

I. Automatic Vehicle Location and the Potential for Pupil Transportation Applications

Automatic vehicle location (AVL) is an automated vehicle tracking system made possible by navigational technologies such as Global Positioning Systems (GPS), dead reckoning, and signposts. AVL has been used for over twenty years for purposes ranging from emergency location of vehicles to fleet management and monitoring to data collection. In the past, AVL systems used dead reckoning and signposts whereby signals were transmitted from a mobile unit to stationary signposts and the position of the vehicle was determined based on known information about the locations of the signposts. The first AVL demonstration project in transit used the signpost technology in the late 1960's in Chicago. The 1990's began the widespread usage of GPS as the navigational technology of choice because of the increased system capabilities from signposts to satellites and the lower GPS receiver costs. Currently, GPS is the most commonly used navigational technology for AVL systems in public transportation.

The applications of AVL for transit are numerous and most are in large, metropolitan, fixed route transit agencies, as well as small, paratransit fleets. According to a synthesis of AVL Systems for Bus Transit, sponsored by the Federal Highway Administration in 1997, AVL systems “measure system performance, ridership, and schedule adherence, provide estimated time of arrival, announce next stop information, and display vehicles on an electronic map.” Many of these applications could be used to better pupil transportation operations, as well. The ability to track the location of school buses during the daily routes could allow for notification to parents and/ or schools of late bus arrivals and provide for quicker response time of necessary personnel in emergencies and breakdowns. Another potential AVL application is to develop a paratransit-similar function for school buses that could locate the closest bus to a location where a student was left and have that bus transport the student to his/ her home. The incorporation of 2-way communication device such as the Mobile Data Terminal (MDT) with the AVL unit would also allow for silent alarm capacity to send signals to the control center calling for the appropriate medical or law enforcement agency.

There is great potential for an AVL system to improve pupil transportation operations and safety. The technology has the potential to change the culture of pupil transportation from reacting to daily crisis to enabling managers to actively monitor fleet activities and resolve crises before they occur.

II. AVL Systems in the Current Market

The current users of Automatic Vehicle Location systems can be roughly classified in three categories: long-haul trucking companies, local delivery companies, and public transportation agencies. The classification is based on the following operating characteristics: data transmission interval, amount of data transmitted, 1-way or 2-way communication.

The vehicle equipped with a GPS unit receives signals from satellites at no cost to customers; the data transmission from vehicle to a control center however is at cost for a wireless carrier. The cost calculations of how wireless carriers charge AVL vendors is similar to the cost for a personal cellular phone, there are limited minutes per month and additional cost if the limitation is exceeded. The transmission of each vehicle location counts as one registration; if the location is transmitted every 15 minutes, then there are 4 registrations per vehicle per hour. For a fleet with 100 vehicles operating 8 hours a day, the total monthly registration would be over 96,000 registrations. Some AVL vendors purchase airtime from wireless carriers, thus the vendor is restricted to allotted monthly total registrations for all their clients. As a result, the registration interval is quite restrictive due to cost. The cost associated with wireless transmission can be eliminated or reduced if the customer can piggyback on existing wireless communication networks. This shared communication practice is called “trunking” and many public transportation agencies take advantage of existing county or city government’s communication infrastructure for their AVL systems.

The amount of data transmitted is another issue to be considered. Imagine passing marbles through a pipe, the amount of time required for five marbles to travel through the length of the pipe is longer than one marble. In this simple analogy, the number of marbles represents the amount of data needing to be transmitted so if an MDT is to be installed on vehicles to facilitate 2-way communication between vehicle operator and central control unit, then the amount of data to be transmitted is increased two fold. In the same token, if the vehicle transmits data relating to engine performance in addition to location, the transmission time is also increased. For this reason, AVL users only transmit engine performance data when the performance is out of a specified value, such as engine fluid temperature.

For the long-haul trucking companies (excepting a few highly sophisticated trucking companies that operate fully integrated AVL and automatic fleet management systems), a majority

of the customers use AVL as an asset location tool. The objective of asset location is simply to determine locations of trucks or trailers. The frequency of how often the locations are updated is no great concern, mostly at an as-needed basis. Also, information beyond locations is not important either. These AVL systems are the least expensive in the market because it does not require the use of an MDT, which eliminates the need of 2-way communication. Furthermore, the control central management software is often provided by the vendor and can be accessed through the Internet. The cost of wireless communication is also reduced to a minimum due to low data transmission frequency.

The AVL system used by local delivery companies is very similar to long-haul trucking with the exception that the data transmission interval is usually set for 15 minutes apart. This means the central control unit is always observing the vehicle history data delayed by 15 minutes, not real-time. The local delivery companies are interested in vehicle information beyond location such as vehicle speed, direction of travel, stop, stop locations matched to the GIS database and other “event-driven” vehicle information. There are also various software functions to query vehicle locations, proximity to a know location, query by zone, and pining vehicle or vehicles.

AVL vendors representing the long haul and local delivery markets are numerous. The hardware configurations are all very similar and the software applications are mostly Internet based. The Internet based application has the advantage of eliminating expansive hardware and communication infrastructure at the client site. The down side of such an arrangement is the difficulty to customize software for individual clients. AVL unit costs range from \$300 to \$500 and the monthly cost from \$35 to \$50 for data transmission.

Public transportation agencies’ AVL systems are by far the most comprehensive and expensive of all three usages. The most significant differences from other user categories are the real-time transmission of vehicle data and the amount of data transmitted. Real-time is of course a relative term, a maximum of five-minute intervals or less is usually preferred in public transportation’s AVL systems. The agencies that implement AVL systems also integrate automatic fleet management system, en-route transit information, automatic passenger counts, emergency notification, and route guidance. The amount of data transmitted is much larger than the long-haul trucking and local delivery services.

AVL systems for public transportation are usually customized to meet individual agency’s needs and communication infrastructure. Since most public transportation operations require two-

way communication using MDT, the vehicle location capability using GPS is usually an added feature. Thus the costs associated with AVL include MDT units, customized software to disseminate vehicle data and hardware hosting the application and communication. It is difficult to obtain a generic cost of AVL for public transportation agencies without studying individual system specifications.

III. National ITS Logical Architecture- User Services

The Intelligent Transportation Systems architecture is based on “user services.” A user service is a combination of technologies that serve a specific function to meet expressed needs. There are approximately 30 user services in the ITS architecture and they are grouped into seven primary “bundles.” These bundles are:

Travel And Transportation Management

Travel Demand Management

Public Transportation Operations

Electronic Payment

Commercial Vehicle Operations

Emergency Management

Advanced Vehicle Control And Safety Systems

An agency considering the implementation of ITS strategies should first identify their needs that can then be identified by specific user services and user service bundles. To better define an agency’s need, each service bundle is further disaggregated into user services and functions. For example, the *Public Transportation Operations* bundle has the following user services:

- Public Transportation Management
- En-Route Transit Information
- Personalized Public Transit
- Public Travel Security

More detailed user service descriptions and function definitions can be found in Appendix A. The purpose of the national standardized ITS program is focused on the development and deployment of a collection of inter-related user services that could be applied to all modes of transportation, transportation management center operators, transit operators, Metropolitan Planning Organizations, and many others who will benefit from deployment of ITS. A standardized architecture will enable the integration of technologies among agencies.

IV. Pupil Transportation AVL Logical Architecture- User Services

Meetings with Wake County Pupil transportation officials have produced the following list of needs in school bus operations and safety.

- Ensure bus start and end times (allows substitute drivers to be notified as soon as the bus is not in motion at the required time to keep buses from being too far behind schedule)
- Ensure schedule adherence (provide notification of late buses)
- Real-time traffic updates (provide notification to bus drivers of road closures due to construction or accidents)
- Real-time engine performance monitoring
- Mechanic notification for 30-day oil change and inspection
- Monitor driver performance for excessive speed
- Track bus speeds on new roads (links) for encoding in the TIMS geocode
- Track bus mileage for automatic reporting on activity buses and field trips
- Automatic auditing for buses and contract vehicles
- Validate planned bus routes (to provide accurate schedules for parents)
- Retrieve stored output data by district
- Track bus location, real-time, for lost student calls and quicker response in breakdowns (allows for student contingency plans for students left at school)
- Track service vehicles for quicker response in bus breakdowns
- Differentiate between driver notification of breakdowns, extreme traffic congestion, extreme sickness or discipline problems requiring EMS or law enforcement, etc.
- Overnight security (to detect vandalism, stolen buses, etc.)
- Automatic passenger counters (to keep accurate records of student counts)
- Route guidance
- Student discipline

There are two distinct vehicle fleets involved in the pupil transportation needs- *Service Vehicles* and *Yellow School Buses*. There are also three tracks into which these needs can be categorized for structure. The related user services and user service bundles can be matched to each track according to the vehicle fleet being considered. The categories are:

Track 1-- Search and Rescue

Track 2-- Vehicle Monitoring and Tracking

Track 3-- Data Retrieval and Analysis-

Search and Rescue is the first and most important of the tracks because allowances are made therein for quicker notification of and response to emergencies. Knowing the exact location of school buses and service vehicles can facilitate quicker response times for necessary personnel to bus breakdown or other emergency sites. On-board 2-way communication, if equipped can give emergency notifications to the dispatch/ operator and identify the type of emergency. Also, overnight security is possible with technologies that “wake” when triggered by bus movement. The ITS user services that are involved in search and rescue are *Emergency notification, En-route driver information, and Route Guidance*.

The *vehicle monitoring and tracking* component allows for better customer service being able to locate each bus and service vehicle periodically, according to a predetermined time interval. Among the potential benefits of the vehicle monitoring and tracking component is the ability to have demand response bus service for new riders that are dropped off by parents and need bus transportation to their homes in the afternoon and for children who have been left at school. Bus servicing could also be improved by GPS in Track 2 because of the automatic notification of mechanical problems. Another important feature to decrease the frequency of late buses is the ability to know when the bus starts. With this, supervisors could be notified and substitute drivers assigned when bus drivers are excessively late or absent. Vehicle monitoring and tracking involves the following ITS user services: *Pre-trip travel information, En-route transit information, Personalized public transit, Public travel security, Automated mechanical inspection, and Automatic passenger counters*.

The final track, *Data Retrieval and Analysis*, would assist data managers and supervisors with route auditing and other data-intensive operational analyses. The ability to track and analyze individual bus speeds would be a large asset in accident investigation, for example. Engine performance data could also be used and analyzed to determine priority in maintenance scheduling. The user services necessary to accomplish these objectives are: *Automatic data-retrieval, Ride matching, and Public transportation management*

V. Pupil Transportation AVL Logical Architecture- Functions

In order to determine and implement the required technologies to solve the pupil transportation problems, the functional relationships among the user services must be identified. The required functions must be noted so that they can be grouped into deployable technology packages. To accomplish the aforementioned objectives of the three pupil transportation tracks, the following functions identified by ITS national architecture would be necessary.

- *Vehicle surveillance*
- *Individual traveler interface*
- *1-way mobile communications*
- *2-way mobile communications*
- *Navigation*
- *In-vehicle sensors/ devices*
- *Routing data processing*
- *Database processing*
- *Inter-agency coordination*

Vehicle surveillance technologies collect information about specific vehicles, such as location. This function provides the information leading to a need for the individual traveler interface. Information about the vehicles obtained in surveillance, such as schedule adherence, is disseminated through kiosks, computers, and in-vehicle displays. These mediums through which information is disseminated are the individual traveler interface technologies.

One-way mobile communications transmit information to a site but cannot receive information from that site. Advisory radio systems, microwave and infrared beams are example technologies of this function. Two-way mobile communications transmit information to and from mobile reception sites. The Nextel radios/ cellular phones currently used by Wake County transportation are technologies involved in this function. The information being communicated is usually obtained from the navigation function. Navigation technologies determine real-time vehicle positions using GPS, dead reckoning, and/ or map matching, for example. The in-vehicle sensor function allows for monitoring vehicle and driver performance and provides for on-board security monitoring as well.

The remaining three functions relate to the administrative component of ITS. Database processing formats the transportation-related data obtained from navigation and surveillance technologies for dissemination through individual traveler interface and communication technologies. This involves data fusion, the effective combination of information from different sources with varying accuracy and frequency by a weighted averaging process. Routing data processing is similar in that information related to the routing of vehicles is fused to develop driver schedules, route selections, and route guidance. Finally, inter-agency coordination brings together emergency services, weather forecasters, and the transit vehicle dispatch/ operators to comprise a complete information system using the Internet, telephone, or wide-area networks.

These are the primary functions, characteristic of the national ITS architecture, that are necessary to meet the needs as expressed by Wake County Public School System's pupil transportation officials.

VI. Pupil Transportation AVL Physical Architecture - Technologies and Function Needs

The building blocks of a system are the separate physical components that when integrated become a fully operational system. The physical building blocks of the AVL system which meet the needs outlined by Wake County pupil transportation require the following components:

- GPS unit (location receiver and data transmitter)
- Mobile Display Terminal (MDT)
- Wireless communication infrastructure
- Control center management software

The GPS unit supports the navigation and vehicle surveillance functions described in Logical Architecture- Functions. The Mobile Display Terminal or MDT supports the following functions: collection of in-vehicle sensors/devices data and 1 and/or 2-way mobile communication of text transmission and emergency notification. The wireless communication network supports the data transmission of GPS and MDT units. The control center hosts the software system for processing routing data, database processing, traveler interface, and inter-agency coordination.

Currently, there is not a commercial AVL system designed for pupil transportation operations. It is however a great interests to both the suppliers and the pupil transportation industry. The category of services required for pupil transportation can be roughly placed between public transportation and local delivery companies from the standpoints of how much data are transmitted and how often. The following sections can be used as system specifications to build AVL system for pupil transportation.

Data Transmission Interval

For school buses serving metropolitan areas, some bus routes may be as short as 10 to 15 minutes serving densely populated areas such as large apartment complexes. The current 15 minutes transmission interval for long haul and local deliveries systems do not provide sufficient number of registrations for the length of the bus route. Yet, public transportation's transmission interval is overkill for the expense, unless piggybacking on an existing radio tower. Transmission interval of 5 minutes would be desirable for pupil transportation with the option to transmit on demand (pinning).

Mobile Display Terminal

The function of MDT is to supplement or replace voice communication between central control and the driver. If the AVL system requires transmission of vehicle sensory data, the MDT is used as a collection point for collected data. Some GPS vendor has additional data port built into the unit to receive and transmit data from another recording devices, however it does not have the intelligent to distinguish if received value is out of specified tolerance (such as engine fluid temperature). Majority of the school buses travel on established bus routes rarely require communication via MDT except in emergency situations. The MDT is thus an optional equipment for AVL system for pupil transportation unless the operation requires automated vehicle fleet management system. The MDT is however very beneficial for buses transporting passengers with special needs.

Control Center Management Software

The control center management software is where all the collected information is disseminated and presented. Learning from the public transportation's AVL installation experiences, this component has caused many problems in the implementation. To save software development costs, it is wise to select an AVL vendor that allows a majority of the information to be accessed through a cooperate web page with the option to download detailed history data for post analysis.

In order to better articulate the management software functions to meet the needs identified by Wake County Public Schools Transportation Services, the procedures as to how and when vehicle locations are reported are presented here in three separate categories: scheduled, on-demand, and event-driven.

Scheduled Location Reporting

- Automatic update of vehicle location at the specified time interval
- Display locations by group of vehicles (separate yellow school buses from service trucks, separate yellow school buses by management areas)

On-demand Vehicle Location Reporting

- Submit inquiry for any vehicle location on demand (ping)
- Submit inquiry for a group of vehicle locations on demand
- Inquiry for vehicle closest to a location input by user or another vehicle location

Even-driven Vehicle Location Reporting

- Security notification of vehicle movement beyond the normal operating hours
- Notification of vehicle delay when it fails to enter predefined geographic area at specific time
- Notification of vehicle locations for excessive idling during normal operating hours

VII. Cost-Benefit Analysis for the AVL Pilot Program

The mathematical process used often in public policy development to determine the overall benefit of a proposed service or program is the cost-benefit analysis. Program costs alone are insufficient to determine the potential success of a program. Both the program costs and potential benefits must be expressed in dollar values to establish a foundation for comparison to verify that the proposed program will provide benefits commensurate to the costs. In considering the investment required to implement an AVL system on the entire fleet of Wake County school buses and service vehicles, a cost-benefit analysis is necessary to determine if the associated benefits at least balance the required costs of this technology.

The primary step of any cost-benefit analysis is to determine the problems and the potential technological improvements that can meet the needs. A list of school bus operational needs is presented in the section covering, Pupil Transportation AVL Logical Architecture- User Services, and Automatic Vehicle Location is the proposed technological improvement. In order to realistically analyze the costs and benefits of an AVL program in pupil transportation, a pilot program has been established.

The focus of the pilot program is Track 1, search and rescue, as presented in the Pupil Transportation AVL Logical Architecture section. Search and rescue is the most important component, involving emergency response and vehicle security. Tracks 2 and 3 provide added value and additional benefits. The 700-vehicle fleet of Wake County yellow school buses is too large to analyze at this phase in research, so the pilot program will encompass service vehicles and a test unit for each of the twelve Wake County districts for a total of 40 GPS units. Within the county, there are 11 operations managers' vehicles, 12 mechanics trucks, and 5 contract vehicles. These 27 units, coupled with the twelve units to be tested in each district, comprise the 40 units for the pilot program.

Several needs will be addressed directly by having GPS units on the service vehicles, according to the objectives of Track 1. Other benefits will result from placing the GPS units on the entire school bus fleet, going more into Tracks 2 and 3. The expected benefits of having GPS on school buses have been scaled down for this analysis because there will be only one GPS unit in each district, as opposed to having one unit on each bus. The needs that should be addressed during this pilot program trial period are:

- Locate service vehicle closest to bus breakdown site for quicker response
- Overnight security (to detect vandalism, stolen buses, etc.)
- Student discipline
- Ensure bus start and end times (allows substitute drivers to be notified as soon as the bus is not in motion at the required time to keep buses from being too far behind schedule)
- Track bus mileage for automatic reporting on activity buses and field trips
- Track bus location, real-time, for lost student calls and quicker response in breakdowns (allows for student contingency plans for students left at school)
- Differentiate between driver notification of breakdowns, extreme traffic congestion, extreme sickness or discipline problems requiring EMS or law enforcement, etc.

Having identified the problems and the desired technology, the next two steps are to determine the associated costs and benefits. With many AVL vendors there is a leasing option for equipment so that the initial capital costs of purchasing equipment can be avoided. For this analysis, the largest cost will be considered, which involves purchasing the GPS receivers. The costs included in the following analysis are average expected expenditures based on vendor estimates of \$350 to purchase a single GPS unit and \$35 per month for communication. The exact monthly cost will be dependent on registration frequency. The information transmission frequency for pupil transportation purposes has not yet been determined but will be between five and fifteen minutes.

The Pilot Program involves 40 GPS units for a total monthly communication cost of \$1400. The initial expenditure for equipment is \$14,000 (\$350 for 40 units). The costs for the first year of operation would therefore be approximately \$30,800. Other costs involved in pupil transportation operations are not included in this analysis because these costs will continue after the implementation of an AVL system. These costs include \$8000 per month to provide cellular service on-board each yellow school bus and \$3000 to provide two-way radio cellular services for the central office, district supervisors, and service workers. The Director of Transportation for Wake County wants AVL to supplement, not replace, cellular technology, desiring that the ability to have direct communications with bus drivers remain.

Operations and maintenance costs would also be required, but the exact amounts are unknown, having no similar program to review. If an AVL system is implemented on each school

bus, a dedicated dispatcher will be necessary, adding a salary package to the costs. For the Pilot Program, however, neither maintenance nor operations costs are considered because current personnel will operate the system and the program is only being considered over one year in which no maintenance is expected.

A benefit is any output, positive or negative, from a policy or program. Four primary benefits are expected from the AVL Pilot Program: savings in mileage and fuel, quicker response time of the necessary personnel in emergencies, decrease in incidents of vandalism, and better customer service. Appendix B details the methods used to determine these benefits and their associated monetary values. The table below organizes the costs and benefits of the AVL program for the one-year trial period of the Pilot Program. The final decision on whether or not to implement a program or policy is based on the net marginal benefit. This value is obtained by subtracting the costs from the monetized benefits. In private industry, a positive value is desired to indicate that a profit would be possible. In public services, such as public school transportation, however, a zero value is acceptable, indicating that the program costs provide at least equal benefits to the citizens. Slightly negative net marginal benefits are sometimes allowed if there are unquantifiable benefits that can help to justify the expenditures in excess of the benefits.

	Annual Costs	Annual Benefits
40 AVL/ GPS units	\$14,000	---
Communication for 40 units	\$16,800	---
Mileage/ fuel savings	---	\$1320
Decrease in incidents of vandalism	---	\$12,000
Better customer service	---	\$706,100
Total	\$30,800	\$719,420

Clearly, the expenditures for the AVL Pilot Program can be justified because the monetized benefits are larger than the costs. A sensitivity analysis is necessary, however, to explore any possible instability in the monetized benefits and determine the impact on the final decision. The mileage/ fuel savings and monetized value of deterring acts of vandalism are based on known monetary values from the operating budget of Wake County Public Schools Transportation. The first real uncertainty appears in the willingness-to-pay survey, used to quantify the benefit of better

customer service (see Appendix B). The survey was not distributed to the population of approximately 350,000 Wake County citizens between the ages of 21 and 64, yet the results were inferred for this population. There is uncertainty whenever a small sample is used to represent the actions or mindset of an entire population. Had the survey been distributed to the applicable 350,000 persons, the responses would be much more reliable. To explore the variability, however, the table of costs and monetized benefits is presented again, slightly altered, below.

	Annual Costs	Annual Benefits
40 AVL/ GPS units	\$14,000	---
Communication for 40 units	\$16,800	---
Mileage/ fuel savings	---	\$1320
Decrease in incidents of vandalism	---	\$12,000
Better customer service	---	???
Total	\$30,800	\$13,320

Without considering the effects of better customer service, the capital costs exceed the monetized benefits by \$17,480. In order to justify this Pilot Program, the benefits should at least balance the costs, meaning that the monetized value of better customer service should be at least \$17,480 per year. Enrollment statistics from the Wake County Planning Department estimate school enrollment for grades K – 12 in the 1999-2000 school year to be 94,782. The survey population considered was 350,000. This is a reasonable estimate because the average, found by dividing the number of children enrolled in Wake County public schools by the estimated applicable population of 350,000, is just over 3 children per person. Worthy of note, however, is the fact that not all 350,000 citizens will have children.

In order to justify \$17,480 in annual benefit from 230,000 persons, assuming that approximately one-third of the 350,000 would be unwilling to pay, the average response would have to be near 8 cent per year. To assume that 230,000 Wake County citizens would value the AVL Pilot Program as at least 8-cent annually is not an excessive assumption. So, without using the \$3.52 estimate calculated from the sample survey respondents, the Pilot Program would still be justified if this value decreased to just \$0.08. This has not even taken into account the unquantifiable benefit of quicker response time in emergencies.

The AVL Pilot Program has been justified according to the four primary benefits, only one of which is unquantifiable. The anticipated public response is positive, based on the sample survey responses. In order to analyze the AVL program for the entire fleet of Wake County school buses and

service vehicles, the survey should be distributed to the general public to get a more reliable measurement of the public value of the program. Also, the operating and maintenance costs should be included in a cost-benefit analysis over more than one year. Extending the cost-benefit analysis to the comprehensive AVL program will create more outputs by incorporating the other needs that were not addressed by this Pilot Program analysis.

Appendix A: Intelligent Transportation Systems User Services

Intelligent Transportation Systems User Service Bundles

Travel and Transportation Management

Travel Demand Management

Public Transportation Management

Electronic Payment

Commercial Vehicle Operations

Emergency Management

Advanced Vehicle Control and Safety Systems

Intelligent Transportation Systems User Services

➤ **Travel and Transportation Management**

1. En-Route Driver Information
Provides driver advisories and in-vehicle signing for convenience and safety
2. Route Guidance
Provides travelers with simple instructions on how to best reach their destinations
3. Traveler Services Information
Provides a business directory, or “yellow pages,” of service information
4. Traffic Control
Manages the movement of traffic on streets and highways
5. Incident Management
Helps public and private organizations quickly identify incidents and implement a response to minimize their effects on traffic
6. Emissions Testing and Mitigation
Provides information for monitoring air quality and developing air quality improvement strategies

➤ **Travel Demand Management**

1. Pre-Trip Travel Information
Provides information for selecting the best transportation mode, departure time, and route
2. Ride Matching and Reservation
Makes ride sharing easier and more convenient
3. Demand Management and Operations
Supports policies and regulations designed to mitigate the environmental and social impacts of traffic congestion

➤ **Public Transportation Operations**

1. Public Transportation Management
Automates operations, planning, and management functions of public transit systems
2. En-Route Transit Information
Provides information to travelers using public transportation after they begin their trips
3. Personalized Public Transit
Provides flexibly-routed transit vehicles to offer more convenient customer service
4. Public Travel Security
Creates a secure environment for public transportation patrons and operators

➤ **Electronic Payment**

1. Electronic Payment Services
Allows travelers to pay for transportation services electronically

➤ **Commercial Vehicle Operations**

1. Commercial Vehicle Electronic Clearance
Facilitates domestic and international border clearance, minimizing stops
2. Automated Roadside Safety Inspection
Facilitates roadside inspections
3. On-board Safety Monitoring
Senses the safety status of a commercial vehicle, cargo, and driver
4. Commercial Vehicle Administrative Processes
Provides electronic purchasing of credentials and automated mileage and fuel reporting and auditing
5. Hazardous Materials Incident Response
Provides immediate description of hazardous materials to emergency responders
6. Commercial Fleet Management
Provides communication between driver, dispatchers, and intermodal transportation providers

➤ **Emergency Management**

1. Emergency Notification and Personal Security
Provides immediate notification of an incident and an immediate request for assistance
2. Emergency Vehicle Management
Reduces the time it takes for emergency vehicles to respond to an incident

➤ **Advanced Vehicle Control and Safety System**

1. Longitudinal Collision Avoidance
Helps prevent head-on, rear-end or backing collision between vehicles, or between vehicles and other objects or pedestrians
2. Lateral Collision Avoidance
Helps prevent collisions when vehicles leave their lane of travel
3. Intersection Collision Avoidance
Helps prevent collisions at intersections

4. Vision Enhancement for Crash Avoidance
Improves the driver's ability to see the roadway and objects that are on or along the roadway
5. Safety Readiness
Provides warnings about the condition of the driver, the vehicle, and the roadway
6. Pre Crash Restraint Deployment
Anticipates an imminent collision and activates passenger safety systems before the collision occurs, or much earlier in the crash event than is currently feasible
7. Automated Highways Systems
Provides a fully automated, "hands-off," operation environment

Intelligent Transportation Systems Function Definitions

Traffic Surveillance:

Surveillance technologies that collect information about the status of the traffic stream. Possible technologies include loop detectors, infrared sensors, radar and microwave sensors, machine vision, aerial surveillance, closed circuit television, acoustic, in-pavement magnetic, and vehicle probes.

Vehicle Surveillance:

Surveillance technologies that collect a variety of information about specific vehicles. These technologies include weigh-in-motion devices, vehicle identification, vehicle classification, and vehicle location.

Inter-Agency Coordination

Technologies that connect travel-related facilities to other agencies such as police, emergency services providers, weather forecasters and observers, and among Traffic Management Centers (TMC), transit operators, etc.

1-Way Mobile Communications

Any communication technology that transmits information to potentially mobile reception sites but cannot receive information back from those sites. Possible technologies providing this function include Highway Advisory Radio, FM subcarrier, spread spectrum, microwave, infrared, commercial broadcasts, and infrared or microwave beacons.

2-Way Mobile Communications

Any communication technology that transmits information to potentially mobile reception sites and allows receipt of information from those same sites. Possible technologies include cellular telephones, 2-way radio, spread spectrum, microwave, infrared, and 2-way satellite.

Stationary Communications

Any Communication technology that connects stationary sites. Technologies include fiber optics, microwave, radio, land lines.

Individual Traveler Interface

Devices that provide information flow to a specific traveler. Technologies meeting this function include touch screens, keypads, graphics displays and computer voices at kiosks; keypads, computer voice, and head-up displays in vehicles; personal communications devices carried with the traveler; and audiotex from any phone.

Payment Systems

Technologies that enable electronic fund transfer between the traveler and the service provider. The technology areas include Automated Vehicle Identification (AVI), smart cards, and electronic funds management systems. This function overlaps with the Electronic Payment user service.

Variable Message Displays

Technologies that allow centrally controlled messages to be displayed or announced audibly to multiple users at a common location such as a roadside display or display board in a transit terminal. These technologies would typically be applied to provide information on highway conditions, traffic restrictions, and transit status.

Signalized Traffic Control

Technologies that allow for real-time control of traffic flow. Possible technologies include optimized traffic signals, ramp metering, reversible lane designation, and ramp/lane closures.

Restrictions Traffic Control

Operational techniques that restrict the use of roadways according to regional goals. Techniques include HOV restriction, parking restrictions, and road use (congestion) pricing.

Navigation

Technologies that determine vehicle position in real time. Technologies that provide this function include GPS, LORAN, dead reckoning, localized beacons, map database matching, and cellular triangulation.

Database Processing

Technologies that manipulate and configure or format transportation-related data for sharing on various platforms. General purpose data base software currently exists and is currently being adapted to transportation needs such as data fusion, and travel services.

Traffic Prediction Data Processing

Data processing relating to prediction of future traffic situations. Algorithms under development include areas such as real-time prediction, and traffic assignment.

Traffic Control Data Processing

Data processing related to the real-time control of traffic. Algorithms under development include optimal control and incident detection, and the interaction of route selection and traffic control.

Routing Data Processing

Data processing related to routing of vehicles including the generation of step-by-step driving instructions to a specified destination. Algorithms under development include the scheduling of drivers, vehicles, and cargo; route selection; commercial vehicle scheduling, and route guidance.

In-Vehicle Sensors/Devices

Technologies providing a range of sensing functions to be located within vehicles. Functions addressed by these technologies include monitoring of vehicle performance and driver performance; determination of vehicle position relative to the roadway, other vehicles, and obstacles; improvement of vision in adverse conditions; and on-board security monitoring.

Appendix B: Determining and Assessing Benefits

There are seven methods used in cost-benefit analyses to determine benefits. These are 1) past performance of similar policies or program in other jurisdictions, 2) vendor performance estimates, 3) "engineered" estimates, 4) mathematical modeling techniques, 5) expert judgement, 6) simulated adversary process, and finally 7) a trial run. Several of these methods can be understood on the basis of wording alone. The engineered estimates and simulated adversary process require more explanation.

Similar to mathematical modeling techniques, engineered estimates are the result of engineering tests and analyses. The simulated adversary process is more of a tool in social policy considerations. Using this method, a group of people discusses the proposed policy, half acting as proponents and the others as opponents. Notes from this session help determine the positive and negative outputs of the proposed policy.

The most useful methods for determination of benefits for the Wake County AVL Pilot Program are vendor performance estimates, expert judgement, and a trial run. The trial runs have been completed with the GPS units currently used to gain familiarity with the system. The pupil transportation officials are the experts who can predict the benefits based on daily involvement in pupil transportation operations. Finally, AVL vendor estimates can help determine some positive benefits of implementing the system.

Recalling the needs that will be addressed by AVL technologies in the Pilot Program, the following benefits have been established using the applicable benefit/ output determination methods.

- Savings in mileage and fuel
- Quicker response time in emergencies
- Decrease in incidents of vandalism
- Better customer service

Being able to track service vehicles will result in a savings in mileage and in fuel as well, because the closest service vehicle will be used for bus breakdowns and parts pick-ups. The knowledge that apprehension of offenders will be almost certain in instances of stolen buses and rock throwing is expected to deter students from participating in these crimes. Better customer service is

a result of knowing the location of the bus and being able to disseminate accurate information to parents or other interested persons.

The fourth step in a cost-benefit analysis is to assess, or monetize, the benefits in order to compare costs and benefits on the same scale, in monetary value. Several methods are available to assess benefits, but only four are applicable to analyzing the four benefits of the AVL Pilot Program. These are:

- Private analog- dollar value assigned corresponding to the current market value
- Intermediate goods- assumes that the output causes another output that can be given a dollar value
- Cost savings- compares alternatives for producing the same benefit and assigns dollar value based on the amount saved by selecting a particular alternative
- Contingent valuation- the program is valued at the total amount citizens are willing to pay for the service, based on a survey.

Fuel savings is given a monetary value using the private analog method, considering the market value of fuel and estimating the total number of miles that will be saved with the implementation of the AVL Pilot Program. The current cost of diesel fuel, on which the vehicles operate, is 90 cent per gallon. Estimating that each of the twelve service trucks will save an average of 10 miles per day, 2400 miles will be saved each month. This leads to savings of approximately \$110 a month in fuel, using a conversion factor of 20 miles per gallon.

The cost savings method is used to assess having quicker response times in emergencies. Currently, two-way radio and cellular technologies are used. These must be compared with the cost of utilizing the GPS unit and two-way radio, for direct communications. Any cost savings resulting from using GPS will be listed as a benefit. Should the GPS costs exceed the current costs, the cost difference will be included as a negative output. The cost of the two-way radios with cellular phone capacities as well is \$30 per unit per month. This includes 150 direct connects, or “hits,” per unit per month. A direct connect is a one-way communication with another unit. One call, then, involves two hits- one to contact a unit and one for a response from the unit. Once this number of hits is exceeded, additional time is charged at a rate of 12 cent per minute. A typical service call requires the dispatch person to direct connect with a service truck to determine their location; this requires at least 2 direct connects. If that person is unavailable, a second person must be located. One service call can easily result in 10 direct connects. The proposed GPS technology involves a cost of \$45 per unit, but has unlimited pinging capacity. (A “ping” is to the GPS software as a direct connect is to

the two way radio/ cellular system.) Cellular capacity is still required with the AVL system, but only two hits are necessary because the closest vehicle would have been located, so the only direct communication necessary is to give instruction to the service truck driver as to what and where the need is.

Upon consideration of the costs involved with quicker response time, cost savings will not adequately analyze these options. A “per ping” cost can not be obtained from the GPS technology because the number of pings is essentially unlimited. Also, the cost of a combined GPS and cellular plan is unknown because a less expensive cellular plan, involving fewer allowable direct connects, could be utilized with the GPS technology. Quicker response time should be remembered as a benefit, but in terms of assessing a monetary value, this output is unquantifiable.

The intermediate goods method is best to assess the potential decrease in incidents of vandalism. Estimating the number of incidents that may be alleviated by warnings of GPS-prompted enforcement, a dollar value can be determined based on the ability to save the average repair expenditure due to vandalism. Acts of vandalism that have occurred in Wake County include stolen buses that are wrecked, buses set on fire, and numerous broken windows due to rock throwing. Fire damage has resulted in repair bills of \$50,000. Broken windows could involve as little as \$50, depending on the number and type of windows broken. \$1000 will be used as the estimated savings from alleviating one act of vandalism a month.

Finally, a willingness-to-pay survey of Wake County citizens will best determine the dollar value to assess for better customer service. A sample survey was distributed to the employees of the Institute for Transportation Research and Education. The survey form is presented in Appendix C. Willingness to pay was assessed by asking the respondents to indicate the amount they would be willing to pay annually to have the AVL program implemented on the Wake County school bus and service vehicle fleet. Dollar values were given in the range of \$0 to \$500. Twelve of approximately twenty surveys were returned. Over 60% of the respondents did not have children enrolled in Wake County public schools. Of these, two respondents indicated an increase in their willingness to pay assuming that they did have children enrolled in the Wake County School System. Of the responses from parents and/ or guardians, all but one involved elementary-aged children. One respondent is the parent of a high school student. There was insufficient data to determine how the average willingness to pay differed for parents of elementary, middle, and high school students.

Averaging the responses yields an average willingness to pay of \$79 per Wake County citizen. Calculating the average with zero values for the two respondents who would only be willing

to pay if they had children enrolled yields an average of \$66 per Wake County citizen. 75% of the parent respondents indicated frequent late bus arrivals of more than ten minutes each time. This provides some explanation for the general willingness to pay of the public for the services provided by AVL. These values, however, represent the public opinion of having the GPS units in place of the fleet of approximately 750 Wake County school buses and service vehicles. This cost-benefit analysis is concerned, primarily, with the Pilot Program. Scaling the willingness to pay down proportionately from 750 units to 40 units yields an average annual willingness to pay of \$3.52 per Wake County citizen for the Pilot Program.

According to 1997 population statistics published by the Demographic and Economic Data Center of the Wake County Planning Department, Wake County has a total population of approximately 550,000. Nearly 36% of these are under 20 or over 65 years of age. This leaves approximately 350,000 Wake County citizens to comprise the general survey population. Assuming that the general public behaves similarly to the sample survey respondents, one third have no willingness to pay for this program. Therefore, approximately 230,000 people would be willing to pay \$3.52 annually to have a AVL program implemented on the Wake County school bus and service vehicle fleet. This yields a total monetized benefit for increased customer service of \$706,100 per year or \$58,841 each month.

Appendix C: Sample Cost Benefit Analysis Survey

Public Value Survey for GPS in Pupil Transportation Operations

The Pupil Transportation Group of the Institute for Transportation Research and Education is evaluating the value of using Global Positioning System (GPS) technologies on school buses in Wake County. The Global Positioning System is a series of devices that use signal from several satellites to determine position coordinates. Automatic Vehicle Location (AVL) is made possible by GPS and can track the current location of vehicles by on-board units that communicate electronically with a central base station. This technology has the potential to increase “customer service” by decreasing the number of late bus arrivals and providing the potential to notify the public when buses are late due to extenuating circumstances, such as traffic jams and road closures. The AVL units could also decrease acts of vandalism that require, at times, thousands of dollars to repair, and allow for quicker response of necessary personnel in emergencies. The target is to have an AVL unit in operation on each school bus and school bus service vehicle, including fuel trucks and mechanics, in Wake County.

*Please answer the applicable questions below to reflect your opinion of this proposed program. **Print the completed survey and place it in the Pupil Transportation Inbox.***

Please remember, at no time will you be asked to pay the amount at which you indicate this program to be valued. This is simply a means of determining, in dollar value, the worth of this program to the general public, including persons with children enrolled in the Wake County Public School System and without.

1. Are you a parent or guardian of a child currently enrolled in Wake County Public Schools? (If no, skip to question #6.)

- Yes No

2. If yes, does your child(ren) ride a Wake County school bus?

- Yes, to school Yes, from school Yes, to and from school
 No Some of my children do, some do not

3. If you have children that do not ride the bus, please explain why.

4. Check the box corresponding to the grade level of your child(ren).

- | | | | |
|----------|-------------------------------------|---------------------------------|-------------------------------|
| Child 1: | <input type="checkbox"/> Elementary | <input type="checkbox"/> Middle | <input type="checkbox"/> High |
| Child 2: | <input type="checkbox"/> Elementary | <input type="checkbox"/> Middle | <input type="checkbox"/> High |
| Child 3: | <input type="checkbox"/> Elementary | <input type="checkbox"/> Middle | <input type="checkbox"/> High |
| Child 4: | <input type="checkbox"/> Elementary | <input type="checkbox"/> Middle | <input type="checkbox"/> High |
| Child 5: | <input type="checkbox"/> Elementary | <input type="checkbox"/> Middle | <input type="checkbox"/> High |

Automatic Vehicle Location (AVL) for Pupil Transportation

5. In the period of August 1999 to March 2000, estimate the number of times and average length of time that the bus arrived late for pick-up or drop-off. Please check one box for number of times **and** one box for length of lateness **per child**.

Child	Estimated Number of Times Bus Was Late				Estimated Length of Lateness (min. = minutes)		
	0 - 5	6 - 10	11 - 15	16 or more	1-10 min	11-20 min	More than 20 min.
1							
2							
3							
4							
5							

6. Check the box below indicating the largest amount that you would be willing to pay **per year** to have the GPS program, explained above, in place on the Wake County school bus and service vehicle fleet.

- \$0 (approximately \$0 per month)
- \$50 (approximately \$4 per month)
- \$100 (approximately \$8 per month)
- \$250 (approximately \$20 per month)
- \$500 (approximately \$41 per month)

7. Add any additional comments below.

Thank you for your time and contribution!