A Report from the University of Vermont Transportation Research Center

Pupil Transportation: Travel Behavior, Traffic Impacts, and Potentials for Improvement

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UVM Transportation Research Center

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Prepared by:
Qingbin Wang
Erica Campbell
Robert Parsons

Transportation Research Center
Farrell Hall
210 Colchester Avenue
Burlington, VT 05405

Phone: (802) 656-1312
Website: www.uvm.edu/transportationcenter

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1. Introduction

Although the student transportation industry has been the largest single carrier of passengers in the United States for several decades, there is very limited information on student travel behavior and preferences, impacts of student travel mode choices on local traffic and environment, reasons why an increasing proportion of students is dropped off at and picked up from school by parents, and ways to improve the efficiency of school transportation. This study collects primary data on student travel patterns in three Vermont school districts, analyzes the data to address a set of research and practical questions, and derives recommendations for improving the efficiency of school transportation and for encouraging students to walk, bike, or take the bus to and from school.

1.1 Background

The student transportation industry has been the largest single carrier of passengers in the United States for several decades (*School Bus Transportation News*, 2007). In the 2004–2005 school year, school districts spent approximately $17 billion to provide an average of 25.146 million daily rides for K–12 students over 4.3 billion miles on 471,380 school buses (*School Bus Transportation News*, 2007). According to the National Center for Education Statistics (2006), expenditures on school transportation represent about 6.2% of the total education budget in the United States, or about $520 per typical schoolchild and $2,400 per schoolchild with special needs each year.

In the state of Vermont, about 1,800 school buses provided an average of 102,000 daily rides for K–12 students in the 2004–2005 school year (*School Bus Transportation News*, 2007). A larger percentage of students in northern regions, such as the northeast, are transported by school buses as compared to their counterpart students in other regions. For example, the ratio of average daily rides provided by school buses to the number of enrolled K–12 students in Vermont was 0.97 in 2004–2005, compared to the national average of 0.52 in the same school year. The ratios for New Hampshire, Maine, Massachusetts, and New York in the same school year were 0.73, 0.80, 0.98, and 0.67, respectively. Note that the ratios are the average number of daily rides, not the number of students who take the school bus, to the number of enrolled students. For instance, if each student rode the school bus twice a day, the ratios would mean that about 48.5% of Vermont students were transported by school bus as compared to the national average of 26%. The relatively more important role of school bus transportation in Vermont and other northeast states is likely a result of those states' northern climate and geographical characteristics. These ratios also suggest great potentials for increasing the use of school bus service in Vermont and across the nation.

School transportation in the United States has changed dramatically over the past five decades. The automobile has become the predominant mode of transportation to school, even for short distances of less than a mile (Dellinger and Staunton, 2002; Bureau of Transportation Statistics, 2004). On the other hand, bicycling and walking to school have decreased significantly (McMillan, 2005). Considering the impacts of increased vehicle miles traveled, such as traffic congestion, air pollution, greenhouse gas emissions, and road infrastructure burden, it is important to examine the reasons why parents increasingly chauffeur their children to and from school. It is also important to understand the factors that have contributed to whether a child takes the school bus or uses nonmotorized transport.

Organized school-vehicle transport began in the 1920s when school "wagons" were replaced by school "trucks" (National Association of State Directors of Pupil Transportation Services [NASDPTS], 2000). With the expansion of the American roadway system and of one-room schoolhouses into larger schools, the need for transport to and from school increased. Between 1940 and 1990, school consolidation cut the number of U.S. schools by 69%, while the U.S. population grew by 70% (Walberg, 1992). While school bus transport was increasingly offered, students continued to walk to and from school at fairly large rates. In 1969, almost half (48%) of children walked or biked to school (Ewing et al., 2004; Federal Highway Administration [FHWA], 1972). In 2001, fewer than 15% of students walked to school, and only about 1% biked to school (Bureau of Transportation Statistics, 2004). School bus transportation has emerged as the largest component of public transportation in the country, yet school bus trips make up only 25% of all school-related trips (Transportation Research Board, 2002; Rhoulac, 2005).

The trends of school transportation observed in the United States have also been reported in many other nations. For example, vehicle trips by parents driving their children to school account for approximately 20% of all car journeys on weekday rush hour mornings in the United Kingdom (Black et al., 2001). A 2002 Scottish study found that car travel was perceived to offer higher levels of safety and convenience for schoolchildren, particularly in terms of flexibility at a time of day when parents are under time constraints (Granville et al., 2002).

Although U.S. K–12 pupil enrollments have increased by 83% from 1900 to 2000, the number of schools and school districts has dramatically decreased (NASDPTS, 2000). Over the past century, consolidation of schools across the United States has reduced the number of school districts from 125,000 to fewer than 15,000 in 2000 (Killeen and Sipple, 2000). Although consolidation trends began to level out after 1975, schools were increasingly being located farther outside urban areas because of school location guidelines. In fact, until June 2004, the Council of Educational Facility Planners International (CEFPI) recommended 1 acre of land for every 100 students plus 10 acres for an elementary school, 20 acres for a middle school, and 30 acres for a high school (CEFPI, 2000). This encouraged school location outside city and village centers, increasing the distance from population centers to schools.

Other factors have contributed to the decrease in walking to school, but school location and the distance between a child's home and school have proved to be critical factors in mode choice for school transport (Black et al., 2001; Ewing and Greene, 2003; McDonald, 2008; McMillan, 2005). A study by McDonald (2008) revealed that community schools, where children live within walking distance of school, are possible only at medium to high population densities. Based on calculated models, densities must be greater than 1,000 people per square mile to create a viable elementary school of 300 students who live within one mile of the school (McDonald, 2008). New CEFPI guidelines removed the building and land size standards, allowing education facility planners to begin using smart growth principles in school designs and encouraging schools to be built in more populated areas (CEFPI, 2000).

Another effect of school consolidation is increased school size. A California study indicated that walking and biking rates were positively associated with neighborhood population density and inversely with school size (Braza et al., 2004; Ewing et al., 2004). In other words, smaller schools are more often found in denser, more urban areas, and these schools have higher walking and biking rates. Another study has shown that school size is not a significant indicator of mode choice, although larger schools may draw students from larger areas and thereby indirectly affect mode choice (Ewing et al., 2004).

Currently, the major effort to change school transportation trends has been through the Safe Routes to School (SRTS) programs, aimed at increasing the number of students that walk and bike to school. Conceived in Denmark and first initiated in the United States in California in 1999, SRTS programs endeavor to make routes to school safer and more walkable through education on road safety for both children and parents, enforcement of traffic laws around schools, and engineering of the street environment along the routes to school in an attempt to control traffic and to enhance pedestrian and bicycling facilities (Transportation Alternatives, 2002). Although this program has positively impacted walking and biking rates (McMillan, 2005), it does not target the high levels of parent pickups and drop-offs at schools. Yet, until the reasons are explored as to why parents are increasingly choosing to drive their children to school, there cannot be recommendations for change.

1.2 Research Objectives

The overall goals of this research project are to collect primary data on school transportation choice, analyze the data to address a set of research and practical questions, and derive recommendations for improving efficiency of school transportation and for encouraging more students to walk, bicycle, or take the bus to and from school instead of being dropped off and picked up by parents. Four specific objectives have been developed to accomplish these goals:

(1) To collect primary data on student transportation modes, preferences for school transportation, perceptions about bus service, and reasons for not riding the bus through a parent survey and on-site counting of parent drop-offs and pickups,

(2) To identify factors that affect student transportation mode choice and quantify their impacts on the probability of selecting a particular mode as well as on the frequency of using the particular mode,

(3) To analyze the correlations between perceptions, preferences, demographic variables, and travel behavior and assess the impacts of parent drop-offs and pickups on road traffic around schools, and

(4) To derive recommendations for improving the efficiency of school transportation and for encouraging more students to walk, bicycle, or take the bus to and from school instead of being dropped off and picked up by parents.

2. Research Methods and Data Collection

This chapter defines the scope of the study, summarizes the student travel behavior theory and presents the model developed for this study, and, finally, describes the data collection procedures.

2.1 Scope of the Study

The scope of this study encompassed 14 public schools in three Vermont school districts. While surveys were conducted in selected schools in the three school districts, traffic counts were taken at three of the schools: one in an urban location (District Three) and two in a rural location (District One). Modal tallies were taken directly from students in two of the schools in District One.

Vermont has 38.2% of its population living in urban areas and 61.8% of its population living in rural areas (U.S. Census Bureau, 2000). The total population is 621,270, with 67 people per square mile (U.S. Census Bureau, 2007). Many schools are consolidated and are attended by children from more than one town. Indeed, two of the three school districts in this study had students from more than one town or city. Although many children still take the school bus to school, some studies have found that 65% of Vermont children are dropped off and picked up at schools in a family vehicle (Vermont SRTS, 2007).

Vermont annual student enrollment for the 2003–2004 school year was 104,449, and the number of K–12 student trips provided at public expense was reported to be 102,000 (www.stnonline.com). These numbers are self-reported by schools to the state department of education. Considering there are two trips per day (to and from school), almost 50% of students ride the bus each day.

Vermont SRTS data collected in 2007 indicated that more children were driven by parents than took the school bus. The SRTS program aims to increase walking and biking rates. In the mornings, 46% of children rode in a car to school, as opposed to only 33% who took the school bus. In the afternoon, these figures differed; the family vehicle accounted for only 36% of trips, compared to the school bus, with 41% (Vermont SRTS, 2007). The morning/afternoon split is evident, and the reasons parents chose to drive their children more often in the morning than the afternoon need to be examined.

SRTS walking and biking rates are probably higher than non-SRTS sites for two reasons: the schools often do not have school bus service for children who live within one mile of the school or do not offer school bus service at all, and these schools are actively trying to promote walking and biking.

2.2 Student Travel Behavior Theory and Model Development

The mode choice modeling used in this research is based on disaggregate mode choice modeling techniques. These methods are based on economic theory and also rely on early psychological probability models. A psychological experiment by Louis Leon Thurstone (1927) revealed that the greater the difference in an attribute (in this case the weight of an object), the greater the probability for choosing correctly (which object was heavier). A landmark study in 1954 by Mitchell and Rapkin established the link between travel and activities, which called for comprehensive inquiries into travel behavior. This led to the development in the 1960s of binary choice models that used disaggregate models from economics and psychology, applying consumer behavior concepts from economics and choice behavior concepts from psychology.

Economists use the theory of utility maximization, similar to Thurstone's (1927) psychological experiment, to develop behavior models to study the probability of choosing a certain mode. For example, some binary models like probit and logit models have been used to model consumer choices (Domencich and McFadden, 1975).

From microeconomic economic theory we know that utility theory is based on several assumptions and can be applied to mode choice modeling. The first of these assumptions is that travelers have perfect information about the market. The second assumption is that travelers, when faced with the same options, will always make the best choice or choices to maximize their satisfaction. Common sense dictates that these assumptions do not always hold true for school transportation travel behavior, or for any transportation travel behavior. Yet by introducing a random component to the model that represents individual tastes as well as observational errors, modelers have been able to salvage the utility model framework.

The logit, nested logit, or probit models require the sample population to be randomly selected from a population of interest and the dependent variable to be associated with the independent variables. Also, there is uncertainty in the relationship between the dependent and independent variables. Finally, the distribution of error terms must be examined to determine if the model is appropriate.

This research used a two-part double-hurdle model (Cragg, 1971) to examine travel behavior for school transport. This method allows for development of a simple binary logit utility model and further calibrates the factors that affect the average number of days for using the particular mode. The binary logit model is used to identify the factors that affect the probability of choosing a particular mode. In this research, factors were included in the survey on the basis of previous studies in the field of student travel behavior and school transport mode choice. In particular, studies by Rhoulac (2005), McDonald (2008), McMillan (2005), and Ewing et al. (2004) were considered when choosing factors to include in the model: safety, distance, convenience, work commutes, children's activities, household activities, perceptions of various modes, and household demographics.

The subsequent ordinary least squares linear regression model allows for the frequency of modal usage to be modeled. The linear regression model, therefore, does not contain the problems inherent with other utility-based models, including the multinomial logit model. Yet it does not predict mode choice; rather, it predicts which factors affect the variations in the number of days that each mode is used. Considering that most students use multiple modes each week for school transport, it is important to determine which factors affect not only mode choice but also the choice to take a mode more often than not. The double-hurdle model was chosen because there are two decisions: (1) whether to use a mode or not, and (2) if a mode is used, how many days is it used? This model was also chosen because of the tendency for students to use more than one mode per week. For instance, survey results indicate that just over 20% of students who are driven by parents (morning and afternoon) use this mode every day; the remaining 80% of those who use this mode do so one to four days per week.

Using econometric-based applications can be problematic if the models are not valid representations of complex processes such as household decision making. Although the models in this research have limitations, they are able to include an array of factors to determine which factors affect mode choice and the number of trips per mode. Moreover, like other activity-based models, they are more relevant for policy application than other models (Goodwin and Hensher, 1978; Stoner and Milione, 1978; McNally, 2000).

Transportation modeling often uses consumer choice theory, based on the economic principle of utility, to model mode choice. The travelers, each with different characteristics, choose a mode according to factors that affect their preference. The determinants of travel behavior are referred to as journey attributes. This study suggests that the reasons for mode choice have involved a variety of factors, including journey attributes and convenience.

The double-hurdle framework is used to identify factors that contribute to the probability that a student is dropped off in the morning (or picked up in the afternoon) and factors that determine the number of times a student is dropped off in the morning (or picked up in the afternoon) per week. Each double-hurdle model includes a binary logit model for the first stage (hurdle) and a linear regression model for the second stage (hurdle). Whereas the binary logistic model for the first hurdle will identify the factors that contribute to the probability that a student is dropped off or picked up at least once a week, the linear regression model for the second hurdle will address the research question, "For students who are dropped off in the morning (or picked up in the afternoon) at least once a week, what are the factors that contribute to the variation in the frequency?"

Most of the models that have been used in travel choice studies can be classified as limited-dependent variable models (i.e., the dependent variables are not continuous variables). These models are developed to deal with problems frequently associated with cross-sectional survey data. For example, in modeling the behavior of being dropped off by a family car or not, the observation from each student is either "dropped off by a family car" or "went to school via another transportation mode," and this dependent variable (Y) is limited to only two possibilities (Y = 1 for using a family car and Y = 0 otherwise). In this case, a binary logit model is generally used to examine the impacts of a set of independent variables (X_1, X_2, …, X_n) on the logit function of the probability for being dropped off at school by a family car (i.e., P is the probability for Y = 1). Estimation results of a logit model can be used to identify factors that significantly contribute to the probability of being driven by parents and to examine the marginal impact of each significant independent variable on the odds ratio of being dropped off by parents. A binary logit model can be represented by the following function:

$$\mathbf{Logit (P) = ln \{P/(1\text{-}P)\} = a + b_1 X_1 + b_2 X_2 + \ldots + b_n X_n + e} \qquad (1)$$

where P, X_1, X_2, …, and X_n are as defined above; a, b_1, b_2, …, b_n are the coefficients to be estimated; and e is the error term.

In this study, the binary logit model is used to identify the factors that contribute to "the probability of being dropped off to school by parents" and other transportation choices. In addition to the results from the two binary logit models, it is important to identify the factors that contribute to the number of times a student is driven to school per week. Note that the analysis about the variation in the number of times being dropped off applies to only the students who are dropped off at least once a week (i.e., Y=1 in the binary logit analysis). This analysis is generally handled by a linear regression model:

$$\mathbf{Z = c + d_1 K_1 + d_2 K_2 + \ldots + d_n K_n + s} \qquad (2)$$

where Z is the dependent variable (i.e., number of times being dropped off or picked up per week); K_1, K_2, …, and K_n are the independent variables; c, d_1, d_2, …, d_n are the coefficients to be estimated; and s is the error term. Therefore, models (1) and (2) together form a simple double-hurdle model.

There is a rich literature on double-hurdle models that includes a wide range of applications. Cragg (1971) developed a double-hurdle model to study the demand for durable goods, Jones (1989) used a double-hurdle model to examine the behavior of cigarette consumption, and Yen and Jensen (1996) developed a multivariate sample-selection model to estimate cigarette and alcohol demand in the United States. Wang et al. (1996) used a double-hurdle model to examine the impact of cholesterol information on egg consumption in the United States.

Although alternative double-hurdle models have been widely used in consumer demand and behavior studies, it is believed that this paper presents one of the first applications of this approach to modeling in general transportation studies and the first to be used in school transport studies. The idea and framework of alternative double-hurdle models are similar, but the variation in model specification and estimation methods is significant. For example, some studies used the same set of independent variables in the first hurdle and second hurdle, but other studies used two different sets of variables.

Also, the models for the two hurdles can be estimated separately or simultaneously with different assumptions about the distribution of the error terms in the two models. This study uses the same set of independent variables in the binary logit and linear regression models, yet the two models will be estimated separately. This can be considered a limitation of the empirical estimation and should be examined in further research.

2.3 Data Collection

The data collection for this study included a Web-based and mail-out/mail-back travel survey, traffic counts on select streets near schools, and student tallies. The survey data was used primarily for analysis.

Surveys were distributed both by mail-out/mail-back and through the Internet. Surveys were distributed to the three districts in different ways: some received mail surveys with links to the Web-based survey, some received primarily e-mails with a direct link, and some parents received only a regularly e-mailed electronic newsletter with a link to the Web survey within the text of the letter. This mixed-method approach could be seen as problematic, but the sample size and number of surveys completed made these mixed methods acceptable. A total of 512 surveys were completed.

This sample was not random, but it employed aspects of cluster sampling and quota sampling techniques. In cluster sampling, samples are grouped as small representations of the total population. The three school districts in the study were chosen for their ability to represent a cross section of Vermont. Each school district is a separate cluster, representing a different demographic (specifically density). In quota sampling, the population is first segmented into mutually exclusive sub-groups, and judgment is used to select the subjects or units from each segment according to a specified proportion. Quota sampling is not random and can be subject to bias. Disaggregate choice calibration methods yield consistent parameter estimates for random and stratified sampling techniques, although quota samples can also be used for disaggregate model calibration (Lerman and Manski, 1976).

Mode choice modeling often involves choice-based sampling, whereby the existing users of a mode (such as school transport modes) will be surveyed. It should be noted that logit models applied to a choice-based sample may yield inconsistent estimates of the coefficients; if this is the case, correction is needed. However, if the application context sample size exceeds 400 observations, which this research has achieved, then simple estimation is sufficient to estimate mode choice (Badoe and Miller, 1995).

The total number of parents surveyed for the first two school districts was 1,195, with a response rate of 426. This represents a response rate of nearly 36%. Although this was not a random sample, the total population (1,195) can be assumed to be representative of Vermont and can be generalized to school districts around the state and to states with similar qualities to Vermont. Unfortunately, the total sample size could not be determined for District Three because the schools e-mailed newsletters with only a Web link in the text of the letter. It is not certain that all parents received or noticed the link. The responses totaled only 85, and the response rate is unknown.

We surveyed parents and guardians rather than children to determine mode choice. This method has limitations because children's preferences certainly affect mode choice. Children contribute to household decision making that results in joint travel arrangements (Vovsha and Petersen, 2005). The idea that children's travel behavior could influence their parents' travel behavior is something that has been considered only recently (Zwerts and Wets, 2006). Although this research does not directly ask children about their travel behavior or personal preferences, parents were asked questions that were intended to include the potential influence of the child's behavior. Examples of this in the survey include asking parents whether they agree with such statements as "the bus stop is too far from home" and "child is in after-school activities."

The survey was designed to determine the reasons for mode choice to and from school. The survey questions for this research were based on findings from the literature review, and from two studies in particular. The first survey came from a University of North Carolina dissertation by Danielle Rhoulac (2003). This survey provided the method of asking information about the child and mode of school transport for each school-age child in the family. It also provided ideas for questions about parents' perceptions about the bus, such as inconsistent arrival times and poor bus behavior. The second survey used to frame specific questions was the national Safe Routes to Schools (SRTS) survey that is conducted with parents at participating SRTS schools. These questions addressed mode choice and safety, specifically focusing on the opinions of parents about walking and biking to school. Both surveys asked separate questions about modes taken in the morning and afternoon. Studies conducted by Rhoulac (2003 and 2005) found that there was a significant A.M./P.M. modal split. Therefore, we adopted this logic and separated morning and afternoon responses, modeling both A.M. and P.M. modes.

Data for this research was collected in three Vermont school districts representing 14 schools. These districts were located in different counties and were chosen to represent a cross section of Vermont, including rural, urban, and village characteristics. Although these districts are located in a northern climate and two of the districts contain some mountainous terrain, it does not appear that these factors would limit the transferability of results. Much of the survey data for the study was collected in spring months without winter driving conditions.

We chose the school districts partly on the basis of their population density: one school district was rural, one had a concentrated village with rural surroundings, and one was an urban cluster. The rural school district (District One) had one combination high school/middle school and five elementary schools. The village district (District Two) had one high school, one middle school, and one elementary school. The urban district (District Three) had one high school, one middle school, and three elementary schools. Only trips made to and from school were included in the analysis; no extracurricular school trips were counted.

There was a slightly different method of distribution in each of the three school districts that participated in this study. For District One, 850 total surveys were mailed, and a link to an Internet survey was placed on the district Web site. A total of 277 surveys were completed, for a response rate of 33%. For District Two, all households in two out of the three schools received surveys. Two hundred fifty parents were sent Web-based surveys to complete, as this district had a comprehensive parental e-mail address list. An additional 71 households were sent a mail-out/mail-back survey. A total of 136 surveys were completed for District Two, providing a 42% response rate. District Three placed a link to the survey in the regularly e-mailed school newsletter. This district had only 84 surveys returned. The actual response rate is unknown because the number of recipients was unavailable.

Table 2-1. Population Density, Income, and Education of the Study Area in Comparison with Data for the U.S. and Vermont

	US	VT	District 1	District 2	District 3
Density (people/ square mile)	79.6	67.5	50	87	1,025
Median household income	50,007	49,383	53,476	51,333	51,566
Median family income	60,374	61,141	63,770	64,067	67,241
Percent with bachelor’s degree or higher	27.0	32.4	N/A	N/A	N/A

Source: U.S. Census Bureau 2006–2007 estimates

Table 2-1 presents a comparison of demographics between the United States, Vermont, and the participating school districts. Vermont’s total 2006 population was 623,908. The state ranks 43rd for smallest land area (9,250 square miles) and had an overall density of 67.5 people per square mile in 2006. District One, Addison Northeast Supervisory Union, is made up of five rural towns: Bristol, Lincoln, Starksboro, Monkton, and New Haven. These towns have population densities of 92, 28, 42, 49, and 40 square miles respectively. The average population density for District One is 50 people per square mile. This district has very low densities and is classified by the Census 2000 Urban Area Criteria as nonurban or rural. District Two contains two towns: Waterbury, with a total population of 6,621, and Duxbury, with 1,289 people. The average population density for the two towns is 87 people per square mile. Although the density within District Two is higher than in District One, District Two is nevertheless also classified as nonurban. District Three, South Burlington, Vermont, had a population in 2000 of 15,819 within 16.6 square miles. The population density was 953 people per square mile. Although Census 2000 defines core census blocks as areas that have an overall density of at least 1,000 people, the population of South Burlington has grown since 2000 into an urbanized area. 2007 estimates indicate that the population of South Burlington reached 17,014, with a density of 1,025 people per square mile. Because these school districts represent a cross section of Vermont by representing average demographic characteristics, this data can be utilized by most Vermont school districts to help make decisions about school transport.

Final demographics to consider are income and education. The average household family income in the survey was reported to be between $50,000 and $74,999. Whereas the 2007 median household income in Vermont was reported to be almost $50,000, the median family income for households with children was reported to be more than $61,000 (U.S. Census Bureau), which falls within the survey income cohort. In the survey, the average education was stated to be between some college/associate's degree and a bachelor's degree. According to the U.S. Census, more than 57% of Vermonters have an education of some college or more. The results in this survey for income and education are similar to the U.S. Census statistics for Vermont.

Comparing income and education nationally, all other New England states except Maine rank higher in household and family income. Yet Vermont's family income is roughly in the middle of all U.S. family incomes, which range from $45,000 to $82,000. This research can also be generalized to other states (or regions within states) with similar population or population density characteristics to Vermont. Many states also have regions that have densities comparable to Vermont. There are major limitations in the ability to generalize the results of this study to urban areas. Data was collected from one urban area (District Three) in the study, but the number of survey responses was far too low to generalize to other urban areas or to analyze the differences between urban and rural areas of Vermont. The majority of the research was gathered from nonurban areas.

Data from these findings can therefore be applied to states with similar demographics to Vermont, such as density, income, and education levels, and with similar school bus ridership levels. These findings may also be applicable to areas or regions within states that have similar demographics.

3. Data Analysis and Results

This chapter presents the descriptive statistics of the data set and reports the estimation results of selected student travel choice models.

3.1 Descriptive Results of the Data

This section describes the survey results. The survey was designed to ask parents or guardians about mode choice for school transport and the reasons for their choice. It also asked demographic and geographic questions, such as income, education, and distance the child lives from school. Parents were asked to complete questions for each child in the household. Each parent survey allowed responses for up to four children. In the first question, the grade, age, gender, school, and distance each child lived from school were recorded. The second and third questions asked how many days each child took a certain transport mode for morning and afternoon. The importance of differentiating the transport to school and from school became evident as we tallied our parent drop-offs and pickups from school. Many more cars were counted driving children to school in the morning than picking children up from school in the afternoon. This morning-afternoon difference was evident in the literature on school transportation as well.

The survey results also indicate a variation in transport modes. Although many students took the same mode every day, there were children who used different modes during the week to get to and from school. For example, in an average week, a child may take the school bus two days, be driven one day, and walk two days. This combination of modal usage led to the use of the double-hurdle modeling technique.

Figure 3-1 indicates that some children use multiple modes per week. For instance, whereas most children do not walk at all (0 Days), some children walk to school 1, 2, 3, or 4 days, using other modes on other days. Some children use multiple modes in a given week, but more children use the same mode every day.

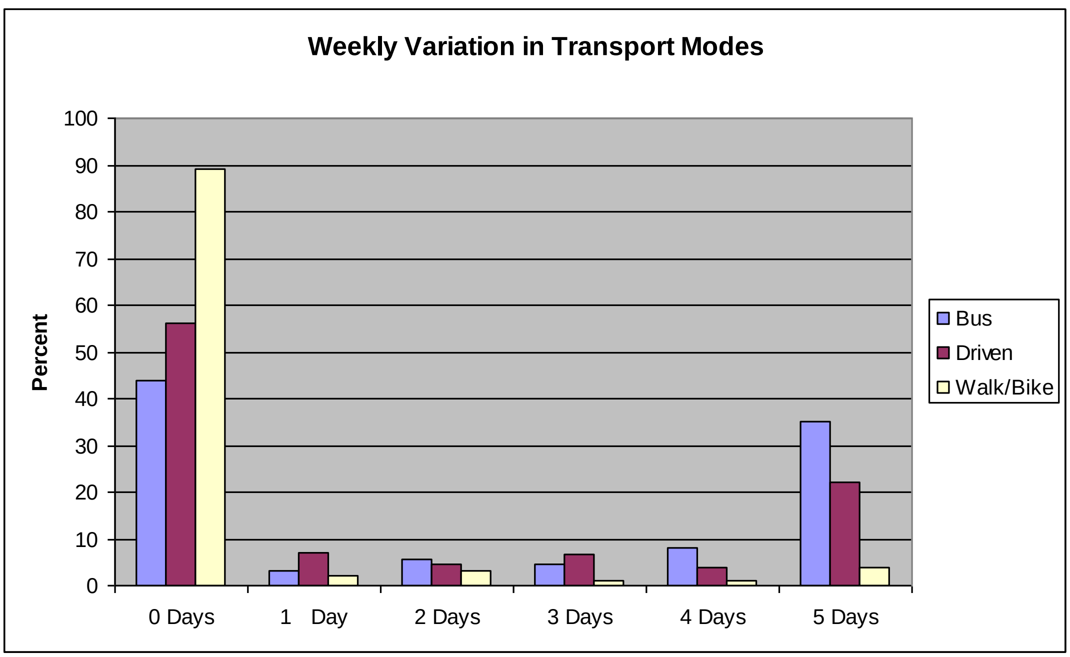

Figure 3-1. Weekly Variation in School Transport Modes

We asked Likert-scale questions to determine parents' opinions about statements on school travel. The statements were related to safety, convenience, child activities, school bus behavior, and time issues. Parents were asked if they strongly agreed, agreed, were neutral or not applicable, disagreed, or strongly disagreed with the statements.

Parents rated how satisfied they were with their child(ren)'s bus service (Figure 3-2) and rated the safety of each transport mode to school as very safe, safe, not sure/neutral, unsafe, or very unsafe (Table 3-1). In general, parents reported they were satisfied with the school bus service, although about 15% of parents said that they were not satisfied with the service. Riding with an adult driver in an automobile was ranked the safest way to get to and from school, closely followed by riding the school bus. Walking and biking were ranked the least safe.

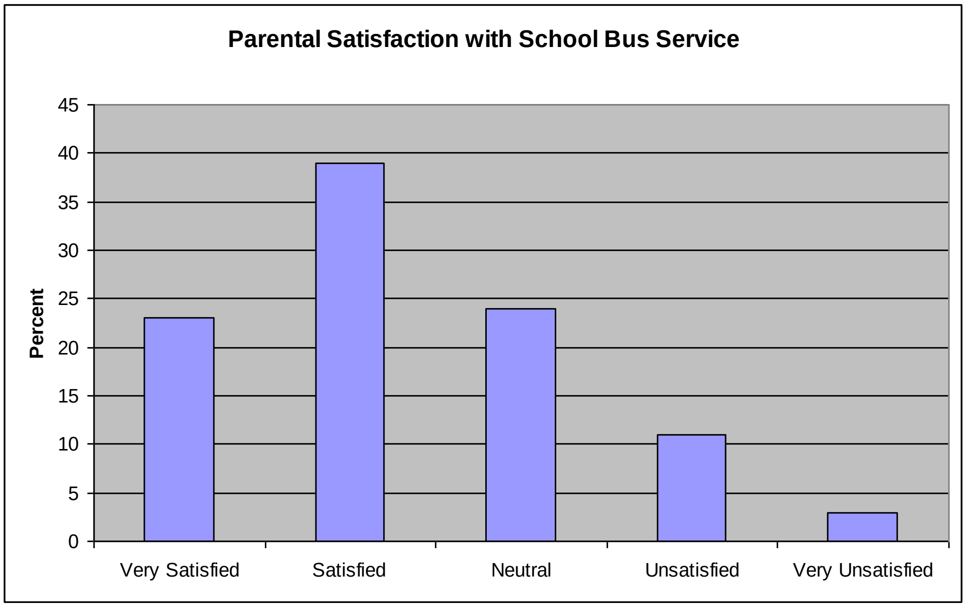

Figure 3-2. Parental Satisfaction with School Bus Service

Table 3-1. Safety Ratings of School Transport Modes

	Adult Driver	School Bus	Walk	Bike
Average (Mean)	1.61	1.84	3.12	3.08

Rating options: 1 = Very safe, 2 = Safe, 3 = Neutral or unsure, 4 = Unsafe

Questions were asked about how many vehicles each family owned and what type of vehicle—car, truck or minivan, or company truck. The car-type data was not used in any analyses in this study, although this data could be used for further analysis to model the effects of mode choice on the environment.

Travel patterns were asked to determine the extent of trip-chaining activities, including parent's work trips and other errands. We also asked whether the school trip is out of the way of the work commute if parents are commuting to work or if it was directly on the same route. They were also allowed to respond that they did not drop off or pick up their children. A significant percentage of parents drop off and pick up their children on the work commute. Table 3-2 presents the results from the survey.

There were several survey questions about opinions on school transport. Tables 3-3 and 3-4 show the results from the survey for both morning and afternoon trips.

Table 3-2. Parent Activity Route for Driving Child to or from School

Driving Route	Parent drives child on way to work	Parent drives child and returns home	Parent drives child and does errands/activities	Parent does not drive child/no response
Morning	35%	11%	4%	50%
Afternoon	23%	15%	7%	55%

Sample size: N = 850

Table 3-3. Opinions on Morning School Transport

	Bus ride is too long	Bus drop-off time is inconsistent	Bus stop too far from home	Bus drop-off time is too late	Bus not safe	Bus behavior is not monitored well enough	Child has after-school activities
N	760	752	752	762	770	776	714
Mean	2.96	3.47	3.80	3.17	3.23	2.76	2.97

Rating options: 1 = Strongly agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly disagree

Table 3-4. Opinions on Afternoon School Transport

	Bus ride is too long	Bus drop-off time is inconsistent	Bus stop too far from home	Bus drop-off time is too late	Bus not safe	Bus behavior is not monitored well enough	Child has after-school activities
N	761	752	754	756	773	773	740
Mean	2.97	3.58	3.69	3.38	3.21	2.74	2.23

Rating options: 1 = Strongly agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly disagree

A survey question asked parents to state which school transportation program they would support, allowing them to check more than one response. Figure 3-3 presents the survey results. The program choices were computerized routing systems (makes the system more efficient), automated GPS call-ahead service (calls you when the bus is close to your bus stop), walk and bike to school week (a designated week promoting these modes), school bus monitoring system (volunteers ride the bus to monitor behavior problems), sidewalk/safety improvement for walking/biking, and "other," which respondents were asked to explain. Some of the other programs that parents listed include bike paths, crossing guards, programs to encourage carpooling, video cameras on buses, seatbelts on buses, and age-divided (decoupled) bus routes.

We also asked how parents felt about the environmental impacts of automobiles versus the school bus. The majority of parents reported the school bus to be better for the environment, and very few parents believe that the automobile is better than a bus. But a surprising 37% of parents believe that there are no environmental differences between the two. Figure 3-4 presents these survey results.

The survey questions included the parent's relationship to the child, number of adult driver's licenses per household, household income, and education of self and spouse. Mothers accounted for 85% of the survey respondents, 13% were fathers, and 2% were a grandparent, guardian, or other. The average number of adult driver's licenses per household was 1.94.

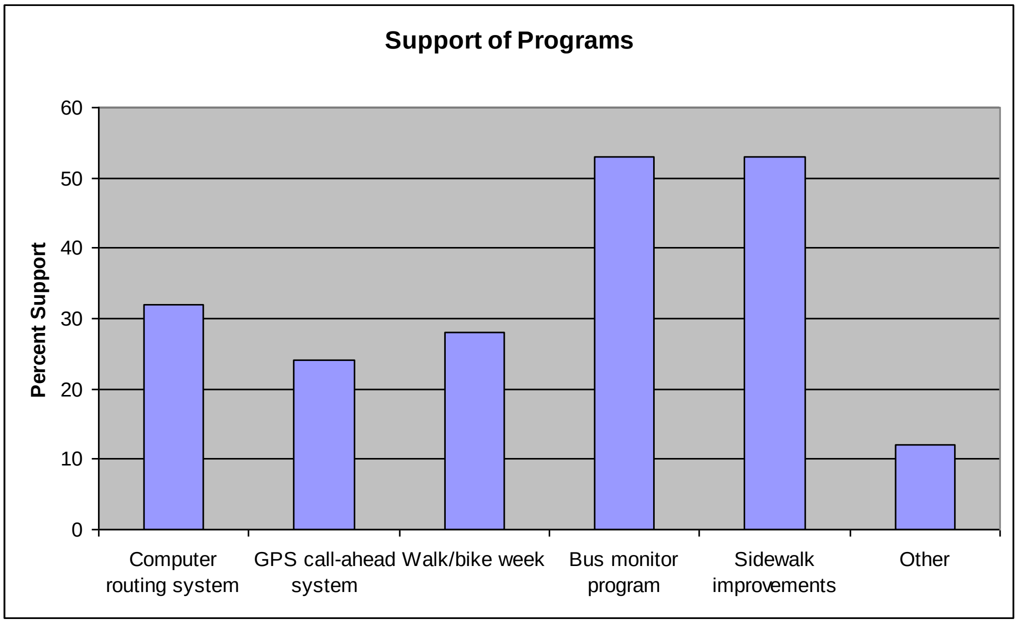

Figure 3-3. Parental Support of Various School Transportation Programs

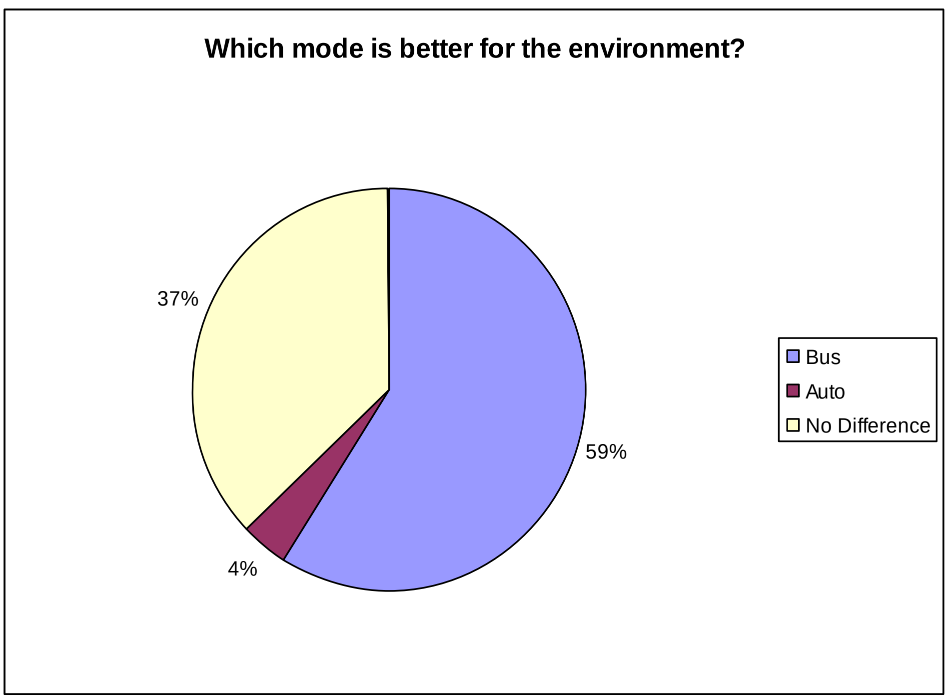

Figure 3-4. Parental Perception of How Mode Choice Affects the Environment

3.2 Survey Results for Mode Choice

The survey indicated that the majority of students are transported to and from school by the school bus. This was followed by parent-driven trips. After parent-driven trips, the "Other" category ranked next. This category represented automobile modes other than parent or guardian driven trips, including carpooling with another family and driving to school by themselves or with other students. A total of 6.1 % of children were transported to school in carpools with children of other families at least one day per week, and 2.4% of children carpooled every day to school. In the afternoon, 3.8 % of students were picked up in a carpool at least one day per week. Figures 3-5 and 3-6 present these survey results.

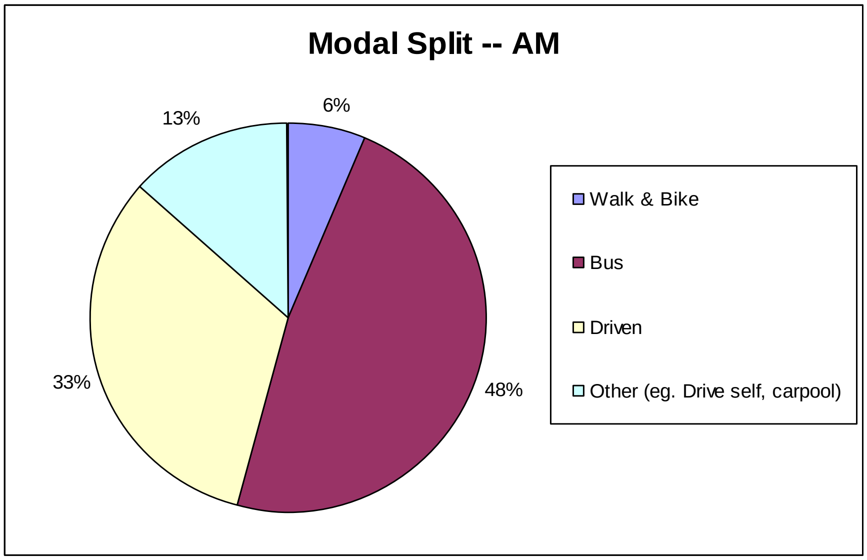

Figure 3-5. Modal Split for Transport to School in the Morning

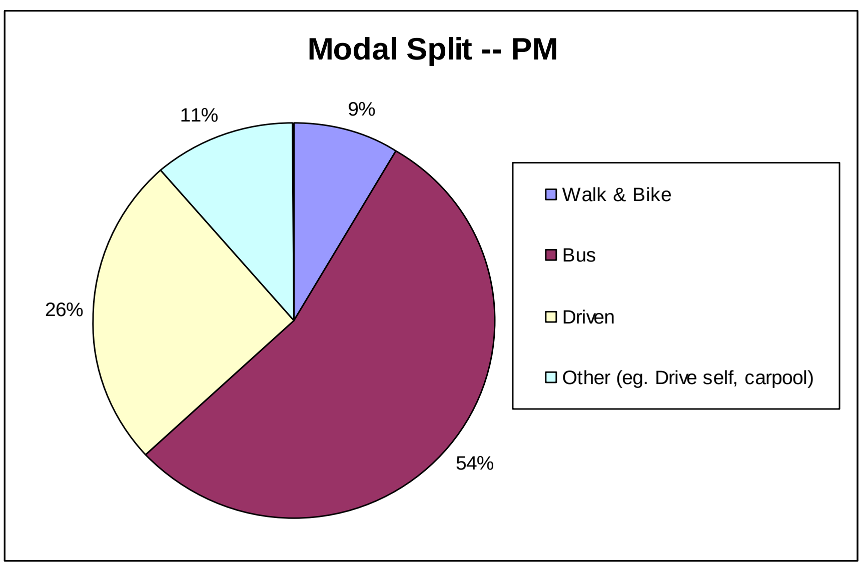

Figure 3-6. Modal Split for Transport to School in the Afternoon

Figure 3-7 presents SRTS data about modal split. This data was collected at SRTS participant schools for a statewide database developed by the Vermont Agency of Transportation. These schools have a few characteristics that may vary from other schools in Vermont. First, the schools are often located in an area that has the population density to support a fairly high rate of walking. Second, these schools actively promote walking and biking to school, through education programs and safety improvements. Third, several of the participant schools do not offer school bus service to some or all of their student body. Therefore, family vehicle, walking, and biking rates are higher and school bus usage rates are lower than the results in our research.

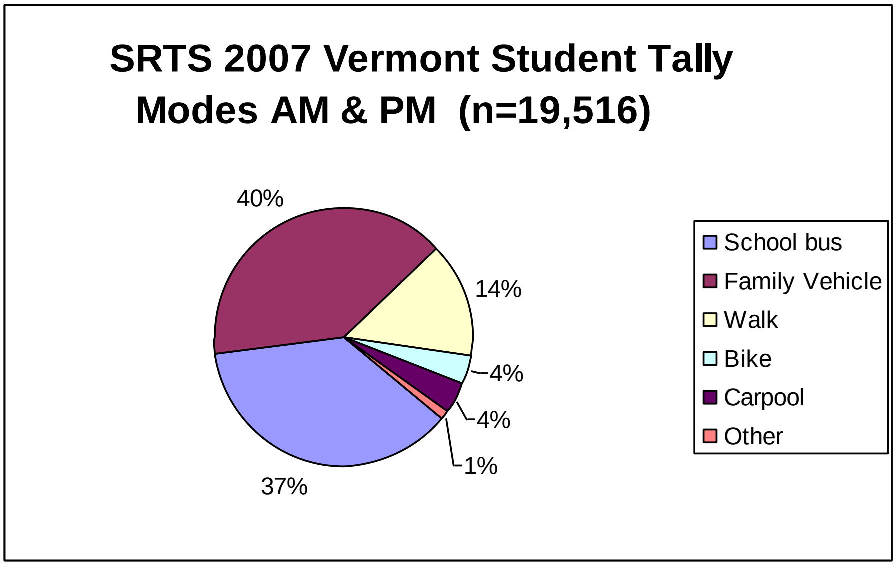

Figure 3-7. SRTS Survey Results (for Comparative Purposes)

3.3 Tally Counts at Schools

Trip data was obtained through student tallies for two schools within District One. Teachers at the schools asked the children which mode they used each day for one week. Figures 3-8 and 3-9 present the results of the tallies.

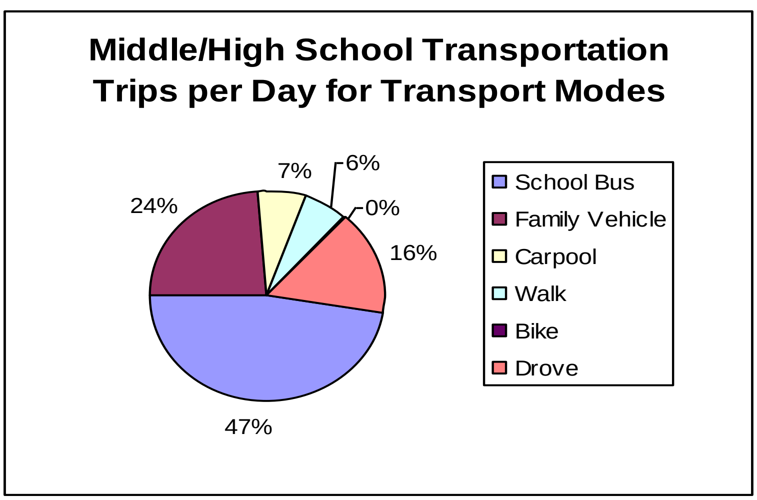

Figure 3-8. Middle/High School Modal Split

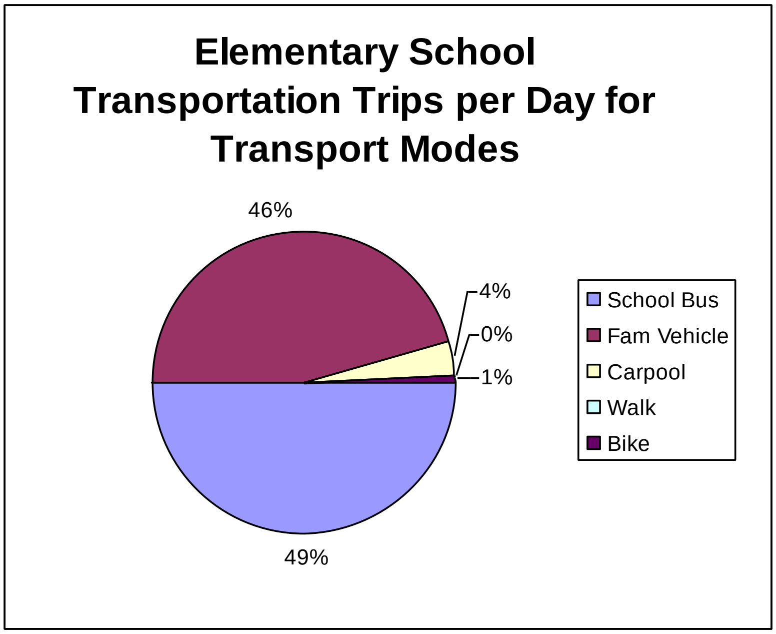

Figure 3-9. Elementary School Modal Split

The tally results at these two schools are similar to the survey results for certain modes. School bus transport was similar for both schools and almost identical to the survey results (49% for morning bus use). Family vehicles percentages were slightly higher for the elementary school and lower for the high/middle school because more of the older students drove themselves to school. For walking and biking, the results were similar to the survey, except for the elementary school. The school is located in a very rural location without a village within close proximity. Moreover, the school is located on a winding road with no crosswalk, making walking and biking potentially unsafe.

3.4 Traffic Count Results

Traffic counts were conducted at three schools, one elementary school in the urban District Three and two schools in the rural District One. Traffic counts were taken daily in both the morning and the afternoon for one week on the major street by the school. The traffic counts were gathered to examine the number of parent-driven trips. A full analysis of the effects of mode choice on traffic congestion is not part of this thesis. The results were used to verify survey results and helped guide survey design. The traffic count data was also provided to schools at which traffic counts were conducted.

For the morning, cars were counted exiting the schools because there was no method to differentiate between parents who would be dropping children off and school teachers who would be parking at the school. It was assumed that anyone exiting the school during a 30-minute period prior to the start of school was a parent/guardian who dropped off a child or children at school. For the afternoon, cars were counted entering the school parking lot. Traffic was counted in 5-minute intervals for 30-minute periods. Two-way street traffic was counted in both the morning and afternoon, providing the base to determine the percentage of traffic attributable to parent-driven school trips (Figure 3-10).

Traffic count results differed for rural and urban schools. Overall, in rural areas, parent-related traffic accounted for a higher percentage of the traffic, as these roads have much lower congestion levels. Rural school traffic constituted a higher percentage of overall morning traffic, while urban school traffic accounted for a lower percentage of the overall morning traffic. This is probably because the urban school is located near one of Vermont’s busiest intersections.

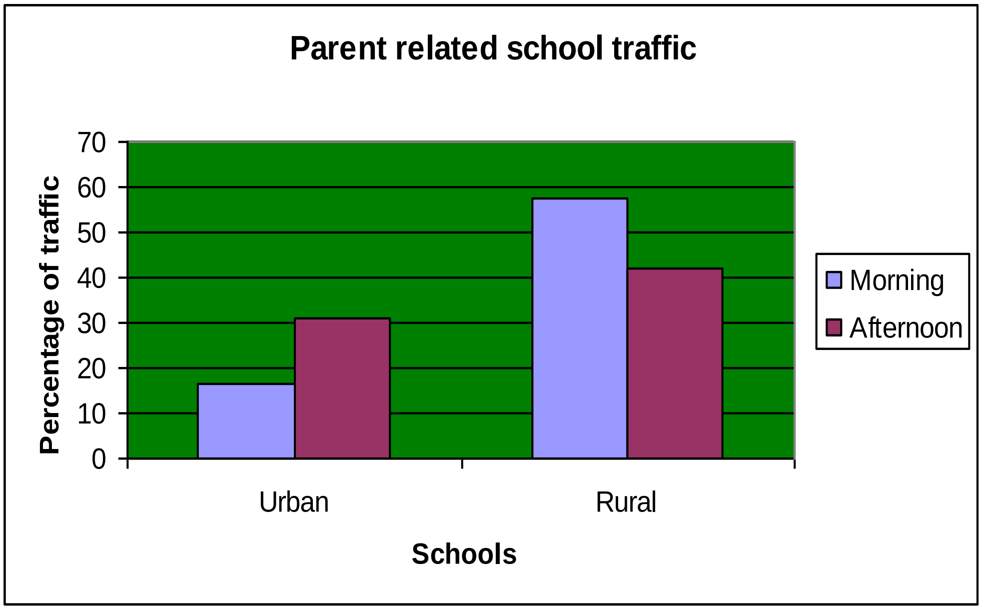

Figure 3-10. Percentage of Traffic Caused by Parent-Driven Trips

3.5 Parent-Driven Trips Model Results

Parent-driven trips were modeled for morning and afternoon. The following variables were formulated from the household survey data and considered in the model development:

A.M.-Dependent Variables:

First Hurdle Model: DrivenAM—a binary variable representing transport to school (1 = driven in family vehicle, 0 = other mode)

Second Hurdle Model: Y = number of times child is dropped off by family vehicle per week

P.M.-Dependent Variables:

First Hurdle Model: DrivenPM—a binary variable representing transport from school (1 = driven in family vehicle, 0 = other mode)

Second Hurdle Model: Y = number of times child is picked up by family vehicle per week

Independent Variables:

- Age: Age of student
- Gender: 1 = Female, 0 = Male
- Distance: The reported distance that a child lives from the school
- AdultLicense: Number of adult driver's licenses per household
- Education: Reported level of education (categories: less than high school, high school diploma or equivalency, some college or associates, bachelor's degree, or graduate or professional degree)
- Income: Reported household income before taxes for 2006 (categories: less than $24,999, $25,000–$34,999, $35,000–$49,999, $50,000–$74,999, $75,000–$99,999, more than $100,000)
- AutoBetterSame: Agreed that auto is the same as or better for the environment than bus
- NumberAuto: Number of automobiles per household
- AutoSafe: Rated family vehicle with adult driver as very safe or safe
- BusLong: Strongly agreed or agreed that bus travel time is too long
- Inconsistent: Strongly agreed or agreed that bus arrival time is inconsistent
- BusEarly/BusLate: Strongly agreed or agreed that bus comes too early in the morning (or late in the afternoon)
- BusStopFar: Strongly agreed or agreed that bus stop was too far from home
- BusNoSafe: Rated bus as unsafe or very unsafe
- BusBehavior: Strongly agreed or agreed that bus is not monitored well enough for behavior problems
- WalkNoSafe: Strongly agreed or agreed that walking and biking are not safe in the morning
- WorkCommute: Parents drop off child on the way to work
- A.M.Activity/P.M.Activity: Child has activities before or after school

Table 3-5 presents the double-hurdle model results for parent-driven trips. For the first hurdle logit models, the B coefficient and the exponentiation of B are listed. For the second-hurdle models, only the B coefficient is listed.

All variables were subject to correlation tests. No variables in these models had correlations with other variables above 0.50. Education and income were not highly correlated. For the first hurdle in the morning model, the overall predictability of the model was 76.3%, signifying that the model is correct at predicting mode choice about three-quarters of the time. For the afternoon model, the overall predictability of the model was 71.6%, indicating the model has the power to predict almost 72% of the cases correctly.

Table 3-6 presents a model summary and analysis of variance results for the second-hurdle models.
The double-hurdle model was analyzed first by examining the first hurdle results (if the mode was used or not) and then by examining the second-hurdle results (the frequency of modal use per week). If there were variables significant for both hurdles, these were assumed to be stronger than if the variable was significant in only one hurdle.

Table 3-5. Model Results for Parent-Driven Trips

Parent-Driven Trips	A.M.			P.M.		
	Logit First Hurdle		Regression Second Hurdle	Logit First Hurdle		Regression Second Hurdle
Independent Variables	**B Coefficient**	**Exp B**	**B Coefficient**	**B Coefficient**	**Exp B**	**B Coefficient**
(Constant)	**–3.508*** **	0.030	–0.811	**–2.60*** **	0.740	0.100
Age	–0.037	0.963	0.007	**–0.116*** **	0.890	**–0.069*** **
Gender	–0.024	0.976	–0.018	**0.551*** **	1.735	0.107
Distance	–0.028	0.972	**–0.057*** **	**0.050** **	1.051	0.019
AdultLicense	0.024	1.274	**0.439*** **	–0.006	0.994	**0.288* **
Education	**0.249** **	1.283	0.089	0.156	1.169	0.065
Income	–0.026	0.974	0.007	0.055	1.056	0.015
AutoBetterSame	**.704*** **	2.022	**0.648*** **	0.111	1.118	**0.392*** **
NumberAuto	–0.136	0.873	**–0.146** **	–0.095	0.910	**–0.127** **
AutoSafe	**1.719** **	5.580	**0.697** **	**1.766*** **	5.909	**0.709** **
BusLong	0.307	1.359	0.254	0.384	1.469	**0.513*** **
Inconsistent	0.312	1.366	–0.021	–0.148	0.862	–0.013
BusStopFar	**1.991*** **	7.321	**1.295*** **	**0.923*** **	2.516	**0.690*** **
BusEarly/ BusLate	**0.750*** **	2.118	**0.378** **	0.103	1.109	0.124
BusNoSafe	–0.235	0.790	–0.101	0.169	1.184	0.187
BusBehavior	0.117	1.124	**0.325** **	0.067	1.069	0.129
WalkNoSafe	–0.265	0.768	–0.099	–0.276	0.759	–0.169
WorkCommute	**1.995*** **	7.349	**1.725*** **	**1.384*** **	3.933	**1.488*** **
A.M.Activity/ P.M.Activity	–0.246	0.782	**–0.446*** **	**0.815*** **	2.259	0.214

* Significant at 90% ** Significant at 95% *** Significant at 99%

Table 3-6. Second-Hurdle Summary: Parent-Driven Trips

	R Squared	F	Sig.	N
A.M. Days driven	0.314	19.030	0.000	767
P.M. Days driven	0.226	11.367	0.000	719

Key Findings:

- Parents chauffer children to school more if they believe that cars are better than school buses or the same as school buses for the environment.
- Parents who drive their children to school rate family vehicle as a very safe way to travel to school.
- Parents are more likely to drive children to and from school, and to do so more often, if they are dropping off on the work commute.
- Parents drive their children more often if they feel that the school bus stop is too far from home.
- Parents who drive children to school feel that the bus comes too early in the morning (they value additional morning time with the children).

- Age is a factor in the afternoon; the younger the child, the more likely he or she is to be picked up by parents.

Unusual/Inconsistent Findings:

- Distance was not a strong variable, but the findings were different for morning and afternoon. In the mornings, the farther the child lived from school, the less likely he or she was to be driven often by parents. In the afternoons, the farther the child lived from school, the more likely he or she was to be picked up by parents.

- The more cars a family has, the less likely the family is to drive children to school.

- Children who have morning activities are less likely to be dropped off at school frequently; children who have afternoon activities are more likely to be picked up at school.

Nonsignificant Variables:

- Income
- Parental perception that the school bus is not safe
- Walking/biking are not safe
- Bus drop-off/pickup time is inconsistent
- Education was significant only in the A.M. logit model
- Gender was significant only in the P.M. logit model

For morning school transport, several variables were significant in the binary logit model. The AutoBetterSame variable was a significant factor. Parents who said they believe cars to be better or the same as school bus use for the environment were more likely to drive their children to school.

Interestingly, the higher the number of automobiles per household, the less likely the children were to be driven to and from school. This result could be due to problems with the models or with factors that were not captured in the model.

Safety was a factor in morning mode choice decisions; SafeCAR was significant with a coefficient value of 1.719. Parents who rated the automobiles as a very safe or safe way to get to school were 4.58 times (458%) more likely to drive their children.

Attitudes about the school bus were also significant variables. The bus coming too early in the morning affected the decision to chauffer children to school, as did the bus stop being too far away from home. If parents felt that the school bus stop is located too far from home, they were more than six times more likely to drive children to school.

In both the afternoon and the morning, parents are more likely to chauffer on the work commute. In the morning, parents are more than six times more likely to drop children off at school if doing so on the work commute, and in the afternoon they are almost three times more likely to pick children up if returning from the work commute.

The multiple regression model used the same independent variables, but to predict the number of parent-driven trips per week for students who are dropped off by parents at least once a week. The same variables that were significant and also had the same direction of the coefficient were AutoBetterSame, AutoSafe, NumberAuto, BusStopFar, BusEarly, and WorkCommute. These significant variables in both models suggest that the choice of whether or not to drive a child to school at least once a week has the same impacts on the number of days a child is driven to school.

Factors that were significant for the number of parent-driven trips per week that were not significant in the logit model were Distance, AdultLicense, NumberAuto, A.M.Activity, and BusBehavior. The farther a child lives from school, the less likely the parents were to make frequent trips to the school. The number of household driver's licenses was also positively correlated with the dependent variable; the more licenses per household, the more likely children were to be frequently escorted to and from school. The perception that the bus is not monitored well enough for behavior problems also affected the number of days a child was driven to school, but for the morning model only. Not significant for first and second A.M. hurdle models were Age, Gender, Income, BusLong, Inconsistent, and perceptions of safety (BusNoSafe and WalkNoSafe).

The results for the afternoon also revealed several variables that are significant in predicting the parent-driven mode. Unlike the A.M. models, Age had a negative coefficient and was significant in both P.M. hurdles. The younger the child, the more likely and frequently parents are to chauffeur children from school. Gender became significant for the afternoons but only in the logit first-hurdle model; girls were more likely to be picked up than boys. Distance was significant only in the logit model, and the Exp B coefficient was almost equal to 1 (Exp B = 1.051), indicating a negligible effect (1.051 – 1 = 0.051, or 5.1%). The multiple regression model for the second hurdle did not indicate distance to be significant in the afternoon, meaning that the number of days that parents pick up children at school is not affected by how far they live from school. AdultLicense was significant only in the second hurdle, suggesting that children who are picked up frequently live in households with a higher number of adult licenses. Education was not significant in the afternoon model.

In the P.M. models, like in the A.M. models, parents' beliefs about the environment were significant, but only in the second hurdle. Also like the A.M. model, the number of automobiles per household was negatively correlated with the number of days children are picked up at school.

Safety perceptions were an additional factor in the afternoon models. Parents who rated the family vehicle as a safe or very safe way to get to and from school were almost six times more likely to pick up their children at school. Perceptions of bus and walking/biking safety were not significant variables.

Certain variables about perceptions of the school bus were significant. Parents pick children up more frequently at school if they believe that the school bus ride is too long in the afternoon. For both P.M. hurdle models, parents' perceptions that the school bus stop is too far from home contributed to the decision to pick up children at school. WorkCommute was also a significant variable in the first and second hurdle. Finally, afternoon activities affect the likelihood of parents picking up their children at least one day per week, but this variable was not significant for the number of days picked up by parents. Children who attend after-school activities are more likely to be picked up at least one day per week by their parents. This would make sense, considering that after-school programs, sports, and classes are often held at school.

There were several variables not significant in either P.M. double hurdle. For instance, neither income nor education were significant in either afternoon model. The perceptions that the school bus arrives in the afternoon at inconsistent times or that the drop-off time is too late were also not significant. Interestingly, bus behavior was not a significant variable in the afternoon, despite dozens of comments by parents in the survey about their displeasure with the behavior on the school bus. (In fact, in the survey, parents hypothetically supported the idea of a bus monitoring program more than any other program.) Finally, bus operational safety and the safety of walking/biking were not significant in either afternoon model.

There were differences and even inconsistencies between the factors that contribute to the choice of taking a particular mode at least once a week and the factors that determine the number of days per week that the mode is used. This could be the result of weaknesses in the models, or it could reflect the distinction between the two models. However, it is apparent that many children use more than one mode per week, so the reasons behind the decision to use a mode at least once a week may differ from the reasons that a particular mode is chosen more frequently. For example, the models indicate that an afternoon activity is a reason for parents to pick up a child at least once a week (first hurdle) but not a reason to pick up a child frequently (second hurdle).

There were, however, several similarities between the models. Parents' commute to work was the most consistent variable in both models. Parents are much more likely to drop off and pick up their children if they do so on the work commute route. Other consistent factors were parents' perceptions about the environment. Parents were more likely to drive their children if they felt that driving an automobile for school transport was better or the same for the environment as the school bus. This may be because they are justifying their choice, yet it may be worth further research investigation into this issue. Education about the differences between the effects of mass transit and of automobile travel on the environment may be useful if schools are interested in decreasing parent chauffeuring or promoting bus ridership.

Safety ratings of the modes for school transport also were effective predictors of mode choice. Overall, if parents felt that the car was safe or very safe, they were more likely to drive their children to and from school.

Perceptions of the school bus affected parents' choice to drive and the number of days children are driven. The perception that the bus stop is too far from home was the only perception of school bus transport that was consistent in both A.M. and P.M. double-hurdle models. Interestingly, this may indicate that time-savings and convenience (and possibly safety factors) outweigh parents' desire for children to walk to and from the school bus stop.

Although not significant in the afternoon models, the bus coming too early in the morning was another factor affecting parent-driven trips. With busy morning schedules, a bus pickup time that is too early may deter using automobile alternatives. Given long walks to the school bus stop, an early pickup time, and a long bus ride, one parent remarked in the survey that dropping his/her children off at school meant they could leave almost one hour later in the morning than if they took the school bus.

This leads to the conclusion that it is the convenience of the automobile more than any other factor that influences parent-driven trips to school. In the case of school transport, convenience entails several factors including parent commute trips, valuable morning time, and long walks to the bus stop that take extra time.

If communities are interested in decreasing the amount of school-related traffic for reasons of traffic congestion or the environment, it may be beneficial to consider programs that are aimed at promoting alternative modes such as riding the school bus, walking, biking, and carpooling. Educating parents about the trade-offs between the environment or traffic congestion and convenience may prove useful in decreasing the popularity of the parent-driven trip for school transport. Further policy recommendations are provided in s Section 4.3.

3.6 School Bus Model Results

The school bus mode is modeled with the same double-hurdle model used for parent-driven trips. Two double-hurdle models (one for trips to school in the morning and one for trips from school in the afternoon) are developed for the school bus mode. The first hurdle is a binary logit model (1 = takes school bus at least one day per week; 0 = does not take school bus) and the second hurdle is a multiple regression model (for the number of days that the school bus was taken per week).

The same variables as in the parent-driven trip models were used, with the addition of one new variable, LiveClose. This variable represents children who live one mile from school. These children live on the edge of what is considered to be a practical walking distance to school (McDonald, 2008). All variables were subject to correlation tests, and no variables in these models had correlations with other variables above 0.50. For the first hurdle for the morning model, the overall predictability of the model was 71.5%. For the afternoon model, the overall predictability of the model was 72.7%. These models have the power to predict more than 70% of the cases correctly.

Table 3-7 presents a model summary and analysis of variance results for the second-hurdle models. Table 3-8 presents the results for morning and afternoon double-hurdle models. For logit models, the B coefficient and the exponentiation of B are provided.

Table 3-7. Second-Hurdle Summary: School Bus Trips

	R Squared	F	Sig.	N
A.M. Days bus taken	0.280	15.297	0.000	765
P.M. Days bus taken	0.146	6.306	0.000	718

Distance was a significant factor affecting the frequency of school bus use. The greater the distance that a child lives from school, the more likely it is that he/she will take the school bus. Age was also significant, as younger children tend to take the school bus less often than older children. In the morning, the number of household adult driver's licenses was a factor; the fewer the licenses, the more likely the bus is to be taken to school. Education was also significant in morning and afternoon models. Children take the bus less frequently if the parent who completed the survey reported a higher education level.

Children are more likely to take the school bus if parents believe that the bus is better than a car for the environment. This may not be a cause behind the choice to take the school bus, but it was a significant factor in the model. The parent-driven trip model indicated that parents who drive their children are more likely to believe that there is no difference between the two modes. Perhaps this is a justification, rather than a cause, for using the mode, but it could be a causal factor in mode choice.

Safety perceptions were also significant. Parents were more likely to rank adult-driven trips lower for safety if their children took the school bus. If parents felt that walking and biking to school were unsafe, they were 100% more likely to have their children take the school bus.

Table 3-8. Model Results for School Bus Trips

School Bus Trips	A.M.			P.M.		
	Logit First Hurdle		Regression Second Hurdle	Logit First Hurdle		Regression Second Hurdle
Independent Variables	**B Coefficient**	**Exp B**	**B Coefficient**	**B Coefficient**	**Exp B**	**B Coefficient**
(Constant)	**4.137*** **	62.65	**6.290*** **	**2.078*** **	7.989	**4.507*** **
Age	**–0.139*** **	0.871	**–0.137*** **	**–0.110*** **	0.896	**–0.075** **
Gender	0.034	1.035	0.024	0.080	1.084	–0.035
Distance	0.134	1.144	**0.095*** **	**0.120*** **	1.128	**0.064** **
AdultLicense	**–0.499** **	0.607	**–0.411** **	0.023	1.024	0.113
Education	**–0.224** **	0.799	**–0.230** **	–0.133	0.875	**–0.186***
Income	0.055	1.057	0.059	–0.016	0.848	0.011
AutoBetterSame	**–0.797*** **	0.451	**–0.622*** **	**–0.554*** **	0.575	**–0.485** **
NumberAuto	**0.171***	1.186	**0.143** **	**0.240*** **	1.271	**0.189** **
AutoSafe	**–1.097** **	0.334	**–1.093*** **	–0.748	0.473	**–1.241*** **
BusLong	–0.0205	0.814	–0.095	**–0.545*** **	0.580	–0.315
Inconsistent	0.294	1.342	0.190	–0.109	0.896	0.173
BusStopFar	**–0.0891*** **	0.410	**–0.988*** **	**–0.423**	0.655	**–0.531***
BusEarly/ BusLate	**–0.0784*** **	0.457	**–0.853*** **	–0.241	0.786	–0.281
BusNoSafe	0.122	1.130	0.188	–0.178	0.837	0.032
BusBehavior	0.045	1.046	0.091	**0.437*** **	1.548	**0.361** **
WalkNoSafe	**0.697*** **	2.009	**0.670*** **	**0.507*** **	1.660	**0.571*** **
WorkCommute	**–1.537*** **	0.215	**–1.645*** **	**–1.183*** **	0.306	**–1.157*** **
A.M.Activity/ P.M.Activity	0.709	2.032	**0.469*** **	**0.570*** **	1.769	0.101
LiveClose	–0.259	0.772	–0.238	0.015	1.015	0.006

* Significant at 90% ** Significant at 95% *** Significant at 99%

The number of automobiles was a significant factor. Interestingly, the more cars and trucks per household, the more likely it is for children to use the school bus. Income was not a significant variable in any model in this study, but income was correlated with the number of cars per household: the more cars, the lower the income.

Perceptions of the school bus were significant, but with many opposite results from the parent-driven trip models. Children who ride the bus more often have parents who are more likely to disagree that the bus ride is long, the bus stop is too far, or the bus comes too early/too late. Interestingly, these same parents, whose children take the bus more often, agree that children have bad behavior on the bus in the afternoon.

Not surprisingly, children take the bus more often if their parents are not dropping them off on the work commute. Children in this model are more likely to take the bus if they have a before-school or after-school activity. This could be due to the amount of time between school and bus arrivals/departures. For example, several schools have brief before-school programs where children can take the school bus, go to the activity for about 30 minutes, and then begin the school day. One example of this is the music program at Thatcher Brook Primary School, which offers before-school music lessons. Many schools in this district also have after-school activity buses. It was not specified in the survey if students were taking the bus directly after school or if they were taking it after an activity. In future surveys this difference should be specified.

3.7 Walk and Bike Model Results

A combined walking and biking mode was also modeled with the double-hurdle model. In the survey, walking and biking modes were separated, but because the percentages were small they had to be combined into one mode. Two double-hurdle models (one for walking or biking trips to school in the morning and one for trips from school in the afternoon) are developed for the walk/bike mode. The first hurdle is a binary logit model (1 = walks or bikes at least one day per week; 0 = does not walk or bike) and the second hurdle is a multiple regression model (for the number of days that a student walks or bikes to school per week).

None of the variables in the models had correlations with other variables above 0.50. For the first hurdle for the morning model, the overall predictability of the model was 93.6%. For the afternoon model, the overall predictability of the model was 91.5%. These models predicted more than 90% of the cases correctly.

The second-hurdle results are presented in Table 3-9. The R squared value is relatively low and therefore the regression models do not have a high predictability power.

Table 3-9. Second-Hurdle Summary: Walk/Bike Trips

	R Squared	F	Sig.	N
A.M. Days walked/biked	0.341	19.315	0.000	766
P.M. Days walked/biked	0.184	8.328	0.000	719

Model results for school bus trips are provided in Table 3-10. Although the overall R squared results were fairly low for the second-hurdle models, there are many significant variables. For first-hurdle logit models, the B coefficient and the exponentiation of B are provided. For second-hurdle regression models, the B coefficient is provided.

The models found that children are more likely to walk and bike to school the older they are. This is a common finding in the literature pertaining to walking and biking to school (McDonald, 2005; Vovsha and Petersen, 2005; Zwerts and Wets, 2006).

Distance was a factor in morning and afternoon models. This is consistent with many studies in the literature (McDonald, 2005; Ewing et al., 2004). The farther a child lives from school, the less likely he or she is to walk or bike. The logit results suggest that a child is less than half as likely to walk or bike to and from school the farther they live from school (Exp B = 0.373 in A.M. model and Exp B = 0.449 in P.M. model). The variable

LiveClose was not significant in the models. Therefore, no conclusions can be made about children who live on the edge of the acceptable walking distance.

Children who live in households with fewer driver's licenses are more likely to walk to school. Yet parents who reported higher education levels were more likely to have their children walk or bike, but only in the morning. Most parental perceptions of the school bus were not significant, with the exception of school bus behavior. Parents who disagreed that bus behavior was poor were more likely to have children who walk to school. For the morning logit model, children were 136% more likely to walk or bike to school if the parents agreed that the school bus comes too early in the morning (Exp B = 2.363).

Parents who disagreed that walking and biking are unsafe were also more likely to have their children walk and bike to school. This is an important finding because it indicates that parents are more likely to allow walking and biking to school if they feel that these modes are safe. Safety programs would be essential to increase walking and biking rates.

Table 3-10. Model Results for Walk/Bike Trips

Walk/Bike Trips	**A.M.**			**P.M.**		
	Logit First Hurdle		**Regression Second Hurdle**	**Logit First Hurdle**		**Regression Second Hurdle**
Independent Variables	B Coefficient	Exp B	B Coefficient	B Coefficient	Exp B	B Coefficient
(Constant)	0.783	2.198	0.425	0.345	1.412	1.556
Age	**0.82****	1.085	**0.020****	**0.120*****	1.128	**0.043*****
Gender	–0.257	0.773	0.002	0.023	1.023	–0.021
Distance	**–0.987*****	0.373	–0.011	**–0.801*****	0.449	**–0.103*****
AdultLicense	**–1.454*****	0.234	**–0.290*****	**–0.692****	0.500	**–0.379*****
Education	**0.303***	1.355	**0.087****	**0.289****	1.335	0.108**
Income	0.101	1.106	0.018	0.070	1.072	–0.001
AutoBetterSame	–0.360	0.697	0.055	0.086	1.090	0.071
NumberAuto	–0.050	0.951	–0.022	**–0.256****	0.774	**–0.126*****
AutoSafe	0.237	1.267	–0.132	–0.607	0.545	–0.158
BusLong	–0.006	0.994	–0.110	0.186	1.204	–0.123
Inconsistent	0.179	1.197	0.015	0.474	1.606	0.121
BusStopFar	–0.499	0.607	–0.125	**1.257****	3.516	0.193
BusEarly/ BusLate	**0.860****	2.363	0.131	–0.796	0.451	–0.093
BusNoSafe	**0.791***	2.205	–0.197	–0.153	0.859	–0.105
BusBehavior	–0.457	0.633	**–0.143***	**–0.736****	0.479	**–0.292*****
WalkNoSafe	**–1.675*****	0.187	**–0.230*****	**–1.275*****	0.279	**–0.334*****
WorkCommute	0.540	1.716	–0.082	0.279	1.322	–0.036
A.M.Activity/ P.M.Activity	–0.681	0.506	–0.067	0.085	1.089	**–0.172***
LiveClose	–1.703	0.182	–1.456	–0.323	0.724	0.191

* Significant at 90% ** Significant at 95% *** Significant at 99%

4. Summary and Conclusions

Sections 1 and 2 of this chapter summarize the research project and major findings, Section 3 presents the major recommendations, and Section 4 discusses the major limitations of this study and suggestions for further research.

4.1 Summary of the Research

This study was conducted to identify the factors that contribute to mode choice for school transportation and to derive recommendations for improving school transportation efficiency. A parent survey was designed and conducted to collect primary data in three school districts in Vermont. The survey includes questions about how each student goes to school in the morning and comes home in the afternoon as well as questions on demographic information and perceptions about school transportation. The survey data was used to estimate econometric models for identifying the factors that affect mode choice and the frequency of using each of the three major modes: parent-driven trips, school bus trips, and walk/bike trips. Double-hurdle models, with a binary logit model and a linear regression model, were estimated for morning and afternoon for each mode. Several significant variables in the models, for example, perceptions of safety, convenience, and the environment, affect mode choice for school transport. Such factors as distance and age of the child also appear to contribute to mode choice.

4.2 Major Findings

Many of the results from this study support findings from the literature. This study found that older children are more likely to walk and bike than younger children. These results are consistent with several other studies (McDonald, 2005; Zwerts and Wets, 2006). This study also supports the findings that older children are less likely to be escorted by parents both to and from school (Vovsha and Petersen, 2005). Although an analysis of student age and school bus mode choice was not found in the literature, this study found that younger children tend to take the school bus less often than older children, which is logical if younger children are driven more often than older students.

The role that distance plays in mode choice for school transport was also consistent with findings of other studies. The research shows that, with increasing spatial separation between school and home, motorized modes (auto and bus) are preferred more (Zwerts and Wets, 2006; DiGuiseppi et al., 1998) and nonmotorized modes (walk and bike) are preferred less (McMillan, 2005; McDonald, 2005; Zwerts and Wets, 2006; Ewing et al., 2004).

This study also found that the greater the distance a child lives from school, the more likely it is that the child will take the school bus and the less likely it is that he or she will be driven to school. A thorough analysis was not found in the literature for the relationship between distance and school bus use. Rhoulac's study (2005) did not find distance to be a significant factor for auto or school bus mode choice. Many research studies have not included distance or travel times in models because their inclusion has led to highly unstable models (Ewing and Greene, 2003).

The significance of convenience factors on mode choice in this study is consistent with other research. Rhoulac (2005) and McDonald (2008) found that convenience was major reason for choice of school transport mode. "The classic choice of car or bus thrives as commuters decide between the perceived convenience of their personal automobiles and the alternatives" (Rhoulac, 2005, p. 98). The fact that many parents transport children to and from school on the work commute makes the automobile mode a much more convenient choice. Rhoulac considered perceptions of the school bus, other than those of safety, to be a factor of convenience, including long bus rides and inconsistent arrival times. Our study found that inconsistent bus arrival times were not a factor in any of the models.

Findings of safety in this study indicate that parents are more likely to chose a mode and use that mode frequently if they feel the mode is safe. Even for biking and walking, parents were more likely to allow their children to walk to and from school if they rated walking or biking as a safe way to get to school. Other studies also indicated that parents' perception about the safety of a mode positively influences the choice of the corresponding mode for school trips (Rhoulac, 2005; McMillan, 2005).

The number of adult driver's licenses per household was a significant factor in this study. In general, the more adult licenses per household, the more likely it was that a child would be driven to school; the fewer adult licenses per household, the more likely it was that a child would take the school bus, walk, or bike. Other studies have examined the effect of a household having a license or not, rather than the effect of the number of licenses. One study found that children are more likely to use the school bus if no adult in the household has a driver's license and much less likely to take the school bus if an adult in the household has a license (Ewing et al., 2004).

There are a few findings within this study that differed from other research studies. These differences may be the result of differences in the study area; this study was conducted primarily in rural areas, whereas most school transportation research has been conducted in urban areas.

Gender was not a significant variable in most of the models in this study, indicating that gender does not play a role in travel choices. Other national research has found that gender is a significant factor in mode choice for school transport. One study found that girls are less likely to walk or bike and more likely to be driven (Zwerts and Wets, 2006).

Income and education also varied from other studies. Although this study indicated that income did not influence mode choice for school transport, other studies have found income to be significant (Ewing et al., 2004; McDonald, 2008). Education was a partially significant variable, yet results differed from other national studies. This study found that children of higher-educated parents are more likely to walk, the opposite of McMillan's 2005 findings.

This study found unusual results for the number of reported household automobiles. One study suggests that car ownership can act as a proxy to income (Black et al., 2001), but this study found that car ownership was inversely correlated with income. This study found that the more automobiles there were per household, the more likely a student would be to take the school bus and walk, and the less likely to be driven to school by parents. An important difference in this study is that it was conducted primarily in rural populations in a state with fairly low population density. A few other studies have examined the relationship between population density and car ownership. Sangi (1979) found that population density could explain 64% of the variation in car ownership rates. Other studies have shown that car ownership levels were not adequate socioeconomic indicators because more poor rural households own cars than poor urban households (Pucher and Renne, 2005). One study indicated that 25% of rural poor had two or more cars per household compared to only 8% of urban poor (Pucher and Renne, 2005).

Environmental perceptions about mode were found to be a significant variable in the mode choice models. One major school mode choice study by Black et al. (2001) examined how perceptions of the environment affect mode choice. Black's study found that changes in environmental awareness have less impact than changes in other attitudes and that environmental awareness may be less influential as a policy focus. The results of this study find that environmental perceptions affect mode choice. Parents are more likely to drive their children if they do not believe there is a major environmental difference between school bus and personal automobile, and children are more likely to take the school bus if their parents believe that the school bus is better for the environment. Although this could be a justification of mode choice more than a causal factor, it certainly warrants further studies on the subject, such as a study of environmental awareness programs on mode choice for school transport.

4.3 Recommendations

The trend of using a private vehicle for school transport has altered school transportation in several ways.

First, there has been an increase in parent-driven trips and a decrease in walking to and from school. Second, if school buses are servicing a school district with regular routes, and parent-driven trips are continuing to increase, it could be assumed that bus ridership numbers are decreasing. Yet most school districts in Vermont and in other less urban areas of the United States offer bus service. Although minimizing the number of routes could result in financial savings for school districts, many of these districts run school bus routes regardless of ridership numbers. Considering the overall efficiencies of the transport system, minimizing parent-driven trips in private vehicles would likely improve the overall efficiency of the school transportation system.

However, schools are currently faced with dramatically rising fuel costs. If schools are aiming to minimize school transport costs by reducing bus service, this study could also be applicable. The survey tool gathered information on all school transport modes, including carpooling. In rural areas with few children, it could be a cost-effective solution to promote carpooling rather than provide bus service that has minimal ridership numbers. This solution unfortunately does not consider equity issues for families; for example, carpooling may be a hardship for some families on limited incomes or without work flexibility or access to automobiles. Before eliminating school bus services, schools should carefully consider equity issues.

Another cost-saving option for schools is to acquire smaller, more fuel-efficient buses and vans. If more children began to walk, bike, or carpool to school, there may be further reductions in the numbers of bus riders. This reduced number of riders may make smaller buses and vans a feasible school transportation choice.

Besides eliminating school bus service, which is not a practical solution in many rural areas such as in Vermont, efficiencies could be achieved with computer applications for bus routes. When presented with a list of programs and asked which ones they would likely support, 30% of parents indicated that they would support computerized routing programs. Routing programs can allow schools to program routes on the basis of specific schedules and modes used by individual students. For example, if a child lives at the end of a route and never takes the bus home on Wednesdays because of an after-school activity, the bus can be routed differently that day to save fuel.

With skyrocketing diesel fuel prices, school districts throughout the United States are being forced to make difficult choices about school transportation. Many school bus districts have voluntarily eliminated idling, and Vermont and some other states have passed laws to ensure that idling does not occur. Other schools have consolidated, rerouted, and trained drivers in fuel-efficient practices. Some areas have turned to more drastic measures, cutting bus service, eliminating routes, creating longer walks to bus stops, eliminating sports and activity trips, and even closing schools for one to two days per week to conserve fuel costs (www.stonline.com).

As fuel prices continue to rise, there could possibly be a reversed trend in school transportation, with an increase in walking, biking, and bus ridership. This could reduce carbon emissions and air pollution, minimize traffic congestion, and, in the case of walking and biking, improve public health, but schools will nonetheless need to find new ways to fund school bus service. Federal support, in the form of Congestion Mitigation and Air Quality Improvement (CMAQ) funding or other congressional bills to assist school districts, may become necessary.

Two questions to consider for policy recommendations are, How do you change behavior? and What is the goal of the behavior changes? Depending on what a state or school is interested in achieving, different policies could be recommended. Behavior changes can be difficult to achieve. There are social marketing campaigns and programs aimed at promoting safety and shifting modal use (e.g., transportation demand management programs such as carpooling initiatives). For school transport, there are programs aimed at promoting walking and biking (e.g., Safe Routes to School, the Walking School Bus). Yet programs aimed at shifting modal use directly away from using personal automobiles are rare. The challenges to overcoming America’s car-centeredness are staggering.

In Scotland, the Scottish School Travel Advisory Group (Scottish STAG) was established in August 2000 with the objective of increasing the proportion of noncar travel to school. A report from this group suggests that shifting people away from personal car use is very difficult; however, similar regional or state advisory councils would be helpful to decrease car travel. Without such an effort it would be difficult to encourage change in school transport trends on a broad level.

For schools and communities, goals may differ. Many schools face budget issues, and school bus transportation is a high expense. Nationally, school districts in rural areas spend twice per pupil what urban districts spend on school transportation (Killeen and Sipple, 2000). Perhaps a better solution for schools would be to reduce costs by using smaller school buses or vans, reducing route numbers and lengths, and even eliminating some or all school bus service. This would have a significant impact on some families, particularly families without cars or the flexibility to drive their children to school or have their children walk or bike to school. School bus efficiency systems, such as computerized routing programs, can eliminate wasteful trips and help keep costs down. If bus service is minimized or eliminated, an organized carpool system might help families that relied on bus service.

There are urban areas in the United States that do not offer school bus service. Vermont's largest city, Burlington, does not provide extensive school bus service, and many smaller cities, including Montpelier, do not offer school bus service to children that live within one mile of the school. The choices for school transport in urban areas when school bus transport is not offered are walking, biking, carpooling, or using a family vehicle or public transport.

A more complex solution to the high expense of bus transport for schools would be to consider the use of public transit service for school transport. The combination of school bus and rural transit service is already occurring in Iowa. Vermont has very limited rural public transit service, and this approach could be a major asset to the state, bolstering public transit services while providing school transportation. Children who live in urban areas take public transit to get to school, including in Vermont's largest city, Burlington. If children who live in cities can take public transit, why is this not more common in rural areas?

Because of school bus safety laws in the United States, there are many legal and regulatory procedures that create serious barriers to combining public transit and school bus operations, including vehicle design standards; federal, state, and regional safety guidelines; driver qualifications; and Americans with Disabilities Act requirements (Transportation Research Board, 1999). If these regulations could be reexamined and reconsidered, it may be possible for rural public transit to be combined with school bus transportation, making the system more efficient economically and environmentally. In states like Vermont, with limited rural transit services, it could also provide more mobility and accessibility to rural residents. Although there are a few cases nationally in which public and school transit have been coordinated in nonurban communities, barriers to the successful implementation of such a service include legislative and institutional policy, restrictive funding requirements, attitudes (especially with respect to safety concerns), and operational issues (Transit Cooperative Research Program, 1999). It is critical that these barriers be carefully explored, policies be reconsidered, and more research be conducted on public transit in nonurban areas.

As society becomes more conscientious about finite resources, environmental degradation, and the effects of global climate change, communities and schools will undoubtedly begin measuring their own effects on the environment, such as a carbon footprint. Even if fuel-efficiency standards in automobiles begin to improve, transportation demand management programs will remain a necessary component of reducing the negative effects of transportation on the environment. For school transportation, the reduction of the negative effects of excessive automobile use on the environment and on congestion requires multiple strategies. These strategies include promoting walking and biking through education and safety (SRTS), promoting carpooling among families who drive to school, and promoting school bus use.

4.4 Limitations of the Study and Suggestions for Further Research

This study had several limitations in the areas of data collection and model development. Although problems exist with the data collection process and with the development of models and selection of variables, we believe that the methods and results of this study are fundamentally sound.

One problem with the data was the number of missing variables. Although missing variables were not common in the survey, any missing data alters the results of models, as an entire case will be omitted from analysis if there is a single piece of missing data. For several variables, data for the missing variables was calculated using averages, such as when the data for distance was averaged, and this number was recoded in the variable for all system-missing variables. For some variables, such as grade, there were very few missing variables, and these missing data points were estimated with the corresponding age (e.g., an age of 13 was estimated to be grade 8). Attempts were also made to develop regression models, turning independent variables into dependent variables to develop a model that could predict the missing variables. This could not be achieved because the R squared value was not high enough to make accurate predictions. For example, when creating a function with income as the dependent variable, the model was not able to predict more than 50% of the variability in income. Certain missing variables could not be calculated accurately, such as gender, and in these cases missing variables were not completed.

This study exclusively examines the attitudes of parents and guardians toward school transport. The assumption was made that accurate data would be collected from parents about all questions, including which mode was used, how far a child lives from school, and demographic questions. Yet critical factors, such as peer pressure or negative student connotations of the school bus, may be overlooked by asking parents rather than children about perceptions of each mode. Indeed, during the research process, one parent claimed that his or her child referred to the school bus as the "shame train." Although these attitudes of children were not directly examined in this study, the researchers hoped to capture some of the perceptions of children through their parents' attitudes.

Variables of the models were chosen on the basis of extensive review of the literature, discussions with school transportation officials, and traffic counts and modal tallies taken at schools. Each variable in the model has merit and adds to the understanding of which factors affect school transport. However, there were two variables that were not in the model that could have been useful to better understand mode choice: the number of children per family and the district in which the child lives.

Each survey respondent (parent or guardian) provided responses for up to four school-age children in the household. A variable representing number of children in each household could have been developed and added to the models to determine the effects of the number of children per household on mode choice.

Another variable that was not considered in the models was the district in which the child lives. Whereas Districts One and Two had a high number of survey responses, District Three had a low number of responses and could not have been modeled accurately. Districts One and Two were tested in a correlation text and were found to have a correlation of 0.66, too high to be considered in the regression models that contained only variables that were less than 0.50 correlated with each other. If the districts were not as highly correlated, there could have been an analysis of the effects of the districts on mode choice.

Another problem inherent with this study is that it was time bound. The survey was conducted only once, rather than multiple times over a period of time. Hence, the research is considered time bound and may not capture factors that would be found over time, such as fluctuations in the price of gasoline or seasonal differences.

Further research is needed to better understand children's travel behavior. Studies that directly examine children's choices and their influence on parents' household decisions will help decision makers better understand how to adequately plan for the effects of school transport and make potential changes to travel behavior. Surveys conducted on school-aged children and surveys that include respondents of all household members—including children and parents—will provide a more accurate model of travel choice.

Before-and-after experimental studies on modal shift would also help gauge the effects of policy on travel behavior. Although some experimental research studies exist for the Safe Routes to School program, very few other studies on modal shift exist. Programs to reduce parent-driven trips to school or to increase school bus ridership are rare, and studies of these programs and their effects on mode choice and modal shift would be useful. Studies of such programs will help decision makers and planners decide how best to meet the goals of a community.

Another area that begs for more research is the effect of mode choice on traffic congestion and the environment. It is difficult to make policy and program recommendations without such analysis. For example, an analysis of the effects of parent-driven trips on the environment and on congestion versus other modes may assist efforts to develop programs and policies aimed at shifting people away from automobile use. Finally, more research is needed to understand how parents, children, and communities might perceive the combining of public transport with school bus transport in rural areas. Until a comprehensive study is conducted that examines this issue, policy recommendations cannot be made about the combination of these services.

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