urban form home and school, home to school pedestrian environment, school characteristics, parental perceptions of crime, traffic safety, neighborhood preference and household level socio-demographic factors.)

BMI was first examined as a continuous measure (addressing the first hypothesized relationship), and then as a grouping variable; youth with BMIs under 25 were classified as normal weight, those with a BMI greater than or equal 25 but less than 30 were classified as overweight, and those with BMIs of 30 or higher were classified as obese. Similar to the models presented for Aim 2, we ran two model variants; one with neighborhood quality assessment and influences on walking behavior, and one without those measures.

Urban form data were assembled according to the methods described Appendix 1.

Results

BMI Regression Models

In both sets of models, the sociodemographic (control) variables had the anticipated relationship; specific details on these variables can be found in Appendix 5. Few of the perception measures proved statistically significant. Increases in perceived quality of schools was associated with higher student BMI, while increased importance of traffic was associated with lower BMI. In the home/school buffer models, only **increased intersection densities around the home** was associated with reduced BMI, and **increased non-retail employment density around the home** was associated with higher BMI. Both of these effects became insignificant when neighborhood assessment and willingness to walk measures were included in the model.

In the route level models, the same patterns of significance were observed in the socio-demographic control variables and the perception variables. Out of the urban form measures themselves, only **intersection density along the route** was significantly (negatively) associated with BMI, and only after the perception variables were entered into the model.

Weight Class Ordered Logit Models

Ordered logit models are employed in situations where there is an implicit hierarchy in the arrangement of dependent values, such as the classification of children as normal weight vs. overweight vs. obese.

The findings for this set of models are similar to those for the continuous BMI models. With regards to neighborhood design around home and school, **intersection density** was still negatively associated with obesity status (as intersection density increases, the less likely a student is to classify as obese). **Non-retail employment density near the home,** and the **neighborhood perception variables** appeared to no longer play a significant role. The **amount of vacant space** near the home may negatively affect (i.e., reduce) obesity category status.

Looking at the route to the school, **intersection density** remains significant and negatively associated with obesity status, while the **neighborhood perception variables** no longer played a significant role.

Conclusion

Higher intersection density, and to a lesser extent reductions in vacant space along school routes, are negatively associated with weight class for youth age 16 to 18. To the extent that intersection density is a proxy measure for higher density street patterns, this would suggest that more walkable neighborhoods may have a beneficial effect on obesity status. Other urban form measures, however, do not appear to play a substantial role in influencing obesity status for children age 16 to 18; far more deterministic are the gender and hereditary traits from parents. That said, the sample sizes involved in these models are quite small, and represent a sample which may or may not be representative of the larger target population. At best, the findings in this study suggest that a larger sample is necessary to begin making arguments about the impact of urban form on obesity.

6. Conclusions

Summary of Findings

Neighborhood design and physical infrastructure is important. Of the neighborhood design variables, higher sidewalk coverage, residential density and intersection density are consistently related with more walking trips to school, fewer emissions, and lower body weights. Intersection density, sidewalks, residential density and employment density all appear to be most important for kids along the route to school rather than at the home or school end of the trip. The relationships to land use mix is less consistent, with effects seen going in both directions (positive and negative) and few strong associations with walking, lower emissions, or lower BMI in youth.

School quality is a transportation issue. Higher parental perception of neighborhood school quality has a positive influence on walking as a mode, particularly for short school trips and for younger children (the most likely to be attending schools in their neighborhood). As parental perception of school quality increases, CO_2 and NO_x emissions drop. This is a strong argument for the impact that school quality may be having, indirectly, on environmental outcomes – if a parent feels good about the local school, they will be 1) probably more likely to send their child there and 2) because it's the neighborhood school, it will be more convenient to walk to.

Policy Implications of Findings

School quality may have a transportation impact. Perception of neighborhood school quality emerged as consistently important in predicting the choice to walk, emissions and body mass index. Better quality neighborhood schools will generate more walking trips, as parents choose to send kids to the neighborhood school rather than another school further away – particularly for elementary school children, who are the age group most likely to have a school nearby.

Fund programs as well as physical infrastructure. The need for programmatic support, in addition to physical infrastructure, is evident in these results, which show that parental perceptions or other demographic factors can undermine an otherwise supportive physical environment. Educational and awareness programs, those that provide adult support for children walking to school such as "walking school buses" and crossing guard programs where they do not exist may help to increase the comfort of families who would not otherwise consider walking as a legitimate travel mode for their children. In high-traffic and higher crime areas, enforcement or other programs that help to increase traffic safety and personal security may be a priority, but ideally would take place alongside infrastructure investment in those areas that are not already pedestrian-friendly. In low income areas it will be important to consider that overall, more youth may be walking regardless of whether or not supportive facilities are available. Currently, the Safe Routes to School (SRTS) program has a target of 10 - 30 percent of funding for programs, which, given the vastly higher cost of physical facilities, is entirely appropriate.

Caveats, Next Steps and Technical Issues

Sample Size

Most importantly, larger sample sizes of youth in particular age groups are still necessary to clarify understanding of how differences in age and distance may be impacting mode choice. A larger sample of youth walking trips could also lend some insight into the relationships found here.

Further research should be based on larger samples of youth of all ages, among other demographic subgroups, and in a wider variety of urban areas – particularly those that have high proportions of students walking or bicycling to school. This would allow an even more detailed understanding of how the factors that impact the choice to walk vary by age and distance. The Safe Routes to School (SRTS) program is one opportunity for detailed data collection. Currently, although program evaluation is not mandatory, two standard surveys have been produced for use by SRTS funding recipients - one for parents and one for students. The student survey consists of basic information on travel to school, and is collected for each class by the teacher. The parent survey contains information on typical travel mode, home location, distance to school, travel time, and factors that influence the parents' choice about whether or not to allow the child to walk to school – crime, weather, having an adult to walk with, traffic and other factors. As of May 1 2008, survey data from 34 states, representing over 17,000 parent surveys and 63,000 students from about 230 schools had been received and compiled (U.S. GAO, 2008). Although evaluation of SRTS programs is not required, a recent GAO evaluation of the SRTS program recommended a mandatory evaluation component to the program, including the development of indicators and program outcomes (U.S. GAO, 2008). The inclusion of a mandatory evaluation component, as long as it is not administratively burdensome, would create consistency and allow the use of the evaluative dataset as a base for further research (whereas research based purely on a voluntary evaluation could produce potentially skewed results).

The SRTS task force report also mentions the need to measure the impact of SRTS programs on physical activity levels, air quality, and other outcomes in cooperation with other federal agencies such as the EPA. The research methods discussed in this project offer some insight here. With some minimal refinements (adding specificity to the existing mode choice questions, and adding height/weight information) the parent survey instrument mentioned above could potentially be used as a basis for developing emissions estimates and BMI based on the methods presented here. Expanding existing travel surveys such as the National Household Travel Survey to include school trips, another recommendation of the SRTS Task Force, could also permit application of these methods.

Weather Conditions

Weather conditions were not reported by participants during their travel days and therefore are not included as an independent variable in the analyses reported on here. It is recognized that weather can be a factor in mode choice. Foul weather may, for example, make a motorized trip (where available) more likely than a walk trip. The possibility of including in the mode choice models objectively measured travel-day specific, regional weather conditions should be explored for use in future analyses.

School Bus Emissions

School bus emissions were calculated based on a shortest time path in the regional travel model. This approach, because it does not consider the bus's actual route, is likely to underestimate the travel distance and therefore emissions. The actual routes used by the bus for each child were not available.

School Bus Availability

District wide policies were used to determine whether or not students had a school bus available to them. However, individual exceptions are possible (the practice of "hazard busing"), and were present in the data (some participants took the bus who did not meet districts distance requirement).

School Bus Occupancy

Data was not available on the actual bus occupancy when the child rode it. For the emissions estimates we assumed 20 people on the bus. Total bus emissions for the trip were divided by this number to account for vehicle occupancy.

Pedestrian Environment

No micro-scale data such as sidewalk condition, obstacles, curb-cuts at intersections, whether intersections have crosswalks, vehicular traffic signals or pedestrian crossing signals (requiring pedestrian actuation) were available for inclusion in the analyses. There was no information on the presence of school crossing guards.

Future analyses of school trips can be improved by collecting trip level data which capture actual routes used, school bus occupancy counts, whether a school bus is an available option. The addition of environment data (e.g. weather and pedestrian environment) relevant to the actual trip made will also provide important attributes for analysis.

Marginal Returns Analysis

As mentioned in the elasticity discussions for Aims 1 and 2, the results presented in this study are subject to diminishing marginal returns; the effects observed from a change in neighborhood design would likely be stronger moving from the 10th to the 20th percentile, and weaker from the 80th to the 90th percentile or beyond. A future extension of this analysis could be to calculate the full spectrum of elasticities for each variable of interest (holding all other elements of the model constant), resulting in a mathematical model capable of forecasting precise amounts of change for each point on this spectrum. This would enhance the accuracy of any environmental impacts (and others) that are estimated based on changes in neighborhood design.

Knowing What Works -- Assessing Causation

The current study relied solely on cross-sectional data making causation impossible to assess. There is a need to understand the causal impacts of specific investments that are made to encourage youth to walk to school. Data is needed at baseline (before) and as a follow up (after) investments are made in infrastructure or in programmatic actions that increase the viability of walking to school. Results from this study help to illuminate some possible domains (home, route, and school environments) where programmatic actions might be effective in promoting active travel to school.

Appendix 1. Data Development and Methods

The built environment measures at the trip end and route levels are described below.

Built Environment Measures

Version 1.5 of the thirteen county parcel file based on tax assessor data and completed as part of SMARTRAQ[20] was used to calculate urban form measures for each buffered grid cell. The text below explains the processes to create net residential density, intersection density and mixed use variables. The text below for net residential density, intersection density and mixed use is excerpted and summarized from the SMARTRAQ final report submitted to the Georgia Department of Transportation[21].

Net Residential Density

Net residential density is the total number of housing units divided by residential land area. The number of housing units comes from Census block data and was aggregated or disaggregated (as needed) to the 200 meter grid polygons. Residential acreage was derived from the ARC 2000 LandPro land cover data (from aerial photography). NRD is highest in traditional neighborhoods with small residential lot sizes and lower in neighborhoods with sprawling development and larger lot sizes.

Intersection Density

Based on the street network for the region the number of intersections per area was determined using GIS. An intersection was defined to have a valence count of three or more, meaning an intersection is where three or more roads meet (excluding controlled access interchanges and ramps intersection with surface streets).

Mixed Use

The mixed-use factor takes into account the number of different land uses among three categories (residential (single and multi-family), commercial, and office) as well as their relative amounts in terms of building floor areas. Building floor area data, by use type, from the parcel level land use database, version 1.5 were aggregated to the desired level. For the grid, it was a simple spatial join for the grid level, and, for the network buffers, a point-polygon operation was used to join the land use data. The mixed value is between zero and one. A greater mixed use value means more even distribution of the relative amount of floor area for the land uses present. A value of one means that the land uses present have equal amounts of total floor area. The formula used is:

$$\text{Mixed Use} = \frac{-\text{sum}\,[Pn * \ln(Pn)]}{}$$

[20] For more details on the development of the parcel file called landuse.shp (version 1.5) please see this document: *SMARTRAQ: Integrating Travel Behavior and Urban Form Data to Address Transportation and Air Quality Problems in Atlanta* – Deliverable #V30 under Georgia Department of Transportation Research Project Number 9819, Task Order 97-13, April 2004. Pgs. 90 - 101.

[21] *SMARTRAQ: Integrating Travel Behavior and Urban Form Data to Address Transportation and Air Quality Problems in Atlanta* – Deliverable #V30 under Georgia Department of Transportation Research Project Number 9819, Task Order 97-13, April 2004. Pgs. 109 - 112.

ln(N)

where N= the number of different land uses

and (Pn) = the proportion of inhabited space in the nth land use, which is the following ratio:

total estimated square footage of building floor area of a certain land use type

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total estimated square footage of building floor area of for all three uses

In addition to the above urban form measures a walkability index was also used. The walkability index measure is the summation of the normalized values of the above three urban form measures. The individual measures were normalized with respect to the meanof the regional set of 200m grids. Higher walk index values indicate higher values, relative to their means, of one or more of the net residential density, intersection density and mixed use.

Population density

The number of jobs per one kilometer buffer was estimated by spatially disaggregating traffic analysis zone level population counts. One kilometer buffers were created around the home and school locations using a road network with roads on which pedestrians are prohibited removed (e.g. interstates, ramps, interchanges, etc).

Employment Density [22]:

The number of jobs per one kilometer buffer and buffered 200m grid was estimated by disaggregating traffic analysis zone level job counts (total, retail, non-retail) to using both the parcel file (v. 1.5) and the Atlanta Regional Commission's land cover data to identify the location and amount of land uses associated with the presence of jobs. One kilometer buffers were created around the home and school locations using a road network with roads on which pedestrians are prohibited removed (e.g. interstates, ramps, interchanges, etc).

Route Measures

For each pair of home/school trip ends two routes were determined between these endpoints. One route was based on the walk mode and the other was based on motorized modes. The walk route was distance based and only used streets on which pedestrians are not prohibited. The motorized route was time based (using posted speeds and road segment lengths) and includes all streets. Average, minimum and maximum values of the urban form measures described above were calculated for the set of grids intersected by each route for each trip.

For Aim 1's trip level analyses the route (motorized or non-motorized) assigned to each trip was determined by the actual mode used by the participant. Similarly, average route-based trip level values created for Aims 2 and 3 analyses accounted for the possibility that a person's set of trips (upon which the averages are calculated) may be made by a combination of motorized and non-motorized modes. The average trip route variables for Aims 2 and 3 are based on the reported mode of each trip.

[22] Please see the following for more details *SMARTRAQ: Integrating Travel Behavior and Urban Form Data to Address Transportation and Air Quality Problems in Atlanta* – Deliverable #V30 under Georgia Department of Transportation Research Project Number 9819, Task Order 97-13, April 2004. Pgs. 113-115.

Arterials crossed per Kilometer of Route:
A continuous variable indicating the number of number of arterials crossed per kilometer of route.
Arterials were defined as segments in the road file (Atl_NonAtt_Utm.shp) which had a posted speed limit of at least 35mph and had at least two through lanes on the left or right side.

Ethnic Diversity Along Route (RTEPopDivIndx)
A continuous variable scaled from 0 to 1 which indicates the level of ethnic diversity within the population for the census block groups intersected along the route to school. Calculated using the same formula as the Cervero/Kockelman mixed use index, substituting the 8 summary ethnic groups available in the U.S. Census (White, Black, Native American, Asian, Hawaiian/Pacific Islander, Hispanic, Other, 2 or More Races) for land use categories.

Homogentity of Ethnicity Along Route (EthnHomogRte)
A dummy variable which identifies whether or not the household is self identified as a member of the majority ethnic group for the census block groups intersected along the route to school, based on the ethnicity reported by the main household respondent (1 = Yes, 0 = No, NULL = insufficient data to determine answer). If the household self identifies with one of the 8 summary ethnic groups available in the U.S. Census (White, Black, Native American, Asian, Hawaiian/Pacific Islander, Hispanic, Other, 2 or More Races), and that ethnic group was the majority for the census block groups intersected along the route to school, then the value is 1; if not, the value is 0. Note: Not all the U.S. Census categories were represented in ethn; if a household did not correspond to a U.S. Census category, the value is intentionally left blank.

Minimum Median Income Along the Route (MinHHIncRte)
The minimum value of median family income in 1999 for the census block group for all census block groups intersected by the route, along the trip shortest path. Values were calculated similarly to the method in AvgIncHHRte, except in Step #4, the *Average* function is replaced with the *Min* aggregation function embedded in Microsoft Access.

Percent of Route with Sidewalks

The percentage of the distance of each trips shortest path route with sidewalk available along the route. The road files used is called "Atl_NonAtt_Utm.shp." This Georgia Department of Transportation's road characteristics data file indicates if a road segment has a sidewalk along it. Consultation with GDOT staff responsible for this dataset confirmed that no other region-wide sidewalk database exists and that this one is considered complete. This data set is used as is. A limitation of this dataset is that it does not provide sidewalk condition data, only presence/absence indicators.

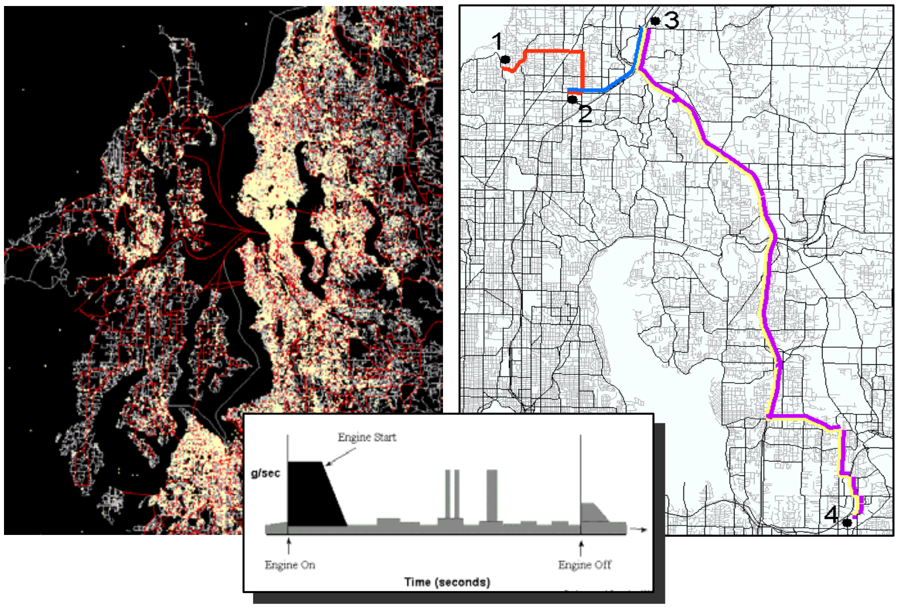
School Bus Availability
For each trip the estimated distance of the trip was compared against the busing policy relevant to the school attended. If the trip distance was less than the stated threshold then school bus was assumed to not be an available option. It is understand that school districts may make exceptions to these policies, however any exceptions relevant to the surveyed population were not known. The school locations address was used to identify which district it is part of. School names, and if needed student age, were used to identify whether the school attended was elementary, middle

or high school. Bus service was assumed to be provided if the trip distance exceeded 1.5 miles except in these cases:

- City of Atlanta -- 1 mile from elementary schools.
- Cobb County -- 0.5 miles for a child attending an elementary school, and 1 mile or a child attending a middle or high school
- Dekalb County – 1 mile.

Appendix 2: Estimating Vehicle Emissions

Estimating Vehicle Trip Emissions from Travel Survey Data



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Abstract:

Understanding the complex relationship between travel behavior, urban form, and public health can be vastly improved through the inclusion of disaggregate or household level measures of vehicle emissions. Our study presents a methodology to derive systematic trip-level emissions from regional household activity and travel studies. These emission estimates provide the basis for modeling statistical relationships between household and person level travel choices, land use patterns, and regional air quality. Emissions information can be estimated for these trips by triangulating reported elements from activity surveys, observed facility performances, design characteristics, and estimated activity parameters revealed in a travel-forecasting model. Therefore, the objectives of this research are to; (1) develop a travel activity estimation methodology that provides necessary variables for trip-level emissions modeling, (2) estimate emissions using the most current USEPA modeling tools, (3) separately model engine start emissions and running exhaust emissions. This concept and technical process is being conducted in two urban areas (Seattle and Atlanta). The process for developing emissions for trips involves estimating the amount of travel time spent on a variety of facility classes and the running of MOBILE 6.2 for a variety of possible trip conditions. Preliminary findings document significant inverse relationships between measures of urban form and per capita emissions, after controlling for demographics and regional location.

Purpose and Objectives

Trip-level emissions were estimated for household travel reported in the Atlanta based SMARTRAQ and 1999 Puget Sound Regional Council's household activity surveys. These emissions estimates for the recorded trips in this survey provides the ability to generate a variety of statistical measures that potentially identify how land use policies and practices impacts not only travel choice, but also air quality. Emissions information can be estimated for these trips using reported elements from the activity survey, and from estimated activity parameters. This paper summarizes techniques used to develop a sub trip level approach to calculating vehicle emissions based on household travel data.

The major objectives of this research were:

- To develop a travel activity estimation methodology that provides necessary variables for trip-level emissions modeling
- To estimation emissions using the most current USEPA modeling tools
- To separately model engine start emissions and running exhaust emissions

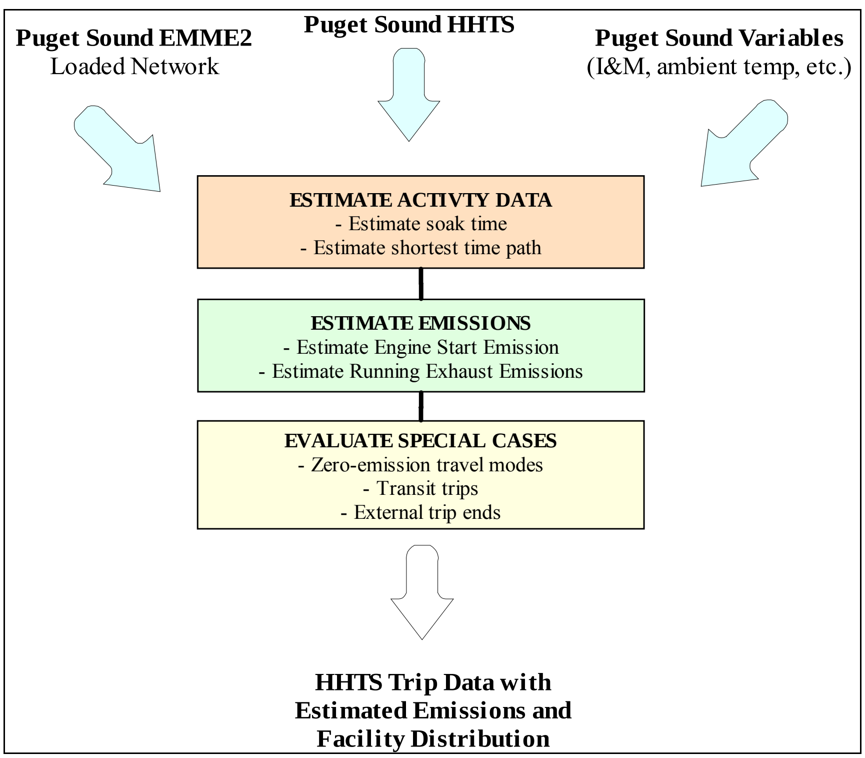

Figure 1: General process for estimating trip level emissions

The general process for the work conducted in the Puget Sound is shown in Figure . Travel survey data, Puget Sound programmatic and atmospheric variables, and the Puget Sound loaded travel demand forecasted model were used as inputs into the process. These elements were used in estimating a link-based emissions factor for each of the trips in the survey. Subsequent aggregation of the emissions per link to the trip, person, and household level enabled the assessment of systematic variation between levels of emissions and specific land use and transportation investment policies under consideration in that region. Findings from this estimation process, including model coefficients are being applied to assess the efficacy of specific programmatic actions at reducing criteria and greenhouse gas emissions for that region.

Trip Activity

For this study, trip activity refers to the mode, path, speed and travel time for the reported trip. Reported fields were used as much as possible to define the trip activity. Some of the reported information could be used to define the emission-specific characteristics of the trip, while other reported elements were used to derive further unreported parameters.

Engine Start Activity (soak time)

The amount of time that a vehicle is at rest with the engine off is an important factor (soak time) in estimating the extent of elevated emissions that occur during the beginning of a trip. A vehicle that has cooled off significantly will require a longer period of time before an engine temperature reaches a point when on-board emissions control equipment can operate efficiently. Shorter engine-off periods do not require as much time (warm starts). Estimating the amount of 'soak time' is simply a matter of determining the amount of time between trips.

Running Exhaust Activity

Running exhaust activity refers to trip characteristics that are necessary for predicting hot-stabilized emissions. The most current USEPA mobile emissions model (MOBILE 6.2) allows users to separately calculate emissions for different road facility types (local, arterial, ramp, and freeway). This has been recently added to the MOBILE 6.x series of models because the driving characteristics (acceleration rates) vary enough amongst the different facility types to warrant different baseline emission rates. This suggests that a vehicle with an average speed of 45 on an arterial has different emissions than a vehicle with an average speed of 45 on a freeway. This capability can help to evaluate the differences in trip emissions for two different trips that have similar travel times but different travel distances. In addition, this also enables us to assess differences in emissions based on the proportion of trip by facility type while accounting for facility performance or "congested flows."

Since the reported trip paths were not recorded, the average speed and distance by facility type must be estimated. The origin and destination coordinates, the trip start time, and loaded Puget Sound Travel Demand Forecasting model networks (AM peak, PM peak, and Off peak) were used in this process as follows:

1. The distance from the origin to the closest point on the road network was determined and stored.
2. The distance from the destination to the closest point on the road network was determined and stored.
3. These estimated distances approximate the amount of local road travel experienced by the traveler.
4. The shortest time path was estimated from the origin to the destination using link travel times (AM peak, PM peak, or Off peak) as determined by the reported trip start time.

5. The traversed links were stored along with the estimated average speed and facility type.

This process was followed for each trip recorded in the survey database. Figure 2 graphically depicts a sequence of consecutive trips as determined from this process.

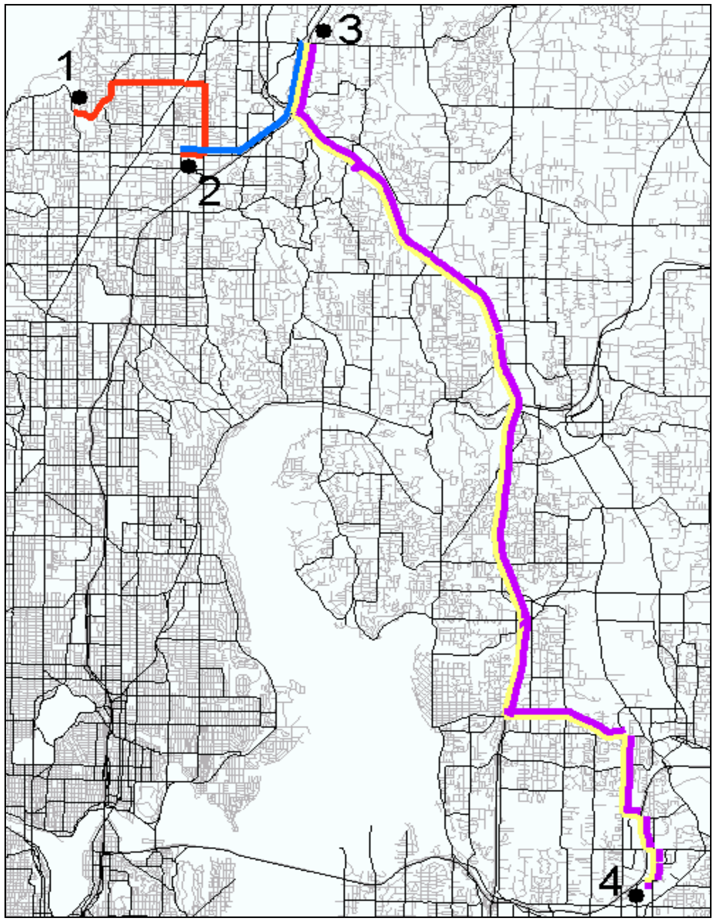

Figure 2: Sequence of trips for respondent

Methodology Assumptions

Two primary assumptions in this estimation process are defined as follows:

Estimated path vs. actual path: The estimated path represents the shortest travel time path for the estimated congestion conditions represented in the loaded model network. The actual travel path followed by the survey respondent may be quite different. This may not be as important as it seems because we are really only identifying the average speeds and fractions of the trip that occurs on arterials and freeways. The respondent's reported time is better indicator of the actual travel time than the estimated path time. The main assumption is that the estimated path is representative of the average speeds by facility type.

Local road travel: Since local roads are not represented in the model networks, Euclidean distances at an average speed of 15 mph were used. The MOBILE 6.2 model assumes that local road average speeds are 22 mph. Our slower speed is designed to account for the fact that the local road path is not as direct as the Euclidean distance.

Trip-Level Emissions Estimation

Emission factors were estimated using the USEPA's MOBILE 6.2 model. These factors were applied to the vehicle activity estimates described in section 2 in order to generate grams of CO, HC, NOx, and CO_2 for each unique trip. Emissions were separately estimated for engine start and running exhaust pollutants in order to facilitate subsequent analysis.

Engine Start Emissions

MOBILE 6.2 allows for 70 different ranges of engine soak time (period of engine 'cool down' between trips). Soak time is the dominant variable in estimating the amount of elevated emissions due to cold or warm start conditions. First, MOBILE 'header', and 'run' parameters were identified for the Seattle region and placed into a MOBILE6 input file. A separate utility program was created to generate the 70 ascii lookup tables that cover the allowed time ranges (ie., 1-2 minutes, 30-35 minutes). 'Scenarios' were added to the input file for each of the 70 possible soak time ranges. MOBILE 6.2 was run with the input file to generate a lookup table that was applied to the individual trips. Another utility program was written and used to cycle through each of the trips and apply the correct engine start value. Figures 3 through 5 show the range of values for each pollutant. CO_2 is not elevated during engine start conditions and does not vary significantly by soak time.

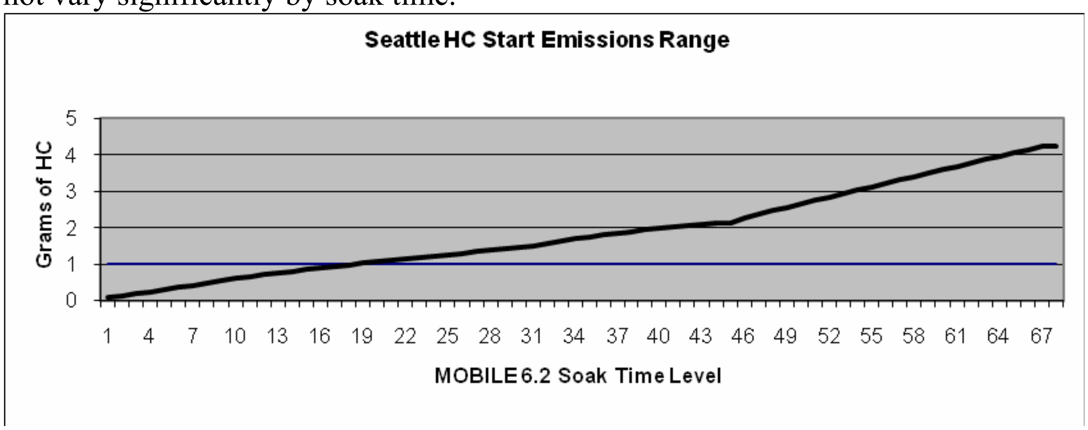

Figure 10: HC Start Emissions Range

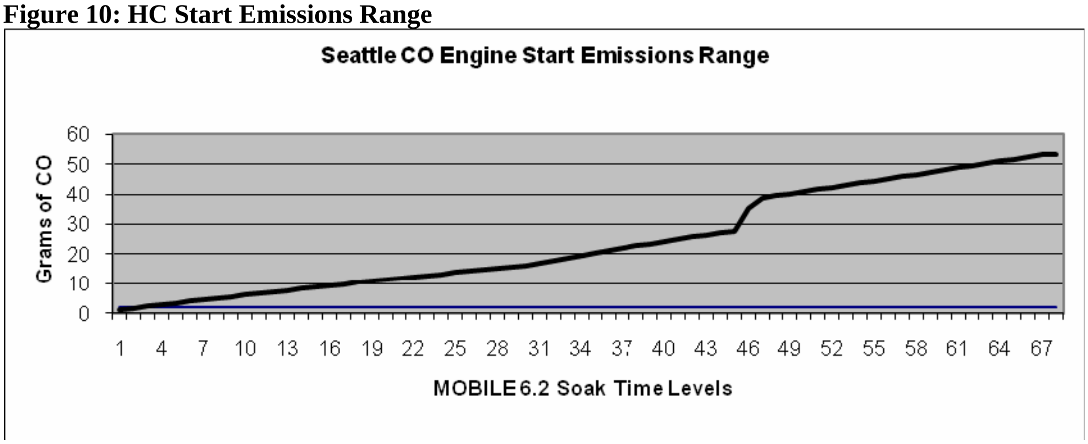

Figure 3: CO Engine Start Emission Range

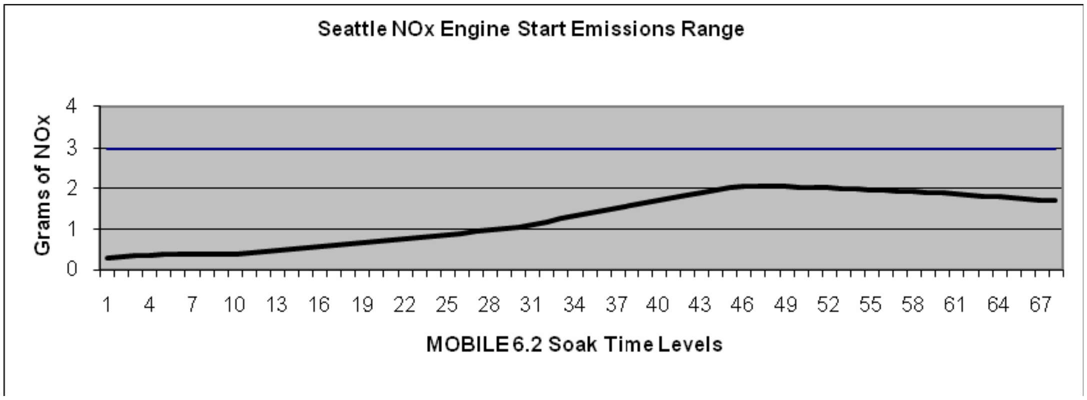

Figure 4: NOx Engine Start Emissions Range

Running Exhaust Emissions

Running exhaust emissions were estimated for each trip in an approach similar to the one used for engine start emissions. MOBILE 6.2 was used to generate a Seattle-specific emissions factor lookup table for each pollutant. MOBILE 6.2 scenarios were generated for each possible speed (5 mph increments) and facility type classification (freeways, arterials, and local roads). Figures 6-8 show the emission rates curves generated in this process. It should be noted that local road emissions do not vary by speed. Therefore, an assumed speed of 22 MPH was applied within MOBILE 6.2 regardless of other input file parameters. It should also be noted that there is very little difference in the emission rates for freeway and arterial for given speed ranges suggesting only limited sensitivity to speed profiles unique to each facility type (e.g. stop and start conditions arterials versus what is more often observed on limited access facilities).

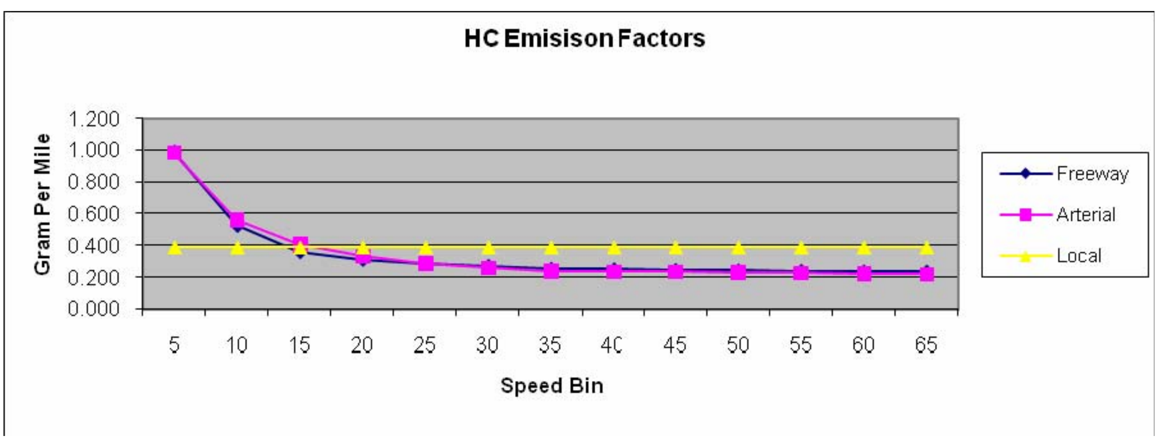

Figure 5: HC Emission Factors

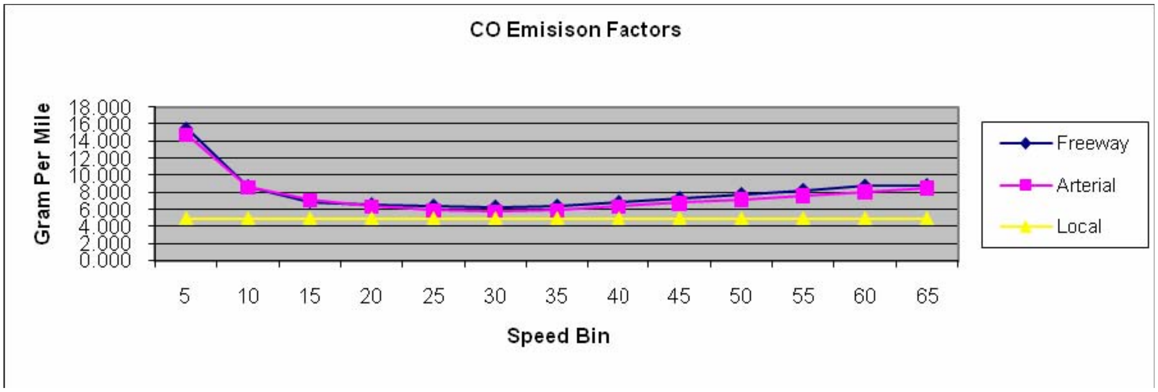

Figure 6: CO Emission Factors

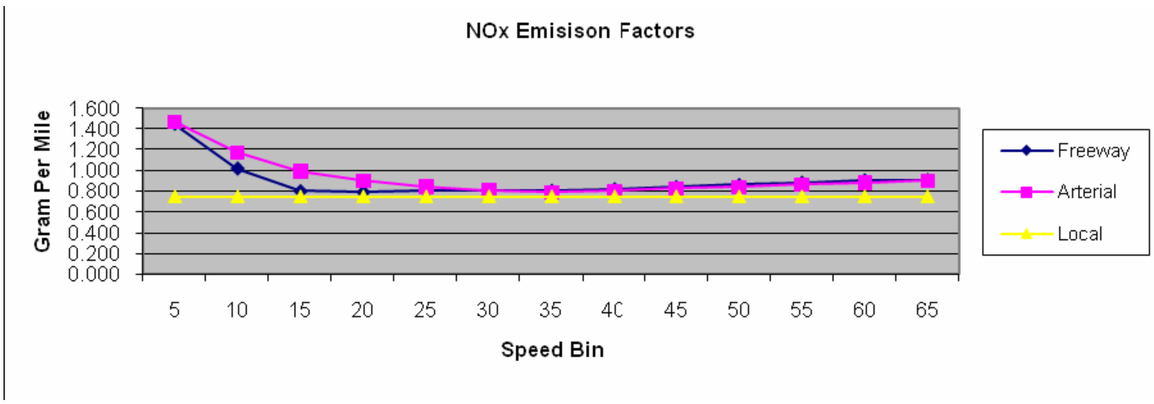

Figure 7: NOx Emission Factors

Assumptions

In both engine starts and running exhaust emissions modeling, assumptions were made regarding the operating conditions and the vehicle age. The model was run assuming that the trips were conducted in July, 1999, that an inspection and maintenance program was being conducted using an IM240 test for odd model year vehicles, and that a default national model year distribution represents Seattle distributions.

Mode Specific Adjustments and Trip Ends

Modal Adjustments

Motorcycle and bus emission rates followed a similar procedure as identified in section 3, but the vehicle type was modeled explicitly. Therefore emission factor lookup tables were generated for both vehicle types.

Buses: Bus trips include school and transit trips (modes 18 and 20). Occupancy rates were assumed to be 20 persons during off-peak conditions and 50 during peak periods. Also, no engine start emissions were assigned to the individual trips. Bus trips also assumed that any estimated local road travel occurred outside of the bus during a trip chain. Bus trips, therefore, only included arterial and freeway trips. Emissions for a person's transit trip were estimated using the portion of the trip that occurred on the bus, divided by the occupancy.

Motorcycles: Motorcycles were modeled exactly like light-duty automobiles except that separate emission factor lookup tables were generated and used.

Non-motorized: Non-motorized modes were assigned 0 emissions. (modes: walk, ferry, bicycle, other, and dk/rf).

Carpool / Vanpool: Carpools were assumed to have an average occupancy rate of 2.2 and vanpools were assumed to have an occupancy rate of 7. Trip emissions were factored by these rates to reflect the per person-trip emissions.

Trips with an External Trip End

Trips that one or both ends outside the model network area were handled in a separate manner to estimate the facility percentages. If the trip was 5 minutes or shorter, it was assumed that the person traveled on local roads only. For trips less than 15 minutes, ten minutes of travel were assigned to arterials and five minutes to local. Any portion of a trip outside the study area and greater than 15 minutes in duration was assigned to freeways. These factors were defined from brief analyses of long trips within the study area.

Results

Table 1 summarizes some of the results from the analysis by reviewing mean emissions by travel mode. A few issues are identified in this table that reveal a need for further refinement. Of particular concern are the school bus and bus transit trips. Emissions for these trips suffer from assumptions regarding occupancy and average speed. Off-peak occupancies were assumed to be 20 persons (peak occupancies were assumed to be 50). Also, travel speeds for buses were assumed to be the same as the modeled link average speed. Reality may show that these speeds are below average. The effect of the increased speed could cause elevated estimation of NOx emissions.

Table 2 - Mean trip emissions by mode

Mode	Number of trips	Mean HC (grams)	Mean CO (grams)	Mean NOx (grams)	Mean CO2 (grams)
Auto Driver	63907	2.61	62.6	7.99	3470
Auto Passenger	22790	1.10	25.7	3.32	1447
Walk	6185	0.00	0.0	0.00	0
School Bus	2818	Xx	xx	xx	xx
Bus (Transit)	2641	2.29	48.0	9.10	1474
Carpool Passenger	946	1.26	30.5	3.87	1677
Bicycle	943	0.00	0.0	0.00	0
Ferry / Boat	663	0.00	0.0	0.00	0
Other	222	0.00	0.0	0.00	0
Carpool Driver	217	1.59	39.0	4.89	2118
Vanpool Passenger	212	0.86	22.4	2.75	1184
Motorcycle, moped	95	12.01	69.9	7.31	1587
Vanpool Driver	63	0.51	12.5	1.58	679
Taxi / Limo	42	5.01	115.5	15.02	6451
DK / RF	22	0.00	0.0	0.00	0

Summary and Conclusions

While considerable attention and debate exists over the impacts of urban sprawl on the environment, surprisingly little work has been done to document the effects of specific land use and transportation investment policies on household vehicle emissions. This paper presents a new approach to estimate household vehicle emissions at the sub trip or facility link level. We believe that this approach can become a useful tool for various agencies to employ to assess how specific transportation and land development activities will, in concert, result in better or worse air quality when factored at the regional scale. While in-vehicle GPS will bring additional objective information on travel patterns, the widespread use of GPS within travel data collection will be several years in the making. In the meantime, more rigorous methods to assess actual travel choices and their air quality impacts are desperately needed. This paper is one attempt to move the state of the practice in this direction and to provide decision makers with a cost effective source of information that can readily be applied at the project or site, sub area, and regional scales.

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Appendix 3. Results – Aim 1 Mode Choice

Contained here are a summary of observation selection, data notes, model results and descriptives.

The Aim 1 mode choice models is at the trip level. Trips included in the Aim 1 analysis set were made by participants 5 to 18 years old, which went directly from home to school or the reverse and were made by walking, school bus, as a passenger in a motor vehicle or as the driver of a motor vehicle. School locations were identified through the reported activity at the location and the location name.

Simple tour-based modeling is used for the mode choice analysis. Home-to-home tours were considered for analysis but were rejected instead for home-to-school or school-to-home tours. Doing so allows the separate consideration of the mode used to arrive at school (typically in the morning) and the one used to return home (typically in the afternoon). If home-to-home tours were used a primary mode would need to be assigned to the tour even if different modes were used in the morning versus the afternoon.

Table 3: Aim 1 Mode Choice Models--Multinomial Logit, Nested, Segmented by Age

Model Type	**MNL**		**Nested**		**Age 5-10**		**Age 11-15**		**Age 16-18**	
Observations	5890		5890		2478		2439		973	
Observations by mode	**Chosen**	**Available**	**Chosen**	**Available**	**Chosen**	**Available**	**Chosen**	**Available**	**Chosen**	**Available**
Walk	321	3557	321	3557	144	1757	130	1344	47	456
Shared ride	2367	5890	2367	5890	1197	2478	887	2439	283	973
Drive alone	417	954	417	954	0	0	0	0	417	954
School bus	2785	5890	2785	5890	1137	2478	1422	2439	226	973
Car drive alone utility	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Constant	**0.978**	**3.8**	**1.04**	**4.0**					0.376	0.6
Car distance (miles)	***0.0531***	***1.8***	***0.0496***	***1.6***					-0.0119	-0.2
Trip back home 0/1	**-0.349**	**-2.2**	**-0.368**	**-2.3**					-0.0885	-0.4
HH cars<drivers 0/1	**-1.32**	**-6.4**	**-1.33**	**-6.3**					**-0.833**	**-2.9**
Age (years over 16)	**1.35**	**9.2**	**1.35**	**9.1**					**1.44**	**8.4**
Male 0/1	-0.0913	-0.6	-0.103	-0.6					0.124	0.6
Income under $20K 0/1	**-2.38**	**-4.1**	**-2.37**	**-4.1**					**-1.92**	**-2.9**
Income $20-50K 0/1	**-0.981**	**-4.5**	**-0.966**	**-4.4**					**-0.837**	**-3.0**
Income over $100K 0/1	**0.736**	**3.6**	**0.741**	**3.6**					**0.829**	**2.7**
Income data missing 0/1	**-1.0**	**-3.0**	**-0.996**	**-3.0**					**-1.29**	**-3.2**
Car shared ride utility	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Constant	**1.41**	**4.7**	**1.51**	**5.0**	**3.52**	**6.6**	0.696	1.5	0.761	0.8
Car distance (miles)	**0.116**	**2.6**	**0.128**	**2.8**	**0.299**	**3.8**	0.0718	1.0	-0.162	-1.5
Car distance squared	0.0013	0.4	5.30E-04	0.2	***-0.0094***	***-1.6***	0.0044	0.8	**0.0173**	**2.5**
Trip back home 0/1	**-0.56**	**-9.1**	**-0.564**	**-9.1**	**-0.623**	**-6.6**	**-0.641**	**-6.7**	-0.0685	-0.3
HH owns no cars 0/1	**-1.36**	**-4.8**	**-1.37**	**-4.8**	-0.365	-0.9	**-2.95**	**-3.9**	-1.3	-1.1
HH cars<drivers 0/1	-0.0711	-0.6	-0.0568	-0.5	**-0.438**	**-2.0**	**-0.624**	**-3.2**	**0.74**	**2.7**
Age (years over 16)	-0.0744	-0.5	-0.0739	-0.5					0.146	0.8
Age (years over 12)	**0.155**	**4.6**	**0.154**	**4.5**			**0.171**	**3.5**		
Age (years under 12)	**0.166**	**5.8**	**0.167**	**5.8**	0.0172	0.2	-0.107	-0.7		
Age (years under 8)	-0.0413	-0.6	-0.0365	-0.5	0.105	0.9				
Male 0/1	-0.0248	-0.4	-0.0259	-0.4	-0.102	-1.1	0.0619	0.6	0.276	1.2
Income under $20K 0/1	**-0.457**	**-2.9**	**-0.496**	**-3.1**	**-1.05**	**-4.3**	-0.0134	-0.1	-0.142	-0.2
Income $20-50K 0/1	0.0689	0.8	0.0535	0.6	-0.0455	-0.3	0.138	1.0	0.192	0.7
Income over $100K 0/1	-0.0801	-0.9	-0.0773	-0.9	**-0.537**	**-3.8**	***0.214***	***1.6***	0.0551	0.2
Income data missing 0/1	0.0497	0.4	0.0805	0.6	0.147	0.7	0.126	0.6	-0.378	-1.0
HH # full time workers	**-0.187**	**-2.7**	**-0.211**	**-3.0**	**-0.561**	**-4.7**	-0.0085	-0.1	-0.0593	-0.3
HH # part time workers	**-0.195**	**-2.3**	**-0.243**	**-2.7**	**-0.782**	**-5.2**	0.134	1.0	0.0554	0.2
HH # non-working adults	-0.0563	-0.8	-0.0869	-1.3	**-0.467**	**-4.0**	**0.289**	**2.7**	-0.219	-1.3
HH # university students	**-0.271**	**-2.1**	***-0.237***	***-1.8***	**-1.08**	**-5.6**	0.126	0.6	**0.667**	**2.4**
HH # schoolkids age 16+	0.0463	0.6	0.0672	0.8	0.0841	0.5	0.0738	0.6	0.191	0.8
HH # schoolkids age 5-15	**-0.208**	**-5.1**	**-0.199**	**-4.8**	**-0.315**	**-4.9**	**-0.164**	**-2.5**	0.102	0.9
HH # car driver work tours	**0.102**	**3.7**	**0.0967**	**3.5**	**0.257**	**5.7**	-0.0227	-0.5	0.0461	0.6
HH fraction of adults w/college degree	**0.54**	**6.7**	**0.539**	**6.6**	***0.233***	***1.8***	**0.835**	**6.3**	**0.667**	**3.0**
Car average speed (mph)	**-0.0309**	**-5.0**	**-0.0328**	**-5.3**	**-0.0599**	**-6.0**	-0.0132	-1.3	-0.0226	-1.4
Car additional variables	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Mot. Route intersection density	-0.0043	-1.0	-0.0028	-0.7	-0.0014	-0.2	-0.0052	-0.7	-9.20E-04	-0.1
Mot. Route mixed use index	**-0.637**	**-2.6**	**-0.638**	**-2.6**	-0.498	-1.2	**-0.997**	**-2.6**	-0.116	-0.2
Mot. Route net residential density	**0.0697**	**3.0**	**0.0656**	**2.9**	***0.0568***	***1.7***	***0.0671***	***1.8***	0.0288	0.4
Mot. Route open space	**0.0205**	**4.2**	**0.0202**	**4.2**	**0.0322**	**3.4**	**0.0162**	**2.2**	0.0089	0.8
Mot. Route vacant space	**-0.0072**	**-5.9**	**-0.0075**	**-6.1**	**-0.0061**	**-3.1**	**-0.0094**	**-4.6**	-6.10E-04	-0.2
Mot. Route fraction w/ sidewalk	**0.358**	**2.7**	**0.308**	**2.3**	**0.489**	**2.5**	0.113	0.5	-0.588	-1.3
Mot. Route arterials crossed per km	0.0322	0.5	0.0727	0.9	0.0918	0.9	-0.126	-1.0	**0.773**	**2.7**
Mot. Route employment density	0.0039	0.8	0.005	1.0	-3.00E-04	0.0	0.0087	1.1	**0.0985**	**4.0**

Model Type	**MNL**		**Nested**		**Age 5-10**		**Age 11-15**		**Age 16-18**	
Observations	5890		5890		2478		2439		973	
Walk utility	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Constant	**-1.86**	**-3.0**	-7.42	-1.1	-1.94	-1.5	-1.2	-1.0	-15.8	-0.6
Walk distance (miles)	**-3.66**	**-8.0**	-12.2	-1.3	**-6.61**	**-7.1**	**-3.36**	**-3.5**	**-10.5**	**-4.3**
Walk distance squared	**0.749**	**4.9**	2.46	1.3	**1.94**	**6.4**	0.473	1.5	0	
Trip back home 0/1	**0.584**	**3.7**	2.35	1.2	**0.604**	**2.4**	**1.08**	**4.0**	1.28	1.4
HH owns no cars 0/1	**1.17**	**3.6**	4.32	1.2	**2.1**	**3.4**	-0.0412	-0.1	**23.3**	**2.0**
HH cars<drivers 0/1	0.293	1.3	1.03	0.9	**-0.903**	**-2.0**	**1.29**	**3.3**	7.45	1.4
Age (years over 16)	**-0.798**	**-2.1**	-3.61	-1.1					**-10.8**	**-2.5**
Age (years over 12)	**0.409**	**4.9**	1.02	1.4			0.0929	0.6		
Age (years under 12)	-0.0064	-0.1	-0.204	-0.7	***-0.39***	***-1.8***	**-1.1**	**-2.2**		
Age (years under 8)	**-0.553**	**-2.9**	-1.71	-1.2	0.0335	0.1				
Male	**0.481**	**2.9**	1.43	1.2	-0.087	-0.3	**1.3**	**4.0**	-0.704	-0.3
Income under $20K 0/1	**1.05**	**3.2**	3.95	1.2	***1.28***	***1.9***	**1.52**	**2.2**	***-12.1***	***-1.6***
Income $20-50K 0/1	**0.468**	**2.0**	1.78	1.1	***0.798***	***1.7***	**1.16**	**2.5**	2.99	0.4
Income over $100K 0/1	-0.151	-0.5	-0.504	-0.5	0.0864	0.2	-0.0458	-0.1	-5.21	-0.6
Income data missing 0/1	0.0599	0.2	0.328	0.3	**2.36**	**3.3**	0.0167	0.0	-8.76	-0.4
Ethnicity=white 0/1	**0.76**	**2.9**	2.32	1.2	**2.02**	**3.3**	**0.986**	**2.0**	4.85	0.9
Home owner 0/1	**0.61**	**2.3**	1.93	1.1	0.558	1.2	0.285	0.6	0.288	0.0
Neighb. Tenure 3+ years 0/1	**-0.689**	**-3.5**	-2.29	-1.2	-0.908	-2.6	**-0.884**	**-2.4**	-8.87	-1.0
W- Traffic	**-0.141**	**-2.3**	-0.466	-1.1	***-0.225***	***-1.8***	-0.0781	-0.7	0.236	0.1
W- Crime	-7.00E-04	0.0	0.0144	0.1	0.0054	0.0	-0.114	-1.0	***-2.51***	***-1.6***
W- Sidewalk	-0.018	-0.3	-0.0787	-0.4	**-0.21**	**-2.0**	-0.0403	-0.4	2.24	1.4
W- Missing data	***0.572***	***1.6***	1.93	1.0	**1.42**	**2.4**	-0.159	-0.2	-1.53	-0.1
Q- affordability	-0.107	-1.4	-0.313	-1.0	-0.027	-0.2	**-0.277**	**-2.1**	1.53	0.7
Q- ease of walking	**-0.184**	**-2.6**	-0.567	-1.2	0.0438	0.4	-0.17	-1.1	***-5.43***	***-1.6***
Q- closeness of job	***-0.119***	***-1.6***	-0.369	-1.0	-0.0269	-0.2	**-0.359**	**-2.5**	-2.64	-0.9
Q- public transportation	***-0.131***	***-1.9***	-0.406	-1.1	**-0.281**	**-2.2**	**0.272**	**2.1**	0.733	0.3
Q- major roads	**0.482**	**6.0**	1.45	1.3	**0.644**	**4.2**	0.0984	0.6	**4.43**	**2.3**
Q- shops and services	**-0.264**	**-3.4**	-0.771	-1.3	-0.237	-1.4	-0.0519	-0.4	***-5.32***	***-1.8***
Q- school quality	0.0961	1.3	0.282	0.9	**0.401**	**2.3**	0.117	0.9	-0.391	-0.2
Q- outdoor recreation	**0.182**	**2.4**	0.566	1.2	-0.0996	-0.6	0.181	1.3	-0.238	-0.1
Q- low crime	**-0.412**	**-4.3**	-1.24	-1.3	**-0.857**	**-4.5**	***-0.335***	***-1.9***	**10.9**	**2.8**
NM Route intersection density	0.0115	1.4	0.0493	1.0	**0.0372**	**2.2**	0.005	0.3	-0.0145	0.0
NM Route fraction w/ sidewalk	**1.67**	**5.6**	4.91	1.3	**2.83**	**5.0**	0.569	1.0	**17.8**	**2.0**
NM Route arterials crossed per km	**0.383**	**3.1**	1.15	1.3	**0.987**	**4.7**	0.34	1.2	-8.36	-1.1
NM Route mixed use index	**-0.972**	**-2.1**	-1.9	-1.1	**-2.4**	**-2.6**	-0.403	-0.5	-9.05	-0.7
NM Route net residential density	**0.148**	**3.2**	0.331	1.3	***0.161***	***1.8***	***0.179***	***1.8***	-3.44	-1.4
NM Route employment density	***0.0169***	***1.7***	0.0478	1.1	0.0096	0.6	0.0171	0.8	0.0174	0.0
NM Route open space, Med.Inc.<$30K	**-0.124**	**-2.0**	-0.479	-1.1	-0.187	-1.0	-0.101	-1.2		
NM Route open space, Med.Inc.>$30k	**0.0596**	**2.9**	0.167	1.3	-0.067	-0.8	**0.0889**	**3.1**	0.575	0.4
NM Route vacant space	3.10E-04	0.1	0.0121	0.8	***0.0093***	***1.8***	-0.0087	-1.5	0.216	1.5
NM Route ethnic diverisity index	***-1.15***	***-1.8***	-4.04	-1.1	**-2.17**	**-2.0**	-1.34	-1.0	34.6	1.2
NM Route - different ethnicity	***0.5***	***1.9***	1.13	1.0	-0.131	-0.2	***0.819***	***1.6***	4.93	0.7
NH median income - NM route minimum (000)	**-0.0137**	**-2.5**	-0.0326	-1.2	-0.0096	-0.8	-0.0142	-1.4	0.198	1.2
NM Route maximum income - NH median (000)	**-0.0163**	**-2.7**	-0.0437	-1.2	**-0.0347**	**-2.5**	-0.017	-1.5	-0.249	-1.4
Home buffer retail employment	**0.0011**	**4.4**	0.0033	1.3	**0.0016**	**4.1**	-3.50E-04	-0.6	**0.0157**	**2.0**
School buffer retail employment	**-0.0013**	**-3.8**	-0.0039	-1.3	**-0.0048**	**-5.0**	-1.40E-04	-0.3	-0.0041	-0.4
School buffer population	**2.40E-04**	**5.0**	6.70E-04	1.3	**5.70E-04**	**5.7**	**1.90E-04**	**2.1**	0.0028	1.0
School bus utility	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
School bus availability 2 (distance-based)	**0.673**	**6.9**	**0.716**	**7.2**	**0.663**	**4.7**	**0.831**	**5.0**	**1.06**	**2.1**
NM Route - different ethnicity	**0.361**	**4.7**	**0.367**	**4.7**	**0.357**	**3.1**	**0.281**	**2.2**	**0.738**	**3.0**
NH median income - NM route minimum (000)	**-0.0116**	**-6.0**	**-0.0115**	**-5.9**	**-0.0148**	**-4.5**	**-0.0074**	**-2.6**	**-0.0193**	**-2.4**
NM Route maximum income - NH median (000)	**-0.0048**	**-2.9**	**-0.005**	**-2.9**	**-0.0088**	**-3.2**	-0.0028	-1.1	0.0059	1.0
Home buffer mixed use index	**0.35**	**2.0**	**0.378**	**2.1**	0.184	0.7	-0.279	-1.0	**2.69**	**4.8**
Home buffer open space	0.0038	1.0	0.0029	0.8	0.0061	0.8	0.0078	1.5		
Home buffer vacant space	**-0.0024**	**-2.5**	**-0.0029**	**-2.9**	-0.0011	-0.7	**-0.0031**	**-2.1**	***-0.0062***	***-1.7***
Home buffer population	**8.90E-05**	**5.7**	**9.10E-05**	**5.7**	***4.00E-05***	***1.6***	**1.50E-04**	**6.0**	4.50E-05	0.9
School buffer mixed use index	**-0.533**	**-3.9**	**-0.546**	**-3.9**	**-0.581**	**-2.4**	**-0.68**	**-3.3**	**-0.876**	**-2.2**
School buffer open space	**0.0222**	**4.6**	**0.0214**	**4.4**	**0.0359**	**3.5**	**0.025**	**3.2**	0.0057	0.9
Schoo buffer population	**3.60E-05**	**2.1**	**3.70E-05**	**2.1**	**5.70E-05**	**2.2**	2.30E-06	0.1	4.20E-05	0.8
Nesting parameter			**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Nest with all motorized alterantives			0.318	1.3	*0.291*	*2.5*	*1.815*	*2.9*	*Did not estimate*	
(T-statisitic with respect to 1.0)				2.8		*6.1*		*1.3*		
Model Fit										
Final log L	-4168.4		-4165.9		-1556.8		-1529.4		-766.8	
Rho-squared(0)	0.289		0.289		0.359		0.316		0.358	
Rho-squared(const)	0.222		0.223		0.265		0.223		0.322	

Table 4: Aim 1 Mode Choice Models -- Segmented by Distance

Model Type	**Distance 0-1.5 miles**		**Distance 1.5-3 miles**		**Distance >3 miles**	
Observations	1738		1819		2333	
Observations by mode	**Chosen**	**Available**	**Chosen**	**Available**	**Chosen**	**Available**
Walk	283	1738	38	1819	0	0
Shared ride	686	1738	1168	1819	1030	2333
Drive alone	55	146	137	299	225	509
School bus	714	1738	993	1819	1078	2333
Car drive alone utility	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Constant	**2.55**	**2.5**	0.27	0.3	***-0.709***	***-1.9***
Car distance (miles)	-0.743	-1.1	0.192	0.5	***0.0747***	***1.7***
Trip back home 0/1	-0.419	-1.0	-0.109	-0.4	**-0.464**	**-2.1**
HH cars<drivers 0/1	0.503	0.9	**-2.53**	**-5.3**	**-1.38**	**-4.6**
Age (years over 16)	**0.859**	**2.0**	**1.94**	**6.2**	**1.26**	**6.6**
Male 0/1	***-0.771***	***-1.7***	0.179	0.6	-0.0256	-0.1
Income under $20K 0/1			**-1.64**	**-2.3**		
Income $20-50K 0/1	***1.14***	***1.9***	**-1.05**	**-2.6**	**-1.44**	**-4.2**
Income over $100K 0/1	**1.48**	**2.6**	0.122	0.3	**1.01**	**3.6**
Income data missing 0/1			-0.497	-0.7	-0.122	-0.3
Car shared ride utility	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Constant	**2.42**	**3.2**	**7.97**	**5.7**	**-2.94**	**-5.0**
Car distance (miles)	**4.39**	**4.8**	**-3.6**	**-3.4**	**0.26**	**2.8**
Car distance squared	**-2.63**	**-5.2**	**0.77**	**3.4**	**-0.0121**	**-2.0**
Trip back home 0/1	**-0.95**	**-7.4**	**-0.476**	**-4.2**	**-0.464**	**-4.7**
HH owns no cars 0/1	**-1.65**	**-4.2**	-5		**-1.41**	**-2.1**
HH cars<drivers 0/1	0.0854	0.3	0.0561	0.2	-0.179	-1.0
Age (years over 16)	**-0.929**	**-2.2**	-0.21	-0.7	0.0815	0.4
Age (years over 12)	**0.554**	**6.3**	**0.207**	**3.1**	0.0418	0.8
Age (years under 12)	**0.228**	**3.8**	**0.163**	**2.9**	**0.24**	**5.0**
Age (years under 8)	0.173	1.3	***-0.226***	***-1.8***	-0.102	-0.8
Male 0/1	**-0.39**	**-2.9**	0.0182	0.2	0.124	1.2
Income under $20K 0/1	-0.177	-0.6	**-0.619**	**-2.0**	**-0.593**	**-2.2**
Income $20-50K 0/1	0.285	1.5	0.203	1.2	-0.107	-0.8
Income over $100K 0/1	-0.25	-1.3	-0.198	-1.2	0.0525	0.4
Income data missing 0/1	0.113	0.4	0.295	1.2	0.058	0.3
HH # full time workers	**-0.489**	**-3.3**	**-0.499**	**-3.8**	0.0725	0.7
HH # part time workers	**-0.545**	**-2.8**	**-0.575**	**-3.4**	0.0055	0.0
HH # non-working adults	**-0.347**	**-2.2**	-0.0886	-0.7	-0.0058	-0.1
HH # university students	**-1.08**	**-4.1**	-0.05	-0.2	0.255	1.2
HH # schoolkids age 16+	0.194	1.0	-0.2	-1.3	**0.219**	**1.8**
HH # schoolkids age 5-15	-0.0898	-1.2	**-0.498**	**-6.1**	**-0.152**	**-2.1**
HH # car driver work tours	**0.191**	**3.2**	**0.14**	**2.8**	***0.0765***	***1.7***
HH fraction of adults w/college degree	**0.364**	**2.1**	**0.584**	**3.7**	**0.728**	**5.6**
Car average speed (mph)	**-0.0746**	**-5.2**	**-0.0823**	**-6.0**	***0.0187***	***1.9***
Car additional variables	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Mot. Route intersection density	**-0.0179**	**-2.4**	**-0.0222**	**-2.5**	**0.0237**	**2.7**
Mot. Route mixed use index	**-2.06**	**-2.8**	***-0.826***	***-1.8***	-0.0867	-0.2
Mot. Route net residential density	0.0339	0.8	**0.147**	**3.2**	0.0367	0.8
Mot. Route open space	**0.353**	**5.2**	**0.0338**	**2.4**	**0.0147**	**2.7**
Mot. Route vacant space	-0.0041	-1.4	**-0.011**	**-4.2**	**-0.0067**	**-3.6**
Mot. Route fraction w/ sidewalk	**1.23**	**5.4**	0.0383	0.1	-0.455	-1.5
Mot. Route arterials crossed per km	-0.139	-1.3	0.0716	0.5	***0.299***	***1.6***
Mot. Route employment density	9.30E-04	0.1	-0.0134	-1.5	**0.0248**	**2.6**

Model Type	**Distance 0-1.5 miles**		**Distance 1.5-3 miles**		**Distance >3 miles**	
Observations	1738		1819		2333	
Walk utility	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Constant	**-2.01**	**-2.5**	35.8	1.2		
Walk distance (miles)	-1.44	-1.1	**-66**	**-2.2**		
Walk distance squared	-0.986	-1.2	**15.2**	**2.2**		
Trip back home 0/1	**0.481**	**2.5**	**1.88**	**2.3**		
HH owns no cars 0/1	**0.759**	**1.9**	**29.3**	**3.4**		
HH cars<drivers 0/1	**0.712**	**2.4**	2.28	1.3		
Age (years over 16)	**-1.63**	**-2.9**	**-9.28**	**-2.6**		
Age (years over 12)	**0.842**	**7.1**	**1.23**	**2.8**		
Age (years under 12)	0.0142	0.2	0.398	0.7		
Age (years under 8)	**-0.798**	**-3.3**	***-2.78***	***-1.6***		
Male	0.256	1.3	**5.65**	**3.0**		
Income under $20K 0/1	**1.12**	**2.7**	***5.82***	***1.8***		
Income $20-50K 0/1	***0.478***	***1.6***	**6.25**	**2.4**		
Income over $100K 0/1	-0.367	-1.1	**-6.81**	**-2.3**		
Income data missing 0/1	-0.0059	0.0	-2.0			
Ethnicity=white 0/1	**0.719**	**2.3**	***5.44***	***1.8***		
Home owner 0/1	**0.668**	**2.0**	0.405	0.2		
Neighb. Tenure 3+ years 0/1	**-0.484**	**-2.0**	**-7.97**	**-3.7**		
W- Traffic	**-0.163**	**-2.2**	-0.621	-1.2		
W- Crime	0.0106	0.1	**1.18**	**2.0**		
W- Sidewalk	-0.0655	-1.0	**1.84**	**2.4**		
W- Missing data	**1.12**	**2.4**	**-6.79**	**-2.4**		
Q- affordability	-0.0472	-0.5	1.58	1.2		
Q- ease of walking	**-0.184**	**-2.1**	0.332	0.5		
Q- closeness of job	***-0.147***	***-1.6***	***1.54***	***1.7***		
Q- public transportation	-0.072	-0.9	-0.33	-0.6		
Q- major roads	**0.321**	**3.5**	**3.03**	**2.1**		
Q- shops and services	**-0.244**	**-2.6**	**-1.65**	**-2.1**		
Q- school quality	**0.275**	**3.1**	**-2.59**	**-2.4**		
Q- outdoor recreation	0.134	1.4	-0.868	-1.1		
Q- low crime	**-0.368**	**-3.1**	0.17	0.2		
NM Route intersection density	-0.006	-0.6	-0.0047	0.0		
NM Route fraction w/ sidewalk	**2.5**	**7.0**	1.62	0.5		
NM Route arterials crossed per km	**0.301**	**2.1**	**-5.36**	**-2.4**		
NM Route mixed use index	**-1.68**	**-2.0**	**-19**	**-3.2**		
NM Route net residential density	**0.169**	**3.1**	-1.31	-1.3		
NM Route employment density	**0.0354**	**2.7**	**0.434**	**2.5**		
NM Route open space, Med.Inc.<$30K	**0.206**	**2.1**				
NM Route open space, Med.Inc.>$30k	**0.43**	**5.8**	***-7.41***	***-1.6***		
NM Route vacant space	0.0044	1.1	**-0.121**	**-2.4**		
NM Route ethnic diverisity index	-0.111	-0.1	**15**	**2.2**		
NM Route - different ethnicity	-0.178	-0.5	**9.16**	**2.8**		
NH median income - NM route minimum (000)	**-0.0385**	**-5.0**	**0.152**	**3.3**		
NM Route maximum income - NH median (000)	**-0.0204**	**-2.6**	**-0.182**	**-2.5**		
Home buffer retail employment	2.60E-04	0.7	**0.0042**	**2.5**		
School buffer retail employment	**-0.001**	**-2.5**	-0.0045	-1.1		
School buffer population	**1.60E-04**	**2.7**	**0.0029**	**3.8**		
School bus utility	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
School bus availability 2 (distance-based)	**0.717**	**4.6**				
NM Route - different ethnicity	**0.41**	**2.6**	**0.339**	**2.3**	**0.484**	**3.7**
NH median income - NM route minimum (000)	**-0.0119**	**-2.7**	**-0.0152**	**-3.9**	**-0.0066**	**-2.1**
NM Route maximum income - NH median (000)	**-0.014**	**-2.8**	0.0012	0.4	**-0.0058**	**-2.2**
Home buffer mixed use index	0.123	0.3	-0.527	-1.5	**1.17**	**4.4**
Home buffer open space	**0.124**	**4.6**	0.015	1.2	-0.0012	-0.3
Home buffer vacant space	**0.0054**	**2.0**	**-0.0059**	**-3.1**	**-0.0031**	**-2.0**
Home buffer population	**1.50E-04**	**3.9**	**1.00E-04**	**3.3**	**5.30E-05**	**2.2**
School buffer mixed use index	-0.615	-1.4	**-0.948**	**-3.2**	**-0.584**	**-3.1**
School buffer open space	**0.121**	**3.9**	0.0054	0.5	**0.0202**	**3.6**
Schoo buffer population	2.30E-05	0.6	2.40E-05	0.6	2.90E-06	0.1
Nesting parameter	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
Nest with all motorized alterantives	*0.513*	*2.1*	*0.477*	*1.3*	*Not applicable*	
(T-statisitic with respect to 1.0)		*2.0*		*1.4*		
Model Fit						
Final log L	-1240.3		-1088.7		-1468.1	
Rho-squared(0)	0.364		0.478		0.195	
Rho-squared(const)	0.326		0.286		0.210	

Table 5: Aim 1 Mode Choice Model Variables

Variable Name	Description
Age (years over 12)	# of years the participant is over 12.
Age (years over 16)	# of years the participant is over 16.
Age (years under 12)	# of years the participant is under 12.
Age (years under 8)	# of years the participant is under 8.
Car average speed (mph)	Average speed along motorized route (based on posted speeds)
Car distance (miles)	distance along motorized route between home/school or school/home
Car distance squared	square of distance along motorized route between home/school or school/home
Ethnicity=white 0/1	Is the reported ethnicity white? Yes (1) or no (0).
HH # car driver work tours	# of work tours made by members of the household, where they are the driver, and the trip occurs on the same day as the school trip
HH # full time workers	# of full time workers in the household
HH # non-working adults	# of non- working adults in the household
HH # part time workers	# of part time workers in the household
HH # schoolkids age 16+	# of school children 16 years or older
HH # schoolkids age 5-15	# of school children 5 - 15 years
HH # university students	# of university students in the household
HH cars<drivers 0/1	Are there fewer vehicles than licensed drivers in the household? Yes (1) or no (0).
HH fraction of adults w/college degree	% of adults with college degrees
HH owns no cars 0/1	Does the household have vehicles available? Yes (1) or no (0).
Home buffer mixed use index	Mixed use of the buffered 200m grid containing the participant's house (Entropy formula using building floor area for commerical, office and residential)
Home buffer open space	Acres of open space in the buffered 200m grid containing the participant's house
Home buffer population	Population count (spatial allocation from traffic analysis zone control totals) in one kilometer road network buffer containing the participant's house
Home buffer retail employment	# of retail jobs in one kilometer road network buffer containing participant's house
Home buffer vacant space	Acres of vacant space in the buffered 200m grid containing the school attended
Home owner 0/1	Is the home owned by the members of the household? Yes (1) or no (0).
Income $20-50K 0/1	Is the household's reported annual income between $20,000 and $50,000? Yes (1) or no (0).
Income data missing 0/1	Is the household's reported annual income unreported? Yes (1) or no (0).
Income over $100K 0/1	Is the household's reported annual income over $100,000? Yes (1) or no (0).
Income under $20K 0/1	Is the household's reported annual income under $20,000? Yes (1) or no (0).
Male 0/1	Is the participant male? Yes (1) or no (0).
Mot. Route arterials crossed per km	# of arterials crossed per kilometer of motorized route
Mot. Route employment density	Average employment density (jobs per acre) for 200m grids along the motorized route
Mot. Route fraction w/ sidewalk	% of motorized route length which has sidewalks
Mot. Route intersection density	Motorized route intersection density (mean of 200m grids intersected by trip path)

Mot. Route mixed use index	Average mixed use index for 200m grids along the motorized route
Mot. Route net residential density	Average net residential density (housing units per acre) for 200m grids along the motorized route
Mot. Route open space	Average acres of open space for 200m grids along the motorized route
Mot. Route vacant space	Average acres of vacant parcels for 200m grids along the motorized route
Neighb. Tenure 3+ years 0/1	Has the household lived at the current address for three or more years? Yes (1) or no (0).
NH median income - NM route minimum (000)	Median 1999 income of the 2000 Census block group containing the participant's home minus the minimum median 1999 income of all the Census block groups intersected by the non-motoized trip path
NM Route - different ethnicity	Identifies whether or not the household is self identified as a member of the majority ethnic group for the census block groups intersected along the route to school, based on the ethnicyt reported by the main household respondent (1 = Yes, 0 = No, NULL = insufficient data to determine answer). If the household self identifies with one of the 8 summary ethnic groups available in the U.S. Census (White, Black, Native American, Asian, Hawaiian/Pacific Islander, Hispanic, Other, 2 or More Races), and that ethnic group was the majority for the census block groups intersected along the route to school, then the value is 1; if not, the value is 0. If a household's self reported ethnicity did not correspond to a U.S. Census category, the value is intentionally left blank.
NM Route arterials crossed per km	# of arterials crossed per kilometer of non-motorized route
NM Route employment density	Average employment density (jobs per acre) for 200m grids along the non-motorized route
NM Route ethnic diverisity index	A continuous variable scaled from 0 to 1 which indicates the level of ethnic diversity within the population for the census block groups intersected along the route to school. Calculated using the same formula as the Cervero/Kockelman mixed use index, substituting the 8 summary ethnic groups available in the U.S. Census (White, Black, Native American, Asian, Hawaiian/Pacific Islander, Hispanic, Other, 2 or More Races) for land use categories.
NM Route fraction w/ sidewalk	% of non-motorized route length which has sidewalks
NM Route intersection density	Non-motorized route intersection density (mean of 200m grids intersected by trip path)
NM Route maximum income - NH median (000)	Maximum median 1999 income of the 2000 Census block group intersected by the non-motoized trip path minus the median 1999 income of the Census block group containing the participant's house
NM Route mixed use index	Average mixed use index for 200m grids along the non-motorized route
NM Route net residential density	Average net residential density (housing units per acre) for 200m grids along the non-motorized route
NM Route open space, Med.Inc.<$30K	Average acres of open space for 200m grids along the non-motorized route, for participants with reported household annual income <$30,000
NM Route open space, Med.Inc.>$30k	Average acres of open space for 200m grids along the non-motorized route, for participants with reported household annual income >$30,000

NM Route vacant space	Average acres of vacant parcels for 200m grids along the non-motorized route, for participants with reported household annual income >$30,000
Q- affordability*	On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood -- Affordability (low cost, taxes).
Q- closeness of job*	On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood -- Closeness to job.
Q- ease of walking*	On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood -- Ease of walking.
Q- low crime*	On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood -- Low crime.
Q- major roads*	On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood -- Near major roads and interstates.
Q- outdoor recreation*	On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood -- Near outdoor recreation (e.g. parks).
Q- public transportation*	On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood -- Near to public transit.
Q- school quality*	On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood -- Quality of schools.
Q- shops and services*	On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood -- Near shops and services.
School buffer mixed use index	Mixed use of the buffered 200m grid containing the school attended (Entropy formula using building floor area for commerical, office and residential)
School buffer open space	Acres of open space in the buffered 200m grid containing the school attended
School buffer population	Population count (spatial allocation from traffic analysis zone control totals) in one kilometer road network buffer containing the school attended
School buffer retail employment	# of retail jobs in in one kilometer road network buffer containing the school attended
School bus availability 2 (distance-based)	Is a school bus avaiable based on distance from home to school and school district policies? Yes (1) or no (0).
Trip back home 0/1	Did the student return home? Yes (1) or no (0).
W- Crime**	On a scale of 1 to 5, with 1 being not at all and 5 being very much, please tell me how much the following factor influences your willingness to walk in your neighborhood: Crime.
W- Missing data	Are there missing data from the W-Crime, W-Sidewalk or W-Traffic variables? Yes (1) or no (0).
W- Sidewalk**	On a scale of 1 to 5, with 1 being not at all and 5 being very much, please tell me how much the following factor influences your willingness to walk in your neighborhood: Availability of sidewalks.
W- Traffic **	On a scale of 1 to 5, with 1 being not at all and 5 being very much, please tell me how much the following factor influences your willingness to walk in your neighborhood: Traffic.

* Note 1: the scale has been modified. It was reversed in the original version posed to the participant, with 1=excellent and 5= poor. Note 2: This question was asked of a random adult for each household. It is treated as a household level variable.
** Note 1: the scale has been modified. It was reversed in the original version posed to the participant, with 1 = very much and 5 = not at all. Note 2: This question was asked of people 16 years or older. The response for the participant was used unless they were younger than 16. In that case the household's main respondent was used. If the main respondent did not answer the question then the answer from next person (in the order recruited) was used.

Table 6: Aim 1 Mode Choice -- descriptives

Variable	N (trips)	Minimum	Maximum	Mean	Std. Deviation
drvmeters	6242	1.3437667	106805.99	6595.802213	8771.610175
drvhours	6242	0.0000334	1.11514473	0.101125994	0.104345441
walkmeter	6238	1.3437667	101049.28	6325.34918	8212.821092
TripDistMl	6294	0.059	45.651	5.350726574	5.290179147
estdist_11092008	6294	0.059	45.651	5.350726574	5.290179147
hrlyparking	6518	0	0.047945205	8.25311E-05	0.001249725
Age (from PERFIN_GT_10B.sav)	6518	5	18	11.38539429	3.708164202
male=1 female=0	6518	0	1	0.507977907	0.499974704
Household size	6518	2	8	4.111997545	1.079489319
Income - Imputed	6518	11	19	16.18425898	2.345410864
hhinc1020K	6518	0	1	0.060601411	0.238616043
hhinc2030K	6518	0	1	0.08054618	0.272157779
hhinc3040K	6518	0	1	0.122890457	0.328336614
hhinc4050K	6518	0	1	0.080699601	0.272394125
hhinc5060K	6518	0	1	0.110463332	0.31349045
hhinc6075K	6518	0	1	0.132402577	0.338953922
hhinc75100K	6518	0	1	0.189475299	0.391915776
hhincover100K	6518	0	1	0.199754526	0.39984645
Total household vehicles	6518	0	7	2.210800859	1.021809106
N_licensed_drivers	6518	0	5	2.028076097	0.760972831
English spoken at home? yes=1 no=0	6518	0	1	0.096348573	0.295091317
Ethnicity	6518	1	9	3.848726603	1.789902475
white10	6518	0	1	0.651426818	0.476555098
N_HH_fulltime_mean/N_HH_over18_mean	6518	0	1	0.655707272	0.316083354
N_HH_bachdeg_mean/N_HH_over18_mean	6518	0	1	0.528329242	0.442941996
AffHm10	6518	0	1	0.320036821	0.466526147
AffResNbr10	6518	0	1	0.683798711	0.465028183
ethnhomogo	6411	0	1	0.762127593	0.425813817
origpopdiv	6423	0	0.709059109	0.330276342	0.156636595
ethnhomogd	6411	0	1	0.760567774	0.426770248
destpopdiv	6422	0	0.710260835	0.331291708	0.156404251
Own/buying the home? yes=1 no=0	6512	0	1	0.824324324	0.380573218
Lived at current address more than 3 yrs? yes=1 no=0	6512	0	1	0.760749386	0.426658777
Quality in neighborhood: Affordability	5716	1	5	3.58659902	1.189935446

Quality in neighborhood: Ease of walking	5722	1	5	3.605907026	1.382609821
Quality in neighborhood: Closeness to job	4202	1	5	3.127320324	1.526320971
Quality in neighborhood: Near to public transit	5581	1	5	2.364809174	1.594752176
Quality in neighborhood: Near major roads and interstates	5732	1	5	3.858339149	1.174748226
Quality in neighborhood: Near shops and services	5725	1	5	3.831965066	1.170206549
Quality in neighborhood: Quality of schools	5691	1	5	3.966438236	1.257706627
Quality in neighborhood: Near outdoor recreation	5684	1	5	3.704257565	1.222253695
Quality in neighborhood: Low crime	5448	1	5	4.026431718	0.991999743
Influence walk in neighborhood: Traffic	6041	1	5	2.917563317	1.682149491
Influence walk in neighborhood: Crime	6016	1	5	2.700631649	1.692182289
Influence walk in neighborhood: Availabilty of sidewalks	6013	1	5	3.057541992	1.722907887
origintperkm	6413	0	120.6150538	29.13731311	15.32773213
destintperkm	6412	0	132.2111935	28.66902128	15.20050592
OrigResDen	6419	0	216.05	2.976491665	5.804333148
DestResDen	6418	0	216.05	2.958554067	5.594465803
OriginMixUse3fsq	6427	0	0.999989814	0.267655713	0.310451943
DestMixUse3fsq	6426	0	0.999989814	0.275095749	0.313153226
Origin -- HomeWlkIndx or SchoolWlkIndx	6465	-3.224846813	32.72770394	-0.022723125	2.003266816
Destination -- HomeWlkIndx or SchoolWlkIndx	6462	-3.224846813	32.72770394	-0.026866776	1.988324171
Origin -- HomeWlkIndx2 or SchoolWlkIndx2	6465	-5.180522861	34.75772775	0.00538457	2.798152222
Destination -- HomeWlkIndx2 or SchoolWlkIndx2	6462	-5.180522861	34.75772775	-0.00372037	2.78204065
SchlBusHmv2	6242	0	1	0.788048702	0.408723266
OrigHHInc	6425	0	200001	71122.44498	30818.28253
DestHHInc	6424	0	200001	71152.43649	31504.9307
OrigOpenSpcRev	6518	0	130.62	0.438646824	4.339827454
DestOpenSpcRev	6518	0	163.08	0.483608469	4.647931744
OrigVacSpcRev	6518	0	237.04	16.34162473	25.6743379
DestVacSpcRev	6518	0	370.46	17.15938325	27.75550865
TAZ level # of retail jobs in buffer	6427	0	3562	224.6161506	312.2068109
TAZ level # of non-retail jobs in buffer	6427	0	16117	993.1177843	1425.505642
TAZ level POPULATION in buffer	6427	0	12291	3509.032675	2022.784698
TAZ level # of retail jobs in buffer	6426	0	3562	228.7709306	317.5121939
TAZ level # of non-retail jobs in buffer	6426	0	16117	1019.825086	1467.014337
TAZ level POPULATION in buffer	6426	0	12291	3511.094149	2023.240353
countymedh	6518	42697	71227	54578.11322	6206.479853
nbrinc	6518	4202	200001	70781.65005	29650.90712
maffHHRte10	6518	0	1	0.307149432	0.46134728

methhom	6135	0	1	0.777669112	0.415846187
mpopdivi	6242	0.028134982	0.710534871	0.370833512	0.145012445
mavintdn	6242	1.287295014	84.72274228	21.87556417	12.08867918
mavmx3sf	6242	0	0.875071618	0.279764598	0.212277274
mavgdnrd	6242	0.31683283	20.79652902	2.923603231	2.406465994
mavzall2	6242	-1.639973199	15.66536739	2.411000212	2.428618121
mpctsdwk	6242	0	1	0.322380752	0.313979526
martlx	6242	0	32	1.2436719	2.623717365
mavhhinc	6242	8820	192620.2143	69387.38345	25817.82323
mminhinc	6242	0	173258	52292.23086	24914.31517
mmxhhinc	6242	9596	200001	87986.8627	35020.93212
mavopspc	6242	0	186.21125	1.755726285	9.142912992
mavvcspc	6242	0	256.1225	32.27313898	37.17054422
mavgnedb	6240	0.043270306	100.9153765	10.46388228	9.2060145
naffHHRte10	6518	0	1	0.305615219	0.460702855
nethhom	6131	0	1	0.777360953	0.416051842
navintdn	6238	1.024132849	85.13271919	22.20193044	12.18930948
npopdivi	6238	0.023995296	0.713273243	0.367832851	0.144823526
navmx3sf	6238	0	0.878417969	0.261961718	0.205743591
navgdnrd	6238	0.347045082	20.6061305	2.825421409	2.328636245
navzall2	6238	-1.661238512	16.28111571	2.336679759	2.413768894
npctsdwk	6238	0	1	0.333472774	0.30930058
nartlx	6238	0	19	1.106604681	2.046991163
navhhinc	6238	8820	188905.8182	69606.22046	25751.33329
nminhinc	6238	0	173258	52697.29978	24805.75726
nmxhhinc	6238	9596	200001	87722.04665	34718.5867
navopspc	6238	0	140.0380645	1.671134825	8.478049081
navvcspc	6238	0	237.6630769	31.56896379	36.32415027
navgnedb	6236	0.014542762	110.8204155	10.21383852	8.982722544
Origin -- net residential density in grid buffer area (hu/res acre)	6408	0.195313231	25.05555646	2.725560453	2.641435888
Origin -- intersections per square kilometer in grid buffer area	6429	0	86.08801038	22.0503885	13.28503166
Origin -- grid buffer land use mix based on 3 land uses (office, commercial, residential) and built square footage	6429	0	0.999351262	0.222926459	0.265549326
Origin -- Walkability: Sum of Z scores for NRD, Mix3_sfq, Int_km	6429	-1.891471175	16.54649638	2.131625792	2.666866024
OgOpen200	6429	0	269.7	1.155084772	10.29454466
OgVac200	6429	0	655.4	31.83311401	47.33505941
Destination -- net residential density in grid buffer area (hu/res acre)	6408	0.195313231	25.05555646	2.717520861	2.620759617

Destination -- intersections per square kilometer in grid buffer area	6428	0	86.08801038	21.85279707	13.19450178
Destination -- grid buffer land use mix based on 3 land uses (office, commercial, residential) and built square footage	6428	0	0.999002531	0.230482577	0.270332844
Destination -- Walkability: Sum of Z scores for NRD, Mix3_sfq, Int_km	6428	-1.891471175	16.31282009	2.13784626	2.660807174
DgOpen200	6428	0	204.93	1.124485065	9.31476388
DgVac200	6428	0	655.4	32.24037337	48.32617312

Table 7: Elasticity of Walking Probabilities based on changes in Perception and Urban Form Variables

Perception Variables Variable	Factor	Median Value	Increase to Next Category	Elasticity
W- Traffic	**-0.141**	3	4	-0.13151
Q- affordability	-0.107	4	5	-0.10147
Q- ease of walking	**-0.184**	4	5	-0.16806
Q- closeness of job	***-0.119***	3	4	-0.11219
Q- public transportation	***-0.131***	1	2	-0.12278
Q- major roads	**0.482**	4	5	0.61931
Q- shops and services	**-0.264**	4	5	-0.23203
Q- school quality	0.0961	4	5	0.100869
Q- outdoor recreation	**0.182**	4	5	0.199614
Q- low crime	**-0.412**	4	5	-0.33768

Urban Form Measures Variable	Factor	Median Value	Increase to 60th Percentile	Elasticity
NM Route intersection density*	**0.0372**	21.0911	22.8260	0.066666
NM Route fraction w/ sidewalk	**1.67**	0.2639	0.3652	0.184361
NM Route arterials crossed per km	**0.383**	0.0000	0.1411	0.055528
NM Route net residential density	**0.148**	2.0822	2.5449	0.070873
NM Route employment density	***0.0169***	7.6147	8.9757	0.023267
Home buffer retail employment	**0.0011**	84	146	0.070579
School buffer retail employment	**-0.0013**	120	206	-0.10578
School buffer population	**2.40E-04**	2941	3454	0.13102

Note: Coefficients in **bold** are significant at the 5% level
Coefficients in ***bold italic*** are significant at the 10% level

* Coefficient for Non-Motorized Route Intersection Density is for the walking mode choice equation for children age 5 - 10 only.

Appendix 4. Aim 2 Results - Vehicle Emissions

Contained here are a summary of observation selection, data notes, correlation tables, model results and descriptives.

Aim 2 was a person level analysis, where an average trip level amount of emissions (and distance) have been estimated for each youth in the sample. For example, if a person made four trips over the two day survey period (two from home to school, and two from school to home) and the grams for emission “x” for each trip were, respectively 4, 0 (walk trip), 4, 4, then the average trip emission for pollutant x is 3g per trip. (4+0+4+4=12g total. 12g/4 trips = 3 g/trip).

The trips used in determining average trip values of emissions generated and distance traveled were the same as for Aim 1, with the additional requirement that the trip must have a value (zero or more) for emissions and distance. Aim 2’s trip requirements were therefore: made by participants 5 to 18 years old, which went directly from home to school or the reverse, were made by walking, school bus, as a passenger in a motor vehicle or as the driver of a motor vehicle, and for which emissions and distance estimates are present. Trips without emissions/distance estimates were due to an inability to locate a trip end (the school), usually due to insufficient information provided by the participant.

Table 8: List of Variables Included in Correlation Matrix

1. School Route Trip Distance (in miles)
2. Density of Intersections per Sq Km within Origin/Home 200m Grid Buffer
3. Density of Intersections per Sq Km within Destination/School 200m Grid Buffer
4. Mixed Use Index within Origin/Home 200m Grid Buffer
5. Mixed Use Index within Destination/School 200m Grid Buffer
6. Residential Density within Origin/Home 200m Grid Buffer
7. Residential Density within Destination/School 200m Grid Buffer
8. Walk Index Score for Origin/Home 200m Grid Buffer
9. Walk Index Score for Destination/School 200m Grid Buffer
10. Population within Origin/Home 200m Grid Buffer
11. Population within Destination/School 200m Grid Buffer
12. Density of Retail Employment within Origin/Home 200m Grid Buffer
13. Density of Retail Employment within Destination/School 200m Grid Buffer
14. Density of Non Retail Employment within Origin/Home 200m Grid Buffer
15. Density of Non Retail Employment within Destination/School 200m Grid Buffer
16. Open Space within Origin/Home 200m Grid Buffer
17. Open Space within Destination/School 200m Grid Buffer
18. Vacant Space within Origin/Home 200m Grid Buffer
19. Vacant Space within Destination/School 200m Grid Buffer
20. Is household affluent w/r/t route to school - Motorized (1 = Yes, 0 = No)
21. Household self identifies as member of majority ethnic group for the census block groups along route to school (1 = Yes, 0 = No) - Motorized Route
22. Population Diversity Index Score - Motorized Route
23. Average Intersection Density along School Route - Motorized
24. Average Mixed Use Index along School Route - Motorized
25. Average Residential Density along School Route - Motorized
26. Average Walk Index Score along School Route - Motorized
27. Pct of Route with Sidewalks Available - Motorized
28. Number of Arterial Streets Crossed along School Route - Motorized
29. Average of Household Median Income for Block Groups along School Route - Motorized
30. Minimum of Household Median Income for Block Groups along School Route - Motorized
31. Maximum of Household Median Income for Block Groups along School Route - Motorized
32. Average Open Space along School Route - Motorized
33. Average Vacant Space along School Route - Motorized
34. Average Employment Density along School Route - Motorized
35. Is household affluent w/r/t route to school - Non-Motorized (1 = Yes, 0 = No)
36. Household self identifies as member of majority ethnic group for the census block groups along route to school (1 = Yes, 0 = No) - Non-Motorized Route
37. Population Diversity Index Score - Non-Motorized Route
38. Average Intersection Density along School Route - Non-Motorized
39. Average Mixed Use Index along School Route - Non-Motorized
40. Average Residential Density along School Route - Non-Motorized
41. Average Walk Index Score along School Route - Non-Motorized
42. Pct of Route with Sidewalks Available - Non-Motorized
43. Number of Arterial Streets Crossed along School Route - Non-Motorized
44. Average of Household Median Income for Block Groups along School Route - Non-Motorized
45. Minimum of Household Median Income for Block Groups along School Route - Non-Motorized
46. Maximum of Household Median Income for Block Groups along School Route - Non-Motorized
47. Average Open Space along School Route - Non-Motorized
48. Average Vacant Space along School Route - Non-Motorized
49. Average Employment Density along School Route - Non-Motorized
50. Dummy Variable for School Bus Availability from Home (1 = Yes, 0 = No)

Table 9: Correlation Matrix for Urban Form Variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1.	1											
2.	-0.1919	1										
3.	-0.1663	0.5713	1									
4.	-0.0467	0.2244	0.1604	1								
5.	-0.0222	0.1548	0.2251	0.1426	1							
6.	-0.1109	0.5282	0.3994	0.4256	0.1929	1						
7.	-0.0977	0.4116	0.518	0.2158	0.4197	0.4629	1					
8.	-0.1574	0.7926	0.5052	0.6845	0.211	0.8337	0.4751	1				
9.	-0.1296	0.5077	0.7896	0.2233	0.6903	0.4594	0.8244	0.5237	1			
10.	-0.0365	0.0555	-0.0225	-0.0917	0.0188	0.0489	-0.0132	0.0099	-0.0085	1		
11.	-0.0288	-0.0194	0.0539	0.0229	-0.1015	-0.009	0.0521	-0.0039	0.0052	0.2317	1	
12.	-0.0316	0.1162	0.0943	0.2224	0.0305	0.1889	0.0614	0.2228	0.0833	0.1226	0.0431	1
13.	-0.0192	0.0787	0.1085	0.0309	0.2108	0.05	0.1738	0.0711	0.2094	0.0574	0.1138	0.1431
14.	-0.018	0.1138	0.1198	0.2906	0.1032	0.2388	0.1314	0.2692	0.1536	0.0312	0.0432	0.2916
15.	-0.0022	0.112	0.1084	0.0825	0.2896	0.1232	0.2283	0.1378	0.2635	0.0593	0.0156	0.0874
16.	0.0294	-0.0562	-0.0523	-0.0208	-0.0174	-0.0264	-0.0239	-0.0465	-0.0423	0.0013	-0.0186	-0.0241
17.	0.0277	-0.0449	-0.0569	-0.0413	-0.0139	-0.0242	-0.0298	-0.0483	-0.0455	-0.0031	-0.0019	-0.0081
18.	0.1076	-0.1714	-0.0503	0.0163	-0.0031	-0.0147	0.0514	-0.0831	-0.0056	-0.0827	0.0049	-0.1006
19.	0.0836	-0.0558	-0.1722	-0.0031	0.0169	0.0462	-0.0198	-0.0098	-0.0855	0.0086	-0.0539	-0.0403
20.	0.1489	-0.0649	-0.0428	0.0062	0.0246	-0.033	-0.0143	-0.0426	-0.0165	-0.0151	-0.0229	-0.0013
21.	-0.0024	-0.1159	-0.1171	-0.0487	-0.0487	-0.0825	-0.0816	-0.1096	-0.11	-0.0304	-0.0392	-0.0073
22.	0.1319	0.2317	0.2472	0.1966	0.2043	0.2151	0.2249	0.2794	0.295	0.0343	0.0347	0.0435
23.	-0.277	0.818	0.8043	0.2142	0.2079	0.4978	0.4979	0.6873	0.6784	-0.0163	-0.0194	0.1379
24.	0.1145	0.2488	0.2503	0.5557	0.5659	0.3564	0.3637	0.4895	0.501	-0.0524	-0.0647	0.1665
25.	-0.0288	0.5596	0.5443	0.339	0.3249	0.7485	0.7432	0.7125	0.6963	0.0145	0.0147	0.1505
26.	-0.1115	0.7151	0.7027	0.4338	0.4285	0.6669	0.6673	0.7937	0.7868	-0.0208	-0.0265	0.1859
27.	-0.2997	0.4755	0.4587	0.1434	0.1348	0.3329	0.334	0.4247	0.4134	0.0208	0.0091	0.1473
28.	0.6266	0.0214	0.029	0.0376	0.0612	0.0214	0.0262	0.0342	0.0499	0.0085	0.0017	-0.0076
29.	-0.0296	-0.1433	-0.1578	-0.2386	-0.2253	-0.2327	-0.2461	-0.2602	-0.2683	-0.0498	-0.0632	0.063
30.	-0.2162	-0.2654	-0.2718	-0.2802	-0.2843	-0.347	-0.3561	-0.3828	-0.3922	0.0191	0.0124	0.0235
31.	0.1812	-0.0068	-0.0236	-0.1452	-0.1201	-0.0737	-0.0832	-0.0916	-0.0942	-0.0916	-0.1097	0.091
32.	0.0795	-0.0907	-0.0923	-0.0252	-0.0361	-0.0528	-0.0522	-0.0758	-0.081	0.0173	0.0166	-0.0351
33.	0.1225	-0.1574	-0.1546	-0.0034	-0.0016	-0.0161	-0.0198	-0.0848	-0.0844	-0.0544	-0.0338	-0.0933
34.	-0.0483	0.3795	0.3626	0.1689	0.1709	0.3805	0.3678	0.4073	0.3946	-0.0226	-0.0292	0.1515
35.	0.1764	-0.0658	-0.0462	0.0024	0.0221	-0.0428	-0.0279	-0.0485	-0.0247	-0.0039	-0.0159	-0.019
36.	-0.0139	-0.1139	-0.1099	-0.0673	-0.0671	-0.1121	-0.1083	-0.1281	-0.1247	-0.0139	-0.0157	-0.0141
37.	0.122	0.2301	0.2438	0.1933	0.1993	0.2102	0.2189	0.2753	0.2889	0.0423	0.0417	0.0418
38.	-0.2185	0.8252	0.8121	0.2272	0.2191	0.5104	0.5113	0.7011	0.6922	-0.0196	-0.0218	0.1386
39.	0.0697	0.2434	0.2461	0.5612	0.5692	0.3501	0.3584	0.4865	0.4983	-0.0602	-0.068	0.1641
40.	-0.0711	0.5733	0.5605	0.3382	0.3214	0.7594	0.7552	0.7233	0.7076	0.0085	0.0075	0.1502
41.	-0.1148	0.7214	0.7108	0.4362	0.4283	0.6689	0.6705	0.7986	0.792	-0.0272	-0.0313	0.1836
42.	-0.1989	0.5176	0.4925	0.1769	0.1696	0.385	0.3819	0.4799	0.4634	0.0038	-0.0072	0.1703
43.	0.6419	-0.0057	-0.0065	0.0215	0.0544	-0.0202	-0.0072	-0.0023	0.0164	0.009	0.0006	-0.0159
44.	-0.024	-0.1377	-0.1534	-0.2323	-0.2181	-0.2256	-0.2371	-0.252	-0.2595	-0.0542	-0.068	0.0653
45.	-0.2054	-0.259	-0.2666	-0.2777	-0.2797	-0.3469	-0.3584	-0.3786	-0.3887	0.0139	0.0067	0.0219
46.	0.19	-0.0059	-0.0215	-0.1413	-0.115	-0.0749	-0.0836	-0.0901	-0.0912	-0.0927	-0.1087	0.0912
47.	0.1071	-0.0876	-0.0897	-0.0255	-0.0341	-0.054	-0.0533	-0.0749	-0.0793	0.022	0.0186	-0.0297
48.	0.1005	-0.1569	-0.1558	-0.0081	-0.0062	-0.0196	-0.0227	-0.0879	-0.0881	-0.0508	-0.0329	-0.0904
49.	-0.0735	0.3764	0.3654	0.1684	0.1663	0.3736	0.3689	0.4028	0.3945	-0.0191	-0.0243	0.1483
50.	0.3918	-0.1937	-0.1999	-0.1059	-0.0902	-0.1637	-0.1683	-0.2035	-0.2022	-0.0632	-0.0568	-0.0439

Correlation Matrix for Urban Form Variables (cont'd)

	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.
1.												
2.												
3.												
4.												
5.												
6.												
7.												
8.												
9.												
10.												
11.												
12.												
13.	1											
14.	0.0781	1										
15.	0.2704	0.1589	1									
16.	-0.0107	-0.0243	-0.0282	1								
17.	-0.0266	-0.0252	-0.0231	0.0194	1							
18.	-0.0407	-0.0124	-0.0334	-0.0179	-0.0026	1						
19.	-0.0826	-0.0233	-0.0112	-0.0037	-0.0137	0.3632	1					
20.	0.0221	0.0441	0.0438	0.0277	0.0195	0.0463	0.0489	1				
21.	-0.0056	-0.009	0.0025	-0.0096	0.0217	0.0513	0.0414	0.1091	1			
22.	0.0298	0.1553	0.1584	-0.0219	-0.0168	-0.008	-0.0193	0.0948	-0.3451	1		
23.	0.1234	0.128	0.1172	-0.0647	-0.0647	-0.1224	-0.1271	-0.0497	-0.1265	0.2606	1	
24.	0.1622	0.2571	0.2527	-0.026	-0.0278	-0.0028	0.0064	0.0486	-0.0804	0.361	0.2797	1
25.	0.1316	0.2065	0.1974	-0.027	-0.0234	-0.0061	-0.0034	0.0093	-0.1128	0.3105	0.6195	0.4914
26.	0.1697	0.2342	0.2236	-0.0514	-0.0506	-0.065	-0.0631	-0.0048	-0.1357	0.3767	0.8409	0.6806
27.	0.1385	0.1438	0.1415	-0.0583	-0.0622	-0.1465	-0.1469	-0.0802	-0.0399	0.0085	0.5641	0.1491
28.	0.0041	0.0192	0.0284	-0.0304	-0.0175	0.0116	0.0081	0.0673	-0.1098	0.2974	-0.0284	0.2327
29.	0.0658	-0.0255	-0.0258	-0.0311	-0.0381	-0.0883	-0.0844	-0.1808	0.1588	-0.3849	-0.1577	-0.3238
30.	0.0251	-0.0965	-0.102	-0.0066	-0.0182	-0.0523	-0.0521	-0.1661	0.152	-0.4445	-0.2878	-0.4771
31.	0.0906	0.0658	0.0799	-0.0431	-0.0454	-0.1075	-0.1019	-0.1169	0.0927	-0.1686	-0.0095	-0.072
32.	-0.0241	-0.0345	-0.0338	0.377	0.5159	-0.0369	-0.0344	0.0142	0.0524	-0.0335	-0.1119	-0.0495
33.	-0.0862	-0.0309	-0.034	-0.003	0.0023	0.6535	0.664	0.1002	0.0536	0.0002	-0.2052	0.0186
34.	0.1519	0.2706	0.2823	-0.0471	-0.0465	-0.1168	-0.109	-0.0145	0.0019	0.0878	0.4093	0.2939
35.	0.0078	0.0484	0.0511	0.0331	0.0231	0.0796	0.0798	0.9195	0.0853	0.1025	-0.0668	0.0404
36.	-0.0118	-0.0157	-0.005	-0.0086	0.0228	0.0426	0.0311	0.1202	0.9458	-0.3584	-0.1252	-0.1085
37.	0.0268	0.1503	0.1528	-0.0224	-0.0165	-0.0032	-0.0115	0.0873	-0.3516	0.9828	0.2572	0.3476
38.	0.1247	0.13	0.1165	-0.0628	-0.062	-0.1152	-0.1187	-0.0416	-0.1364	0.2868	0.9852	0.3107
39.	0.1613	0.2595	0.2539	-0.0199	-0.0211	-0.0136	-0.0038	0.0283	-0.081	0.3285	0.2844	0.9523
40.	0.1343	0.1987	0.1906	-0.0241	-0.0204	-0.0004	-0.0002	-0.0057	-0.1104	0.2865	0.6408	0.4605
41.	0.1695	0.2302	0.2183	-0.0474	-0.0461	-0.064	-0.0624	-0.0136	-0.1394	0.3668	0.8427	0.6585
42.	0.1559	0.176	0.1654	-0.0592	-0.0635	-0.1332	-0.1338	-0.0819	-0.0511	0.0536	0.5978	0.211
43.	0.0009	0.0156	0.0288	-0.0255	-0.0082	0.0524	0.042	0.0902	-0.0844	0.2764	-0.0553	0.1824
44.	0.0707	-0.0195	-0.0196	-0.0324	-0.0403	-0.0906	-0.0873	-0.1663	0.1628	-0.3733	-0.1544	-0.3133
45.	0.0268	-0.0996	-0.1052	-0.008	-0.021	-0.0565	-0.0563	-0.1585	0.1477	-0.4357	-0.2818	-0.4668
46.	0.0908	0.0671	0.0806	-0.0427	-0.0425	-0.1069	-0.1005	-0.1089	0.099	-0.1643	-0.0125	-0.0726
47.	-0.0176	-0.0361	-0.0349	0.3851	0.4786	-0.041	-0.0378	0.026	0.0551	-0.0259	-0.1128	-0.0423
48.	-0.0823	-0.0344	-0.0358	0.0007	0.0064	0.6566	0.667	0.0904	0.0629	-0.0206	-0.201	0.0037
49.	0.1507	0.2736	0.2829	-0.0492	-0.0481	-0.118	-0.1114	-0.0123	-0.0026	0.0802	0.4078	0.2713
50.	-0.0245	-0.0218	-0.0068	0.0132	0.0128	-0.0042	-0.0003	0.0375	0.067	0.0093	-0.2321	0.0068

Correlation Matrix for Urban Form Variables

	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.
1.												
2.												
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17.												
18.												
19.												
20.												
21.												
22.												
23.												
24.												
25.	1											
26.	0.8729	1										
27.	0.3939	0.489	1									
28.	0.1312	0.1168	-0.1518	1								
29.	-0.2536	-0.2908	0.0551	-0.1334	1							
30.	-0.467	-0.4928	-0.0469	-0.32	0.8005	1						
31.	0.0301	-0.018	0.1083	0.1236	0.839	0.4411	1					
32.	-0.0681	-0.0986	-0.1138	-0.037	-0.0687	-0.0247	-0.0891	1				
33.	-0.024	-0.1064	-0.2037	0.0318	-0.1159	-0.0691	-0.1295	-0.0414	1			
34.	0.5431	0.5203	0.3632	0.0764	0.2585	-0.0439	0.4464	-0.097	-0.1435	1		
35.	-0.0248	-0.0296	-0.0979	0.064	-0.1816	-0.1645	-0.1369	0.0198	0.1106	-0.0691	1	
36.	-0.1276	-0.1505	-0.0348	-0.1178	0.1688	0.1662	0.0979	0.0481	0.0484	0.0025	0.1022	1
37.	0.2935	0.3637	0.0063	0.2848	-0.3845	-0.4349	-0.1827	-0.0356	0.0037	0.0803	0.1067	-0.3638
38.	0.6351	0.8501	0.5358	0.0353	-0.185	-0.3226	-0.0152	-0.109	-0.1898	0.4166	-0.0575	-0.137
39.	0.46	0.6543	0.1658	0.1842	-0.3149	-0.4507	-0.0895	-0.0429	0.0001	0.2742	0.0273	-0.11
40.	0.9739	0.8629	0.4161	0.0975	-0.2596	-0.453	0.0037	-0.0679	-0.0359	0.5286	-0.026	-0.1244
41.	0.8514	0.9848	0.4878	0.1176	-0.3006	-0.4907	-0.0368	-0.0948	-0.1106	0.5073	-0.0299	-0.1548
42.	0.4767	0.5597	0.906	-0.0267	0.016	-0.1228	0.1325	-0.1119	-0.1941	0.4144	-0.1085	-0.0539
43.	0.097	0.0723	-0.1276	0.77	-0.0824	-0.2678	0.147	-0.019	0.0455	0.0678	0.1078	-0.0951
44.	-0.242	-0.281	0.0524	-0.1242	0.9875	0.7934	0.8389	-0.0663	-0.1156	0.262	-0.1855	0.1693
45.	-0.4594	-0.4833	-0.0486	-0.3081	0.7964	0.9831	0.4477	-0.027	-0.0698	-0.0388	-0.1646	0.1576
46.	0.0267	-0.021	0.0991	0.1315	0.8339	0.443	0.9878	-0.0856	-0.1269	0.4459	-0.1319	0.1055
47.	-0.0674	-0.0962	-0.1205	-0.0224	-0.0691	-0.0281	-0.0856	0.9128	-0.0391	-0.1043	0.0318	0.0488
48.	-0.024	-0.1094	-0.1959	0.0146	-0.1058	-0.0644	-0.1246	-0.0405	0.9838	-0.1397	0.1015	0.0551
49.	0.5164	0.5014	0.3733	0.0491	0.247	-0.0262	0.4143	-0.099	-0.1484	0.9657	-0.0622	0.0028
50.	-0.1351	-0.1674	-0.2498	0.2381	0.1119	-0.047	0.2356	0.0283	0.0095	-0.0319	0.0609	0.0529

Correlation Matrix for Urban Form Variables

	37.	38.	39.	40.	41.	42.	43.	44.	45.	46.	47.	48.
1.												
2.												
3.												
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29.												
30.												
31.												
32.												
33.												
34.												
35.												
36.												
37.	1											
38.	0.2845	1										
39.	0.3266	0.3061	1									
40.	0.2834	0.6537	0.4591	1								
41.	0.3638	0.8625	0.6719	0.8705	1							
42.	0.0445	0.5947	0.2203	0.4901	0.5647	1						
43.	0.2699	-0.0124	0.1552	0.072	0.0734	-0.0479	1					
44.	-0.3865	-0.1816	-0.3149	-0.2538	-0.2967	0.0212	-0.0805	1				
45.	-0.4375	-0.3162	-0.4464	-0.4519	-0.4856	-0.1285	-0.2586	0.7996	1			
46.	-0.1794	-0.0174	-0.0915	0.0007	-0.0398	0.1352	0.1522	0.8437	0.4477	1		
47.	-0.029	-0.1107	-0.0331	-0.0643	-0.0907	-0.1184	0.0028	-0.0641	-0.0309	-0.0781	1	
48.	-0.0172	-0.192	-0.004	-0.0377	-0.1138	-0.1925	0.0351	-0.1076	-0.0629	-0.1225	-0.039	1
49.	0.0691	0.4134	0.2712	0.522	0.5022	0.4111	0.0563	0.2592	-0.0169	0.4184	-0.1077	-0.1483
50.	0.0029	-0.2134	-0.0287	-0.1607	-0.18	-0.241	0.2282	0.1189	-0.0377	0.2349	0.0287	0.0023

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50.	-0.0404	1

Table 10: Average Total Emissions Per Person - Home and School Buffer Measures[23]

	Avg. Distance Model**		CO_2 Model		HC Model		NOx Model	
Explanatory Variable	Coef.	T	Coef.	T	Coef.	T	Coef.	T
Student Age	**0.0703**	**2.16**	***16.7267***	***1.68***	**0.0309**	**3.18**	**0.0485**	**2.47**
Gender (1 = Male, 0 = Female	0.0603	0.27	-11.6115	-0.17	0.0322	0.49	0.0591	0.44
Size of Household	-0.1148	-1.01	**-256.4623**	**-7.39**	**-0.2099**	**-6.23**	**-0.5438**	**-7.94**
Household Income between $30,000 and $49,999	**1.1148**	**2.80**	178.9865	1.47	0.1740	1.47	0.1518	0.63
Household Income between $50,000 and $74,999	**1.0575**	**2.55**	**255.1976**	**2.00**	0.0346	0.28	-0.0462	-0.18
Household Income between $75,000 and $99,999	**1.5080**	**3.45**	**473.0532**	**3.53**	0.1024	0.79	0.2940	1.11
Household Income $100,000 and higher	**2.0378**	**4.55**	**480.8583**	**3.50**	0.1587	1.19	0.1628	0.60
Total Number of Vehicles in Household	0.1917	1.30	67.3830	1.49	**0.1580**	**3.61**	**0.3092**	**3.47**
Number of Drivers in Household	-0.2027	-0.94	**270.7970**	**4.10**	***0.1253***	***1.95***	**0.5810**	**4.46**
Dummy Variable for Ethnicity of Household (1 = White, 0 = Non-White)	**-0.5217**	**-1.88**	**-144.7633**	**-1.70**	-0.0636	-0.77	-0.1118	-0.67
Assessment of Neighborhood Walkability (1 = Poor - 5 = Excellent)	0.1398	1.58	3.6163	0.13	0.0129	0.49	0.0294	0.55
Assessment of Neighborhood Proximity to Transit (1 = Poor - 5 = Excellent)	-0.0278	-0.31	41.7143	1.51	0.0290	1.08	**0.1223**	**2.25**
Assessment of Neighborhood Proximity to Maj. Roads (1 = Poor - 5 = Excellent)	0.0346	0.32	***54.2854***	***1.66***	**-0.0653**	**-2.06**	-0.0295	-0.46
Assessment of Neighborhood Quality of Local Schools (1 = Poor - 5 = Excellent)	**-0.8856**	**-8.64**	**-278.5891**	**-8.86**	**-0.1361**	**-4.46**	**-0.4002**	**-6.45**
Assessment of Neighborhood Proximity to Parks & Rec. (1 = Poor - 5 = Excellent)	***-0.1782***	***-1.68***	14.6035	0.45	0.0003	0.01	0.0563	0.88
Assessment of Neighborhood Crime Prevalence (1 = Poor - 5 = Excellent)	***0.2340***	***1.77***	14.4702	0.36	0.0196	0.50	-0.0317	-0.40
Influence of Traffic on Willingness to Walk (1 = Not Important - 5 = Very Important)	0.1120	1.37	33.8339	1.35	0.0110	0.45	0.0355	0.72
Influence of Crime on Willingness to Walk (1 = Not Important - 5 = Very Important)	-0.1197	-1.50	-36.1338	-1.47	***-0.0418***	***-1.76***	***-0.0899***	***-1.86***
Influence of Sidewalks on Willingness to Walk (1 = Not Important - 5 = Very Important)	***-0.1149***	***-1.73***	-28.6951	-1.41	**-0.0634**	**-3.21**	**-0.0967**	**-2.41**
Density of Intersections per Sq Km within Home 200m Grid Buffer	**-0.0536**	**-4.22**	**-7.7860**	**-2.00**	**-0.0106**	**-2.81**	**-0.0152**	**-1.98**
Density of Intersections per Sq Km within School 200m Grid Buffer	0.0164	1.35	**9.4075**	**2.52**	0.0007	0.20	0.0077	1.04
Mixed Use Index within Home 200m Grid Buffer	-0.0899	-0.15	16.4722	0.09	0.0506	0.29	-0.0139	-0.04
Mixed Use Index within School 200m Grid Buffer	**0.9997**	**2.26**	**429.1087**	**3.17**	0.0638	0.48	**0.9630**	**3.60**
Residential Density within Home 200m Grid Buffer	0.0108	0.16	-16.9116	-0.80	0.0011	0.05	-0.0202	-0.49
Residential Density within School 200m Grid Buffer	-0.0389	-0.67	-5.7555	-0.32	-0.0068	-0.39	-0.0163	-0.47
Population within Home 200m Grid Buffer	0.0001	1.34	-0.0084	-0.48	1.79E-05	1.05	1.08E-05	0.31
Population within School 200m Grid Buffer	***-0.0001***	***-1.92***	-0.0259	-1.31	-2.16E-05	-1.12	-5.27E-05	-1.35
Density of Retail Employment within Home 200m Grid Buffer	-0.0005	-1.15	0.0113	0.09	-0.0002	-1.44	-0.0002	-0.63
Density of Retail Employment within School 200m Grid Buffer	0.0001	0.35	-0.1177	-1.03	-6.67E-05	-0.60	-0.0003	-1.18
Density of Non Retail Employment within Home 200m Grid Buffer	-6.65E-06	-0.07	-0.0201	-0.70	9.46E-06	0.34	-3.09E-05	-0.54
Density of Non Retail Employment within School 200m Grid Buffer	-5.52E-05	-0.68	0.0013	0.05	1.06E-05	0.44	3.36E-05	0.68
Vacant Space within Home 200m Grid Buffer	-0.0015	-0.58	0.0142	0.02	-0.0003	-0.32	0.0008	0.50
Vacant Space within School 200m Grid Buffer	**0.0110**	**4.43**	**2.3345**	**3.05**	**0.0021**	**2.83**	***0.0029***	***1.94***
Dummy Variable for School Bus Availability from Home (1 = Yes, 0 = No)	**4.1702**	**14.39**	**796.4788**	**8.96**	**1.0984**	**12.73**	**1.9353**	**11.04**
Regression Constant	**4.4371**	**4.13**	**1126.7000**	**3.42**	**1.8483**	**5.78**	**2.7004**	**4.16**
Number of Observations		1579		1579		1579		1579
Adjusted R^2		0.2402		0.2004		0.2171		0.2252

Note: Coefficients in **bold** are significant at the 5% level
Coefficients in ***bold italic*** are significant at the 10% level

** Distances to School predicted from this model had adjusted R2 .1567 for predicting Avg. CO_2 emissions, .1889 for predicting Avg HC Emissions, and .1705 for predicting Avg NOx for all school trips in bivariate regression models

[23] Note: Vehicle ownership and the dummy coded (yes=1 or no=0) household income variables were found to be correlated below the standard |r|≥.7000 threshold.

Table 11: Average Total Emissions Per Person - School Route Buffer Measures[24]

	Avg. Distance Model**		CO2 Model		HC Model		NOx Model	
Explanatory Variable	Coef.	T	Coef.	T	Coef.	T	Coef.	T
Student Age	***0.0563***	***1.78***	12.7467	1.28	**0.0282**	**2.97**	**0.0460**	**2.40**
Gender (1 = Male, 0 = Female	0.0850	0.40	7.0215	0.10	0.0247	0.38	0.0521	0.40
Size of Household	-0.1670	-1.52	**-269.2149**	**-7.79**	**-0.2190**	**-6.64**	**-0.5650**	**-8.48**
Household Income between $30,000 and $49,999	**1.1794**	**3.07**	***227.0788***	***1.88***	0.1571	1.36	0.1872	0.80
Household Income between $50,000 and $74,999	**1.0172**	**2.53**	**281.3065**	**2.22**	0.0046	0.04	-0.0447	-0.18
Household Income between $75,000 and $99,999	**1.6101**	**3.81**	**539.7074**	**4.06**	0.0784	0.62	0.3413	1.33
Household Income $100,000 and higher	**2.1864**	**5.05**	**535.7291**	**3.93**	0.1788	1.37	0.2613	0.99
Total Number of Vehicles in Household	0.1093	0.77	37.9611	0.85	**0.1435**	**3.36**	**0.2679**	**3.11**
Number of Drivers in Household	0.0333	0.16	**324.2438**	**4.92**	**0.1759**	**2.80**	**0.6891**	**5.42**
Dummy Variable for Ethnicity of Household (1 = White, 0 = Non-White)	-0.1207	-0.45	-10.7485	-0.13	0.0104	0.13	0.0951	0.59
Assessment of Neighborhood Walkability (1 = Poor - 5 = Excellent)	***0.1652***	***1.92***	9.9163	0.37	0.0136	0.53	0.0259	0.50
Assessment of Neighborhood Proximity to Transit (1 = Poor - 5 = Excellent)	-0.0276	-0.31	42.8850	1.53	0.0331	1.24	**0.1292**	**2.40**
Assessment of Neighborhood Proximity to Maj. Roads (1 = Poor - 5 = Excellent)	***-0.1874***	***-1.80***	1.5499	0.05	**-0.1098**	**-3.50**	***-0.1220***	***-1.93***
Assessment of Neighborhood Quality of Local Schools (1 = Poor - 5 = Excellent)	**-0.7011**	**-7.03**	**-229.7157**	**-7.32**	**-0.0997**	**-3.32**	**-0.3144**	**-5.19**
Assessment of Neighborhood Proximity to Parks & Rec. (1 = Poor - 5 = Excellent)	-0.1416	-1.38	16.0658	0.50	0.0077	0.25	0.0719	1.15
Assessment of Neighborhood Crime Prevalence (1 = Poor - 5 = Excellent)	***0.2541***	***1.96***	19.6427	0.48	0.0266	0.68	-0.0173	-0.22
Influence of Traffic on Willingness to Walk (1 = Not Important - 5 = Very Important)	0.1258	1.59	37.9019	1.52	0.0111	0.47	0.0460	0.96
Influence of Crime on Willingness to Walk (1 = Not Important - 5 = Very Important)	-0.1230	-1.58	-38.2663	-1.57	-0.0369	-1.58	***-0.0871***	***-1.85***
Influence of Sidewalks on Willingness to Walk (1 = Not Important - 5 = Very Important)	-0.1039	-1.62	***-35.6460***	***-1.76***	**-0.0574**	**-2.97**	**-0.1016**	**-2.60**
Average Intersection Density along School Route	**-0.0881**	**-6.15**	**-12.1761**	**-2.70**	**-0.0208**	**-4.81**	**-0.0361**	**-4.15**
Average Mixed Use Index along School Route	**3.3910**	**5.62**	**941.0798**	**4.95**	**0.6628**	**3.65**	**1.7384**	**4.74**
Average Residential Density along School Route	**0.3732**	**4.81**	**82.3849**	**3.38**	**0.0825**	**3.54**	**0.1785**	**3.79**
Average Employment Density along School Route	-0.0067	-0.44	-3.3941	-0.70	-0.0035	-0.75	-0.0095	-1.01
Average Vacant Space along School Route	***0.0054***	***1.81***	1.1779	1.25	0.0015	1.61	0.0014	0.76
Pct of School Route with Sidewalks Available	**-2.7667**	**-6.32**	**-571.6082**	**-4.15**	**-0.5583**	**-4.24**	**-1.0710**	**-4.03**
Number of Arterial Streets Crossed per Mile of School Route	-0.1262	-0.73	27.8738	0.52	-0.0496	-0.96	0.0209	0.20
Dummy Variable for School Bus Availability from Home (1 = Yes, 0 = No)	**3.5816**	**12.52**	**657.5187**	**7.30**	**0.9837**	**11.44**	**1.6753**	**9.65**
Regression Constant	**4.5338**	**4.57**	**1068.2170**	**3.42**	**1.8577**	**6.22**	**2.6516**	**4.40**
Number of Observations		1595		1595		1595		1595
Adjusted R^2		0.2963		0.2195		0.2528		0.2554

Note: Coefficients in **bold** are significant at the 5% level
Coefficients in ***bold italic*** are significant at the 10% level

** Distances to School predicted from this model had adjusted R2 .1774 for predicting Avg. CO2 emissions, .2232 for predicting Avg HC Emissions, and .2014 for predicting Avg NOx for all school trips in bivariate regression models

[24] Note: Vehicle ownership and the dummy coded (yes=1 or no=0) household income variables were found to be correlated below the standard |r|≥.7000 threshold.

Table 12. Elasticity of School Trip Distance and Emissions, Based on Select Neighborhood Design Measures

Urban Form Variable	Median Value	Increase to 60th Percentile	Avg. Distance To School E(*Miles to School*) @ Median	E(*Miles to School*) @ 60th %	%ΔE/%Δx
Density of Intersections per Sq Km within Home 200m Grid Buffer	21.44026	23.90801	5.4068	5.2745	-0.2125
Vacant Space within School 200m Grid Buffer	12.04	24.11	5.1485196	5.2818007	0.0258
Average Intersection Density along School Route	20.56502	22.58348	5.5097081	5.3318155	-0.3290
Pct of School Route with Sidewalks Available	0.2313894	0.3356988	5.6646064	5.3760122	-0.1130

Urban Form Variable	Median Value	Increase to 60th Percentile	CO2 Emissions E(*CO2 Emissions*) @ Median Val.	E(*CO2 Emissions*) @ 60th %	%ΔE/%Δx
Density of Intersections per Sq Km within Home 200m Grid Buffer	21.44026	23.90801	1032.4856	1013.2716	-0.1617
Vacant Space within School 200m Grid Buffer	12.04	24.11	980.33953	1008.5175	0.0287
Average Intersection Density along School Route	20.56502	22.58348	1049.8354	1025.2584	-0.2385
Pct of School Route with Sidewalks Available	0.2313894	0.3356988	1086.8935	1027.2694	-0.1217

Urban Form Variable	Median Value	Increase to 60th Percentile	HC Emissions E(*HC Emissions*) @ Median	E(*HC Emissions*) @ 60th %	%ΔE/%Δx
Density of Intersections per Sq Km within Home 200m Grid Buffer	21.44026	23.90801	1.8377096	1.8114754	-0.1240
Vacant Space within School 200m Grid Buffer	12.04	24.11	1.7883574	1.8136645	0.0141
Average Intersection Density along School Route	20.56502	22.58348	1.8627249	1.8208408	-0.2291
Pct of School Route with Sidewalks Available	0.2313894	0.3356988	1.8914945	1.8332606	-0.0683

Urban Form Variable	Median Value	Increase to 60th Percentile	NOx Emissions E(*NOx Emissions*) @ Median	E(*NOx Emissions*) @ 60th %	%ΔE/%Δx
Density of Intersections per Sq Km within Home 200m Grid Buffer	21.44026	23.90801	2.7155011	2.6779273	-0.1202
Vacant Space within School 200m Grid Buffer	12.04	24.11	2.6465141	2.681737	0.0133
Average Intersection Density along School Route	20.56502	22.58348	2.7531277	2.6802974	-0.2695
Pct of School Route with Sidewalks Available	0.2313894	0.3356988	2.8114389	2.699727	-0.0881

This table answers how much of a percentage change in trip distance and emissions we can expect for a given change from the median of neighborhood design variables, focusing on those that are the most consistently significant. As in Aim 1, the increment of change was from the median value to the 60th percentile, listed in the first two columns of Table 10. Those two values were used to calculate the expected value of the outcome (either distance or emissions), holding all other model inputs constant at their average values. The expected values are denoted with an "E" preceding each outcome, in the third and fourth column of the table. Taking the ratio of percentage changes in expected outcome values to percentage changes in neighborhood design values generated an elasticity estimate (the last column of Table 10, under the heading %ΔE/%Δx) which was relevant over this limited range of values for the specified neighborhood design element. This elasticity estimate clarifies the relationship between small percentage changes in urban form and resulting changes in environmental outcomes.

Table 13: Aim 2 Sample Descriptives

Variable	N (people)	Mean	Std. Dev.	Min	Max
Average Trip Distance to School (in Miles)	2053	5.476625	5.307692	0.059	45.4525
Student Age	2053	11.27228	3.7233	5	18
Size of Household	2053	4.069167	1.067456	2	8
Total Number of Vehicles in Household	2053	2.198246	1.030319	0	7
Number of Drivers in Household	2053	2.010229	0.766878	0	5
Assessment of Neighborhood Walkability (1 = Poor - 5 = Excellent)	1816	3.587555	1.40092	1	5
Assessment of Neighborhood Proximity to Transit (1 = Poor - 5 = Excellent)	1777	2.386607	1.599444	1	5
Assessment of Neighborhood Proximity to Maj. Roads (1 = Poor - 5 = Excellent)	1819	3.868609	1.164566	1	5
Assessment of Neighborhood Quality of Local Schools (1 = Poor - 5 = Excellent)	1805	3.956787	1.252631	1	5
Assessment of Neighborhood Proximity to Parks & Rec. (1 = Poor - 5 = Excellent)	1801	3.694059	1.228465	1	5
Assessment of Neighborhood Crime Prevalence (1 = Poor - 5 = Excellent)	1732	4.042148	0.979844	1	5
Influence of Traffic on Willingness to Walk (1 = Not Important - 5 = Very Important)	1911	2.903192	1.68689	1	5
Influence of Crime on Willingness to Walk (1 = Not Important - 5 = Very Important)	1901	2.685955	1.691389	1	5
Influence of Sidewalks on Willingness to Walk (1 = Not Important - 5 = Very Important)	1902	3.059411	1.73346	1	5
Density of Intersections per Sq Km within Home 200m Grid Buffer	2053	22.48517	13.15487	0	86.08801
Density of Intersections per Sq Km within School 200m Grid Buffer	2038	21.51346	13.39308	0	83.01509
Mixed Use Index within Home 200m Grid Buffer	2053	0.1899881	0.247322	0	0.999351
Mixed Use Index within School 200m Grid Buffer	2038	0.2637425	0.278069	0	0.999003
Residential Density within Home 200m Grid Buffer	2047	2.837727	2.687795	0.195313	21.95114
Residential Density within School 200m Grid Buffer	2028	2.71259	2.709248	0.202571	25.05556
Population within Home 200m Grid Buffer	2053	3738.146	2093.728	86	12291
Population within School 200m Grid Buffer	2036	3244.342	1874.284	0	10371
Density of Retail Employment within Home 200m Grid Buffer	2053	203.4988	301.0339	0	3562
Density of Retail Employment within School 200m Grid Buffer	2036	257.2675	332.5974	0	2718
Density of Non Retail Employment within	2053	908.2065	1343.78	0	16117

Home 200m Grid Buffer					
Density of Non Retail Employment within School 200m Grid Buffer	2036	1102.548	1493.24	0	16117
Open Space within Home 200m Grid Buffer	2053	1.237185	11.24432	0	269.7
Open Space within School 200m Grid Buffer	2038	1.192236	10.46434	0	201.68
Vacant Space within Home 200m Grid Buffer	2053	32.04238	47.17839	0	450.55
Vacant Space within School 200m Grid Buffer	2038	32.82185	49.51334	0	655.4
Average Intersection Density along School Route	2006	5424.537	3022.986	318.0975	21036.75
Average Mixed Use Index along School Route	2006	0.2796364	0.209734	0	0.875072
Average Residential Density along School Route	2006	2.974413	2.478366	0.316833	20.60613
Average Employment Density along School Route	2005	10.61061	9.373664	0.04327	100.9154
Average Open Space along School Route	2006	1.718926	9.184463	0	186.2112
Average Vacant Space along School Route	2006	32.80405	37.78128	0	256.1225
Pct of School Route with Sidewalks Available	2006	0.3249441	0.31536	0	1
Number of Arterial Streets Crossed per Mile of School Route	2006	0.2095072	0.581929	0	12.5

Table 12: Aim 2 Sample Descriptives (continued)

Variable	**N (people)**	**Percent**
% Male	2053	50.85%
% of households with reported annual income between $30,000 and $49,999	2053	19.73%
% of households with reported annual income between $50,000 and $74,999	2053	24.16%
% of households with reported annual income between $75,000 and $99,999	2053	19.63%
% of households with reported annual income $100,000 and higher	2053	19.78%
% White	2053	65.32%
% with school bus as available option (based on trip distance, school policy)	2008	79.08%

Appendix 5: Aim 3 Results - Body Mass Index (BMI)

Contained here are a summary of observation selection, data notes, model results and descriptives.

Aim 3, like Aim 2, is a person level analysis. The dataset for this analysis is restricted to those participants with body mass index values and who are 5 to 18 years old. In this age range only 16 – 18 year old participants provided the height and weight data needed to create the BMI value. Weight and height were self-reported by the participants. Each person's BMI was calculated using this formula: Weight [in pounds] x 704.5 / (Height* Height [in inches]). Due to the inclusion of school based urban form measures the analysis set also required that participants had at least one trip to school.

The travel survey contained a series of questions asking people to rate the quality of various neighborhood attributes, and to rate level of influence different factors have on their willingness to walk in their neighborhood. These questions are used in the analyses reported below. The questions are "On a scale of 1 to 5, with 1 being poor and 5 being excellent, please rate the quality of the following attribute of your neighborhood:

- Affordability (low cost, taxes).
- Closeness to job.
- Ease of walking.
- Low crime.
- Near major roads and interstates.
- Near outdoor recreation (e.g. parks).
- Near to public transit.
- Quality of schools.
- Near shops and services.

Please not that for analysis purposes the original scale has been modified. When the question was originally posed to the participant the scaled was reversed from what is written above, with 1=excellent and 5= poor. Also this question was asked of a random adult for each household. It is treated as a household level variable.

The questions regarding willingness to walk are "On a scale of 1 to 5, with 1 being not at all and 5 being very much, please tell me how much the following factor influences your willingness to walk in your neighborhood," Crime, Availability of sidewalks, and Traffic.

Please note that for analysis purposes the original scale has been modified. When the original question was posed to the participant the scale was reversed from what is written above, with 1 = very much and 5 = not at all. Also, this question was asked of people 16 years or older. The response for the participant was used unless they were younger than 16. In that case the household's main respondent was used. If the main respondent did not answer the question then the answer from next person (in the order recruited) was used.

Table 13: BMI Regression Model – Home and School Buffer Measures

Explanatory Variable	No Neighborhood Quality Indicators		Add Neighborhood Quality Indicators	
	Coef.	T	Coef.	T
Average Trip Distance to School (in miles)	0.0455	0.99	***0.1041***	***1.69***
Dummy variable for Student took at least 1 Motorized School Trip (1 = Yes, 0 = No)	0.1778	0.33	0.3763	0.61
Gender (1 = Male, 0 = Female	**1.8248**	**3.62**	**1.3576**	**2.35**
Size of Household	***0.4623***	***1.81***	0.3636	1.24
Average BMI of Parents/Guardians in Household	**0.3593**	**6.73**	**0.3453**	**5.41**
Household Income between $30,000 and $49,999	-0.3949	-0.39	-0.0594	-0.05
Household Income between $50,000 and $74,999	-0.4715	-0.48	-1.0668	-0.88
Household Income between $75,000 and $99,999	0.1719	0.16	-0.3494	-0.26
Household Income $100,000 and higher	-1.2708	-1.19	-2.0830	-1.55
Vehicles per Driver in Household	0.1509	0.25	0.1254	0.19
Dummy Variable for Ethnicity of Household (1 = White, 0 = Non-White)	-0.9726	-1.36	***-1.5329***	***-1.77***
Dummy Variable for Household Tenure (1 = 3 years or more, 0 = less than 3 yrs.)	-0.2314	-0.31	-0.0079	-0.01
Assessment of Neighborhood Walkability (1 = Poor - 5 = Excellent)	--------	--------	0.0134	0.06
Assessment of Neighborhood Quality of Local Schools (1 = Poor - 5 = Excellent)	--------	--------	***0.4532***	***1.68***
Assessment of Neighborhood Proximity to Parks & Rec. (1 = Poor - 5 = Excellent)	--------	--------	-0.1332	-0.53
Influence of Traffic on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------	***-0.3330***	***-1.66***
Influence of Crime on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------	0.1444	0.70
Influence of Sidewalks on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------	0.2055	1.23
Density of Intersections per Sq Km within Home 200m Grid Buffer	***-0.0505***	***-1.82***	-0.0429	-1.19
Density of Intersections per Sq Km within School 200m Grid Buffer	0.0091	0.33	-0.0324	-0.96
Mixed Use Index within Home 200m Grid Buffer	0.8272	0.61	0.0437	0.03
Mixed Use Index within School 200m Grid Buffer	-1.2745	-1.39	-0.8894	-0.85
Residential Density within Home 200m Grid Buffer	-0.0085	-0.05	-0.1187	-0.62
Residential Density within School 200m Grid Buffer	-0.0097	-0.07	-0.0252	-0.15
Population within Home 200m Grid Buffer	-5.81E-06	-0.04	-6.37E-05	-0.40
Population within School 200m Grid Buffer	-0.0001	-0.58	-8.41E-05	-0.48
Density of Retail Employment within Home 200m Grid Buffer	-0.0001	-0.12	-0.0012	-1.04
Density of Retail Employment within School 200m Grid Buffer	-0.0008	-0.89	-7.30E-05	-0.08
Density of Non Retail Employment within Home 200m Grid Buffer	***0.0004***	***1.73***	0.0004	1.51
Density of Non Retail Employment within School 200m Grid Buffer	-0.0001	-0.66	1.40E-05	0.11
Vacant Space within Home 200m Grid Buffer	-0.0048	-0.92	-0.0047	-0.86
Vacant Space within School 200m Grid Buffer	-0.0008	-0.12	-0.0047	-0.62
Dummy Variable for School Bus Availability from Home (1 = Yes, 0 = No)	0.0374	0.04	-0.9892	-0.86
Regression Constant	**13.0011**	**5.28**	**15.0501**	**5.03**
N		253		201
Adjusted R^2		0.2472		0.2092

Note: Coefficients in **bold** are significant at the 5% level

Coefficients in ***bold italic*** are significant at the 10% level

Table 14: BMI Regression Model – Route Level Buffer Measures

	No Neighborhood Quality Indicators			Add Neighborhood Quality Indicators	
Explanatory Variable	Coef.	T		Coef.	T
Average Trip Distance to School (in miles)	0.0250	0.47		0.1003	1.54
Dummy variable for Student took at least 1 Motorized School Trip (1 = Yes, 0 = No)	0.1581	0.29		0.2932	0.49
Gender (1 = Male, 0 = Female	**2.1237**	**4.19**		**1.5286**	**2.70**
Size of Household	***0.4765***	***1.90***		0.3019	1.06
Average BMI of Parents/Guardians in Household	**0.3948**	**7.37**		**0.3788**	**6.03**
Household Income between $30,000 and $49,999	-0.0599	-0.06		0.2344	0.20
Household Income between $50,000 and $74,999	-0.5723	-0.60		-1.4889	-1.27
Household Income between $75,000 and $99,999	0.0013	0.00		-0.3019	-0.24
Household Income $100,000 and higher	-1.0942	-1.03		-2.0857	-1.60
Vehicles per Driver in Household	0.0640	0.10		-0.2231	-0.33
Dummy Variable for Ethnicity of Household (1 = White, 0 = Non-White)	***-1.2246***	***-1.78***		-1.3161	-1.63
Dummy Variable for Household Tenure (1 = 3 years or more, 0 = less than 3 yrs.)	-0.4242	-0.56		-0.5434	-0.63
Assessment of Neighborhood Walkability (1 = Poor - 5 = Excellent)	--------	--------		0.0587	0.27
Assessment of Neighborhood Quality of Local Schools (1 = Poor - 5 = Excellent)	--------	--------		***0.4687***	***1.80***
Assessment of Neighborhood Proximity to Parks & Rec. (1 = Poor - 5 = Excellent)	--------	--------		-0.0494	-0.19
Influence of Traffic on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------		**-0.3743**	**-1.96**
Influence of Crime on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------		0.1739	0.88
Influence of Sidewalks on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------		0.2132	1.32
Average Intersection Density along School Route	-0.0569	-1.54		**-0.1305**	**-3.01**
Average Mixed Use Index along School Route	-1.3875	-0.92		-1.9814	-1.16
Average Residential Density along School Route	0.0621	0.32		0.1810	0.79
Average Employment Density along School Route	0.0302	0.81		-0.0143	-0.28
Average Vacant Space along School Route	0.0003	0.04		-0.0055	-0.64
Pct of School Route with Sidewalks Available	-0.5134	-0.47		1.5998	1.35
Number of Arterial Streets Crossed per Mile of School Route	1.5690	1.57		0.7211	0.60
Dummy Variable for School Bus Availability from Home (1 = Yes, 0 = No)	-0.1347	-0.13		-0.3118	-0.27
Regression Constant	**12.0216**	**5.01**		**13.6467**	**4.74**
N		238			190
Adjusted R^2		0.2724			0.2669
Note: Coefficients in **bold** are significant at the 5% level					
Coefficients in ***bold italic*** are significant at the 10% level					

Table 15: Weightclass Ordered Logit – Home and School Buffer Measures

Explanatory Variable	No Neighborhood Quality Indicators Coef.	No Neighborhood Quality Indicators Z	Add Neighborhood Quality Indicators Coef.	Add Neighborhood Quality Indicators Z
Average Trip Distance to School (in miles)	0.0069	0.22	0.0415	0.95
Dummy variable for Student took at least 1 Motorized School Trip (1 = Yes, 0 = No)	0.0640	0.17	0.1926	0.44
Gender (1 = Male, 0 = Female	**1.0852**	**3.07**	***0.6821***	***1.68***
Size of Household	0.1411	0.86	-0.0492	-0.25
Average BMI of Parents/Guardians in Household	**0.1768**	**5.01**	**0.1976**	**4.26**
Household Income between $30,000 and $49,999	-0.5699	-0.91	-0.2633	-0.35
Household Income between $50,000 and $74,999	-0.4213	-0.71	-0.8409	-1.04
Household Income between $75,000 and $99,999	-0.2900	-0.43	-0.3168	-0.37
Household Income $100,000 and higher	-0.9269	-1.38	-1.2311	-1.38
Vehicles per Driver in Household	0.2369	0.65	0.2141	0.51
Dummy Variable for Ethnicity of Household (1 = White, 0 = Non-White)	-0.7657	-1.64	***-0.9491***	***-1.65***
Dummy Variable for Household Tenure (1 = 3 years or more, 0 = less than 3 yrs.)	-0.5109	-1.06	-0.6811	-1.18
Assessment of Neighborhood Walkability (1 = Poor - 5 = Excellent)	--------	--------	-0.1459	-0.97
Assessment of Neighborhood Quality of Local Schools (1 = Poor - 5 = Excellent)	--------	--------	0.1069	0.57
Assessment of Neighborhood Proximity to Parks & Rec. (1 = Poor - 5 = Excellent)	--------	--------	0.0913	0.50
Influence of Traffic on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------	-0.1484	-1.07
Influence of Crime on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------	0.1979	1.39
Influence of Sidewalks on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------	0.1071	0.91
Density of Intersections per Sq Km within Home 200m Grid Buffer	***-0.0319***	***-1.84***	***-0.0433***	***-1.68***
Density of Intersections per Sq Km within School 200m Grid Buffer	0.0076	0.42	-0.0191	-0.73
Mixed Use Index within Home 200m Grid Buffer	0.3068	0.36	-0.2658	-0.24
Mixed Use Index within School 200m Grid Buffer	-0.7284	-1.13	-0.5777	-0.78
Residential Density within Home 200m Grid Buffer	-0.0030	-0.03	0.0505	0.40
Residential Density within School 200m Grid Buffer	0.0764	0.77	-0.0251	-0.17
Population within Home 200m Grid Buffer	0.0000	0.43	0.0000	0.17
Population within School 200m Grid Buffer	-0.0001	-0.88	-0.0001	-0.73
Density of Retail Employment within Home 200m Grid Buffer	0.0003	0.36	-0.0009	-0.94
Density of Retail Employment within School 200m Grid Buffer	-0.0009	-1.51	-0.0003	-0.44
Density of Non Retail Employment within Home 200m Grid Buffer	0.0001	0.34	0.0002	0.83
Density of Non Retail Employment within School 200m Grid Buffer	-0.0001	-1.17	-0.0000352	-0.37
Vacant Space within Home 200m Grid Buffer	***-0.0100***	***-1.93***	***-0.0101***	***-1.86***
Vacant Space within School 200m Grid Buffer	0.0056	1.34	0.0043	0.88
Dummy Variable for School Bus Availability from Home (1 = Yes, 0 = No)	0.5589	0.83	0.1866	0.23
Cutpoint (normal weight)	5.2957		4.1785	
Cutpoint (overweight)	7.4786		6.4729	
N		253		201
Psuedo R^2		0.1933		0.2073
Note: Coefficients in **bold** are significant at the 5% level				
Coefficients in ***bold italic*** are significant at the 10% level				

Table 16: Weightclass Ordered Logit – Route Buffer Measures

	No Neighborhood Quality Indicators			Add Neighborhood Quality Indicators	
Explanatory Variable	Coef.	Z		Coef.	Z
Average Trip Distance to School (in miles)	0.01987	0.54		0.0648	1.38
Dummy variable for Student took at least 1 Motorized School Trip (1 = Yes, 0 = No)	0.13822	0.37		0.1253	0.28
Gender (1 = Male, 0 = Female	**1.05604**	**3.06**		0.6318	1.58
Size of Household	0.18295	1.21		0.0539	0.30
Average BMI of Parents/Guardians in Household	**0.18151**	**5.17**		**0.2075**	**4.54**
Household Income between $30,000 and $49,999	-0.30287	-0.50		-0.0712	-0.10
Household Income between $50,000 and $74,999	-0.64108	-1.11		-1.1871	-1.49
Household Income between $75,000 and $99,999	-0.56407	-0.84		-0.5202	-0.60
Household Income $100,000 and higher	-0.92718	-1.39		-1.4223	-1.54
Vehicles per Driver in Household	0.22699	0.63		0.0052	0.01
Dummy Variable for Ethnicity of Household (1 = White, 0 = Non-White)	-0.68705	-1.58		-0.6915	-1.33
Dummy Variable for Household Tenure (1 = 3 years or more, 0 = less than 3 yrs.)	-0.38228	-0.84		-0.6058	-1.13
Assessment of Neighborhood Walkability (1 = Poor - 5 = Excellent)	--------	--------		-0.1221	-0.83
Assessment of Neighborhood Quality of Local Schools (1 = Poor - 5 = Excellent)	--------	--------		0.1646	0.92
Assessment of Neighborhood Proximity to Parks & Rec. (1 = Poor - 5 = Excellent)	--------	--------		0.0903	0.51
Influence of Traffic on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------		-0.1627	-1.25
Influence of Crime on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------		0.2240	1.64
Influence of Sidewalks on Willingness to Walk (1 = Not Important - 5 = Very Important)	--------	--------		0.0898	0.79
Average Intersection Density along School Route	-0.01226	-0.50		**-0.0669**	**-1.97**
Average Mixed Use Index along School Route	-0.72721	-0.73		-0.8755	-0.70
Average Residential Density along School Route	0.00025	0.00		0.0777	0.41
Average Employment Density along School Route	0.00951	0.41		-0.0024	-0.06
Average Vacant Space along School Route	0.00127	0.24		-0.0023	-0.37
Pct of School Route with Sidewalks Available	-0.15572	-0.22		1.0407	1.25
Number of Arterial Streets Crossed per Mile of School Route	0.43078	0.71		-0.0404	-0.05
Dummy Variable for School Bus Availability from Home (1 = Yes, 0 = No)	0.09031	0.12		-0.0376	-0.04
Cutpoint (normal weight)	6.0499			5.6062	
Cutpoint (overweight)	8.0701			7.8624	
N		238			190
Adjusted R^2		0.1669			0.1923
Note: Coefficients in **bold** are significant at the 5% level					
Coefficients in ***bold italic*** are significant at the 10% level					

Table 17: Aim 3 BMI Descriptives

Variable	N (people)	Mean	Std. Dev.	Min	Max
Student BMI	289	23.05517	4.576108	14.37755	45.02831
Average Trip Distance to School (in miles)	269	6.729708	6.188944	0.06214	35.199
Size of Household	289	3.750865	1.034244	2	8
Average BMI of Parents/Guardians in Household	284	26.69042	4.539224	18.00958	46.86666
Vehicles per Driver in Household	287	1.024506	0.444582	0	3
Assessment of Neighborhood Walkability (1 = Poor - 5 = Excellent)	229	3.663755	1.36868	1	5
Assessment of Neighborhood Quality of Local Schools (1 = Poor - 5 = Excellent)	230	3.765217	1.213681	1	5
Assessment of Neighborhood Proximity to Parks & Rec. (1 = Poor - 5 = Excellent)	227	3.779736	1.315306	1	5
Influence of Traffic on Willingness to Walk (1 = Not Important - 5 = Very Important)	271	2.586716	1.666347	1	5
Influence of Crime on Willingness to Walk (1 = Not Important - 5 = Very Important)	270	2.477778	1.639846	1	5
Influence of Sidewalks on Willingness to Walk (1 = Not Important - 5 = Very Important)	270	2.8	1.730118	1	5
Density of Intersections per Sq Km within Home 200m Grid Buffer	289	22.3515	12.5452	0.612579	83.78159
Density of Intersections per Sq Km within School 200m Grid Buffer	276	22.8819	13.99688	1.224417	78.09024
Mixed Use Index within Home 200m Grid Buffer	289	0.172793	0.233605	0	0.999351
Mixed Use Index within School 200m Grid Buffer	276	0.289922	0.288221	0	0.980487
Residential Density within Home 200m Grid Buffer	289	2.79476	2.875989	0.313963	21.72057
Residential Density within School 200m Grid Buffer	275	2.694087	2.454957	0.247984	15.17217
Population within Home 200m Grid Buffer	289	3653.048	1910.939	117	9564
Population within School 200m Grid Buffer	283	3240.519	1718.008	0	8582
Density of Retail Employment within Home 200m Grid Buffer	289	209.2284	290.08	0	1593
Density of Retail Employment within School 200m Grid Buffer	283	280.6082	302.3342	0	1343
Density of Non Retail Employment within Home 200m Grid Buffer	289	903.4291	1370.357	0	8958
Density of Non Retail Employment within School 200m Grid Buffer	283	1409.322	2263.629	0	16117
Open Space within Home 200m Grid Buffer	289	0.745087	9.783191	0	163.08
Open Space within School 200m Grid Buffer	276	0.738843	3.40012	0	34.42
Vacant Space within Home 200m Grid Buffer	289	30.99239	49.5503	0	450.55

Vacant Space within School 200m Grid Buffer	276	28.56264	40.51195	0	215.46
Average Intersection Density along School Route	269	22.80242	11.41171	2.222083	74.33771
Average Mixed Use Index along School Route	269	0.315217	0.20029	0	0.842521
Average Residential Density along School Route	269	3.057735	2.346807	0.437934	14.11806
Average Employment Density along School Route	269	11.29752	8.797244	0.146898	60.49372
Average Open Space along School Route	269	1.891086	8.67127	0	75.90504
Average Vacant Space along School Route	269	30.16017	34.17484	0	183.5598
Pct of School Route with Sidewalks Available	269	0.334016	0.299883	0	1
Number of Arterial Streets Crossed per Mile of School Route	242	0.217213	0.255352	0	1.466993

Table 18: Aim 3 BMI Descriptives (continued)

Variable	**N (people)**	**Percent**
% participants who drove to school at least one time	289	46.02%
% Male	289	53.63%
% of households with reported annual income between $30,000 and $49,999	289	18.69%
% of households with reported annual income between $50,000 and $74,999	289	26.99%
% of households with reported annual income between $75,000 and $99,999	289	19.38%
% of households with reported annual income $100,000 and higher	289	22.84%
% White	288	71.88%
% of participants living at the same address for 3 yrs or more	289	82.70%
% with school bus as available option (based on trip distance, school policy)	270	90.74%

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