Automated Vehicle Location for School Buses

Can the Benefits Influence Choice of Mode for School Trips?

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School-related traffic congestion is a problem in many communities. Nearly 60 percent of all school trips are made in personal automobiles and only 25 percent in school buses (*1*), although the National Highway Traffic Safety Administration (NHTSA) has described the school bus as "the safest form of transportation for children" (*2*).

With the goal of enhancing student safety and reducing school-related traffic problems, research was conducted between 2000 and 2003 into the household attributes and behaviors that influence school transportation mode choice. The research looked to identify problems and prioritize solutions for increasing the attractiveness of school bus service, including improvements available through automated vehicle location (AVL) technologies.

One objective was to determine the impact that AVL could have in prompting a shift to the school bus from the private automobile. The focus was on students who had to travel by a motorized mode because of the distance from home to school.

The study findings indicate that the application of AVL technologies to school buses can prompt a shift from the personal automobile for students in kindergarten through eighth grade. The addition of AVL tracking and traveler information technologies could produce a modal shift of 16 percent from automobile to the school bus.

AVL for School Buses

For nearly 15 years, intelligent transportation systems (ITS) have been a major focus in the transportation industry. Engineers, researchers, and policy makers have worked to develop, test, deploy, categorize, and structure countless technologies to improve the safety and efficiency of nearly every aspect of the transportation system.

ITS applications are serving highway, transit, rail, and pedestrian and bicycle systems. Only in the past 5 years, however, have researchers investigated and studied ITS technologies to improve safety and efficiency in school transportation systems on a regional or larger scale.

The number of children making daily school trips by automobile poses problems. Health advocates argue that more children should use pedestrian or cycling modes for school trips. School districting policies, however, preclude many children from nonmotorized modes because home-to-school distances are too long.

From a traffic engineering perspective, if students who live too far away to walk or bike would travel by school bus, the automobile demands on the street networks adjacent to schools would decrease. School-related automobile traffic causes queueing on nearby streets and increases commuter delays. Injury and fatality statistics show that large numbers of school trips by automobile also contribute to safety problems.

Collecting Data

To determine if the benefits of implementing AVL on school buses could prompt a significant shift from travel by private automobile, data were collected from survey questionnaires completed by parents of children in kindergarten through eighth grade in the public school system of Wake County, North Carolina (*3*). The demographics suggest that this area is a representative suburban community of the southeastern United States.

High school students were not included in the data collection because driving has social implications for that age group in suburban environments. The influences on a high school student's decision to drive—or to ride with a driving friend or relative—to and from school were not easy to express quantitatively for statistical evaluation. Moreover, a preliminary assessment determined that the reasons for driving were not likely to be influenced by benefits from the addition of AVL technology to school buses.

Right: Palm Beach School District in Florida is the largest school district to use global positioning systems (GPS) to track its fleet of school buses.

PHOTO: GEOSPATIAL TECHNOLOGIES, INC.

Below: School district dispatchers use real-time vehicle information and locations to track and reroute vehicles as needed.

The school district buses are mounted with a unit (*left*, GST Tracker from GeoSpatial Technologies) that combines geographic information system, GPS, wireless communications, and Internet map servers.

Data on approximately 250 students in kindergarten through eighth grade were analyzed to assess the impacts of AVL on the choice of mode for school trips. Although information was received for more than 700 students, only 255 met the criteria for inclusion in the assessment. Three classes of students were excluded from the analyses:

1. Students who lived within walking distance of the school,
2. Students who lived beyond the base attendance area for the school, and
3. Students already riding the school bus both in the morning and in the afternoon.

In addition to obtaining information about student, household, and school trip characteristics, the survey included two questions to assess the potential for changes in response to AVL technologies:

- *If your child does not ride the school bus, would you allow him/her to ride if for a charge of $5-$10 per month you would be provided with a pager that would sound in your home a few minutes before the bus actually arrived (shortening the time that you and/or your child must wait at the bus stop)?*
- *If your child does not ride the school bus, would you allow him/her to ride if the school bus positions were monitored regularly at the school transportation office (increasing student safety and improving the on-time arrival of buses)?*

AVL Functions

These questions were based on specific AVL systems available for school buses. The systems use Global Positioning System (GPS) and two-way radio or cellular communications for vehicle tracking, providing periodic real-time vehicle position updates to a central computer. The software displays the bus locations and other information, such as speed, on area maps that can zoom to the street level.

Another function is to provide traveler information. GPS transmitters on board school buses receive positional coordinates, which are relayed to receivers in homes and schools. Pager-like devices that contain the receiver notify the households about the arrival of the bus (*4*).

Some units dynamically display a countdown of the distance from the bus to the assigned bus stop. Other units transmit an audible sequence of beeps about five minutes before bus arrival, alerting students to be at the bus stop.

The notifications provide the rider with safety benefits and increase the operating efficiency of the school bus system. Bus annunciation systems work well in areas where "school children and their parents…walk long distances to their bus stop and then wait with great uncertainty for their school bus to arrive. The waiting exposes children to all kinds of inclement

weather conditions, roadside safety hazards, and other personal safety and security threats" (5).

The AVL analysis focused on the potential for a modal shift in school trips after the implementation of vehicle tracking and traveler information on school buses.

Modal Shift Potential

To determine quantitatively how likely a student would be to change from the automobile to the school bus after the application of one or both of the AVL functions, parents' answers to the two specific questions were assigned numerical probabilities:

- A "yes" to either question was assigned a probability of 1.0, meaning that the child would definitely shift modes under the given circumstances.
- If the parent answered "maybe," a probability of 0.5 was assigned, to represent a 50-50 likelihood of switching from the private automobile to the school bus.
- If the answer was "no," a probability of 0.0 was assigned, to indicate that the student was not at all likely to shift modes.

Assigning numerical probabilities was necessary for a quantitative analysis of the survey results. The numeric values may be imprecise but are not arbitrary, because they reflect as closely as possible a student's likelihood to shift modes based on the parental response to the survey.

The computed probabilities of modal shifts cannot be definite, because personal opinions change. If the same respondents were to participate in the survey a second time, changes in the answers to the AVL assessment questions would be likely.

For each of the 255 students, a mode shift probability was computed for the two AVL functions—vehicle tracking and traveler information. The overall probability of a mode shift by an individual student was calculated by adding two quantities: one-half of the probability of shifting to the school bus if bus tracking technologies were installed, plus one-half of the probability of shifting to the school bus if traveler information technologies were installed.

For example, a parent who answered "no" to the question about traveler information and household notification and "yes" to the question about vehicle tracking would register an overall mode shift probability of 0.5, according to the following computation:

$$\frac{1}{2}(0.0) + \frac{1}{2}(1.0) = 0.5$$

The average probability of a mode shift for the entire data set was calculated to be 0.40, indicating that 40 percent of all students using the automobile for at least their morning school trip may shift to the school bus for at least one trip if vehicle tracking and traveler information technologies were deployed on the school buses. Specifically, 50 percent of the students who came to school by automobile in the morning and returned by school bus in the afternoon may shift to the school bus with the addition of vehicle tracking and traveler information technologies.

Of the students riding in an automobile for morning and afternoon school trips, 30 percent indicated a possibility of shifting to the school bus. The difference between the 50 percent and 30 percent is intuitively reasonable, because students already using the school bus service for one trip would be more likely to shift modes and use the school bus for both trips than students who do not use the school bus service at all.

If 40 percent of all students using the automobile for the morning trip or for both school trips shifted to the school bus for the morning school trip, the overall modal shift would be 16 percent. A 16 percent shift from the automobile to the school bus in a school district the size of Wake County, with a student population of approximately 104,000, would increase school bus ridership by more than 16,500 trips. The size of this shift could decrease traffic congestion around the school and could increase student safety, with so many students transferring to the statistically safer school bus mode.

Parental Preferences

The separate consideration of the effects of the notification and the tracking technologies may be useful for school districts that cannot afford a complete AVL system.

Some traveler information and household notification systems, for example, operate independently of AVL. These systems transmit a signal from a unit on board a school bus to the in-home pagers associated with the route. When the bus comes within 1 mile of a pager programmed with the corresponding code, the pager sounds, notifying the household that the children should begin moving to the bus stop.

Would notification alone prompt a large enough shift to justify the necessary expenditures? According to the survey results, more parents indicate a willingness to shift modes in response to the benefits of the bus tracking function than in response to the benefits of household notification.

The average likelihood of a shift in modes in response to the availability of traveler information is 28 percent, and the average likelihood of a shift in modes in response to the availability of vehicle tracking technologies is 51 percent. The results suggest that parents would assign more value to school transportation staff's knowing the location of the buses than to advance notification of the arrival time of the school bus.

TABLE 1 Average Probability of Shifting from Personal Automobile to School Bus for at Least One Morning or Afternoon School Trip

AM Mode, PM Mode *	Overall Modal Shift Probability	Traveler Information Probability	Vehicle Tracking Probability
AU, SB	0.50	0.40	0.60
AU, AU	0.30	0.20	0.40
SB, AU	0.50	0.20	0.80
Total	0.40	0.28	0.51

** AU = personal automobile, SB = school bus*

The parental preference for bus tracking technologies may be explained by other results of the survey, which show an on-time school bus arrival rating of 70 percent. Parents likely assigned less value to notification because the buses arrived at the regularly scheduled times. A summary of the modal shift probabilities is presented in Table 1.

AVL and Mode Choice

A second component of the school transportation research project was to determine the factors that influence the choice between school bus and personal automobile for students in kindergarten through eighth grade. Statistical analyses of the individual, household, and trip characteristics of these students, living beyond a walkable distance, found that six independent variables were statistically significant predictors of mode choice (*3*):

- The total number of children in kindergarten through eighth grade in the household;
- The student's grade level;
- The average median household income for the zip code boundary in which the student lives;
- The school transportation mode that the parent perceives to be most safe;
- The convenience of the automobile for school trips in an individual household in relation to student schedules, automobile ownership, and ability to chain trips and to carpool; and
- Parent work schedules, safety concerns, and other problems and technologies that promote or constrain school bus use.

Some of these variables are subjective and disallow widespread use of the model without intensive data collection. The variables were included in the analysis, however, to account for each factor that might have significant influence on mode choice for school trips.

The AVL improvements to the school bus, for example, could be incorporated into the school bus convenience factor to reflect the additional convenience of AVL tracking or notification technologies for individuals and households. The research results suggest that increases in the school bus level of service through AVL should be included in the modeling for school trip mode choice.

The school bus and automobile convenience terms also could be redefined to be less subjective. Automobile convenience could include only household automobile ownership, and school bus convenience could include only the presence or absence of AVL technologies.

Another Study's Findings

A school trip mode choice study conducted by the U.S. Environmental Protection Agency (EPA) also investigated the influences on mode choice for school trips (*6*; see article by Ewing, Forinash, and Schroeer, page 4). The models estimated the shares of four school trip modes—car, bus, bicycle, and walking—to assess the implications of school siting for travel.

The researchers considered a range of independent variables from the categories of trip, traveler, school, and characteristics of the built environment. The variables found to influence school trip mode choice significantly were the following:

- Annual household income;
- The number of vehicles per household member;
- Walk time for the trip, along minimum path distances at the nominal walking speed of 3 miles per hour (mph);
- Bike time for the trip, along minimum path distances at the nominal biking speed of 12 mph;
- The proportion of street miles with sidewalks, averaged for the origin and destination zones; and
- Average accessibility indices for the origin and destination zones, determined by the number of trip attractors in a zone and the travel time between the trip zones.

The results from EPA's school trip mode choice models do not support the significance of AVL tech-

PHOTO: ZETRON

Grand Prairie Independent School District (ISD) near Dallas, Texas, modernized its school bus dispatch by installing radio communication and automatic vehicle location (AVL) systems (Integrator RD from Zetron).

nologies on school buses in influencing choice of mode. None of the independent variables could reflect the effects that adding AVL to school buses would have on mode choice.

The EPA models are multinomial logit models—each study unit had a choice among four modal alternatives. The models for the Wake County study, however, are binomial, estimating the modal share between the motorized options of school bus and personal automobile.

Another difference in the studies is the grade level of the students—the EPA study included all grade levels, kindergarten through 12th grade. The differences in the studies' findings suggest that AVL technology improvements to school bus level of service decrease in influence on mode choice as the modal options expand and as the grade level of the students increases.

Adverse Impacts

Increasing school bus ridership by a considerable amount, such as 16 percent, may not produce entirely positive effects. School transportation staff who deal with fleet logistics would have to estimate the additional number of buses and drivers needed to accommodate the increase and put these into operation quickly to maintain the level of service.

In North Carolina, the state government uses an efficiency rating to allocate funds for school transportation, calculated primarily from a ratio of the number of students transported and the number of buses used. A source for the initial funding of the additional buses and bus driver salaries would have to be identified, until the district could prove the need for the increase with the change in ridership counts. The school district must be prepared to handle the increase in ridership if the addition of technology is to be effective.

School bus–related crashes also may increase as the number of students using the school bus service increases. According to NHTSA, a school bus–related crash is any injury or fatality that occurs in the vicinity of a school bus, even if the school bus was not directly involved. An increase in school bus–related crashes may not be notable and may be offset by other factors, yet school transportation staff should note that an increase may occur.

Quality and Efficiency

The research indicates the potential for a significant modal shift from the personal automobile to the school bus after the deployment of AVL tracking technologies. Traveler information technologies, which notify households about a school bus arrival, were not as important to parents as vehicle tracking. This is likely because 70 percent of school buses arrive on time in the county, according to the survey results.

PHOTO: ZETRON

Antennas mounted on top of ISD school buses function as part of radio communication and AVL.

Nonetheless, with both the tracking and notification functions implemented, a modal shift as large as 16 percent could result.

Potential applications of this school transportation research are many. School districts can focus resources on solutions to school transportation problems that have a proven impact on mode choice. Manufacturers can generate more effective AVL products with the greatest potential for increasing school bus ridership.

Overall, quality and efficiency of travel could increase in communities throughout the country as the results of this research are applied. Fewer personal automobiles on school campuses can be expected to decrease crashes between vehicles, pedestrians, and buses, increasing the safety of students, school staff, and commuters.

Acknowledgments

The research for this project was conducted at the Institute for Transportation Research and Education, North Carolina State University, and was funded by the Federal Highway Administration through an Eisenhower Graduate Fellowship.

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