8-1-1993

IVHS Applications for Measurements of Roadway Performance: AVL Feasibility Analysis

CUTR

IVHS Applications for Measurement of Roadway Performance: AVL Feasibility Analysis

Technical Memorandum 1
Existing Use of AVL in Transportation Planning Applications

Prepared for the

Florida Department of Transportation

by the

Center for Urban Transportation Research
College of Engineering
University of South Florida

August 1993

I. PURPOSE

The Florida Department of Transportation has entered into a contract with the University of South Florida on behalf of the Center for Urban Transportation Research (CUTR) to investigate the feasibility of using automatic vehicle location (AVL) to measure roadway performance.

In March of 1993, the City of Miami asked CUTR to set up a field operational test of the use of AVL to measure vehicle operating speeds on the city's seventeen transportation corridors. This first technical memorandum explores other instances of the use of AVL in transportation planning applications. This report describes the applicability of collected data to transportation planning applications, successes or failures of on-going projects, as well as costs. This memorandum also compares costs between AVL and traditional methodologies of collecting data on vehicle operating speeds.

A subsequent technical memorandum will evaluate results from the "Miami Experiment" and determine the applicability of data collected by an AVL system to (1) measure LOS on an specific roadway (2) to quantify the effects of transportation engineering improvements and (3) to collect other kinds of data useful in transportation planning applications. A third technical memorandum will investigate the feasibility of using AVL in other areas of the state. Findings from the three technical memoranda will be incorporated into a final report.

II. INTRODUCTION

The term Intelligent Vehicle Highway Systems is used to describe projects which apply advanced technologies to improve the efficiency and capacity of transportation systems. Passage of the Intermodal Surface Transportation and Efficiency Act (ISTEA) of 1991, with its emphasis on IVHS, focused national attention on this emerging field. The ISTEA brought more than exposure to IVHS, authorizing $660 million over six years for research and operational test of IVHS technologies. During the Clinton Administration, Congress has appropriated $90 million for IVHS in addition to the ISTEA funding. States and regional authorities have followed the federal lead, also providing funding for numerous IVHS projects.

There are many ways in which advanced technologies may be applied to transportation. The two types of IVHS projects discussed in this report are Advanced Traveler Information Systems and Electronic Toll Collection. Advanced Traveler Information Systems (ATIS) projects use a variety of technologies to communicate real-time, up-to-the-minute traffic information to travelers using a variety of modes. Electronic Toll and Traffic Management (ETC) projects enable drivers to pay tolls without stopping their cars at toll plazas, where payment is accomplished using wireless communications between a transponder ("tag") inside vehicle and an antenna installed at the roadside. Automatic vehicle identification (AVI) is the technology which makes ETC systems possible. Since passage of ISTEA in 1991, the U.S. Department of Transportation has funded over 15 ATIS-type projects. Twelve toll authorities in the U.S. have installed and eight agencies are planning to install ETC systems on their toll roads.

While the term ETC describes the use of AVI technology for more efficient collection of tolls, without any action required by the driver or toll collector. ETC is the foundation of electronic toll and traffic management (ETTM) systems. ETTM uses AVI technology not only for toll collection, but also for more broad-based traffic management purposes, such as the projects described in this report.

Another type of IVHS application is Automatic Vehicle Location (AVL). AVL is a means of continuously monitoring the location of vehicles in a road network. Typically, vehicles are equipped with a transponder, the size of a video cassette tape, which transmits a radio-frequency (RF) signal to a central location at regular intervals. AVL systems are being used by all kinds of customers in all kinds of applications around the world. Delivery companies use AVL to plan the most efficient dispatch of their fleet vehicles. Transit agencies use AVL in conjunction with information displays to inform passengers when the next bus will actually arrive, as opposed to when it is scheduled to arrive. Paratransit operators use AVL to log the distance of traveled by Medicaid patients, and later use this data when applying for reimbusement from the state. Private citizens can even subscribe to an AVL service which will instantly dispatch a tow-truck to their car in the event of a breakdown or to recover their car if it is stolen.

Vendors can set up AVL systems with relatively little investment in infrastructure, and consequently little need for federal or state financial support. *GPS World* magazine, *The IVHS Index*, IVHS America's *APTS Vendor Catalogue* and the Federal Transit Administration's *APTS State of the Art* report list over two dozen vendors of AVL systems using a variety of different positioning technologies: dead-reckoning, map matching, LORAN-C, ground-based radio navigation and global positioning systems (GPS). Eleven transit agencies in North America have installed and fifteen agencies are planning to install AVL systems on their buses.

Of the traveler information and electronic toll collection projects in the United States, the following are the only projects which use AVL to gather traffic information:

- TravTek - Orlando, FL
- ADVANCE Project - Chicago, IL
- TRANSCOM Project "E-ZPass" - New York City, NY
- Illinois Tollway "I-Pass" - Chicago, IL
- Houston AVI - Houston, TX
- CAPITOL - Washington, DC

Each of these projects is profiled, providing information on the following issues:

- Who are the participants?
- What kind of positioning technology does the AVL system use?
- What kind of vehicles are being used as probes?

- How many probe vehicles/drivers are expected to participate?
- How are probe vehicles/drivers recruited?
- How are drivers' concerns about privacy addressed?
- What kind of data is collected?
- What kind of analysis is performed on the data and what is its output?
- Who will use the data and for what purpose?
- What is the current status of the project?
- How much does the entire data collection system cost?

The Miami Experiment is the only IVHS project which currently uses data gathered by automatic vehicle location for transportation planning purposes.

Finally, this paper compares costs of collecting vehicle travel speeds using AVL and conventional methods. Since start-up costs of AVL systems are large but day-to-day costs are small, in comparison to conventional data collection methods, the AVL method is found to be less expensive than conventional travel-time studies given sufficient length of the data gathering experiment.

III. THE MIAMI EXPERIMENT

In March of 1993, the City of Miami asked CUTR to set up a field operational test of the use of AVL to measure vehicle operating speeds on the city's seventeen transportation corridors. CUTR set up a data gathering experiment which used data compiled from AVL units installed in the vehicles of 25 volunteer drivers who traversed the City road network as part of their normal daily commute. The technology vendor of the AVL system was AirTouch Teletrac, which donated the equipment at minimal cost. The "Miami Experiment" ran from April 25 to August 15, 1994, recording over 5,000 vehicle trips.

The AirTouch Teletrac AVL system locates vehicles using a positional technology called ground-based radio-navigation, (a.k.a. "terrestrial radio-navigation" and "signal tri-lateration.") When using this type of positioning technology, the AVL vendor sets up a network of receiving antennas throughout a metropolitan area. Each probe vehicle is equipped with device (a "transponder") which broadcasts a radio-frequency (RF) signal to all nearby antennas. From the time it takes for the signal to travel from the transponder to the antenna, the system can determine the distance of the vehicle to each antenna. If the signal was received by three or more antennas, the vehicle's position can be uniquely determined.

Ground-based radio-navigation use a less sophisticated technology that the satellite-based global positioning system (GPS) systems and, consequently, guarantee less accuracy. Ground-based radio-navigation AVL systems are among the least expensive AVL systems for the user. However, since constructing the necessary infrastructure requires significant financial investment on the part of the AVL vendor, these systems are usually only available in dense urban areas with large market potential. AirTouch Teletrac has radio-navigation AVL systems operating in Los Angeles, Chicago, Detroit, Dallas/Ft. Worth, Houston and south Florida. The south Florida AirTouch Teletrac system can locate a vehicle anywhere in Dade, Broward and Palm Beach counties. The company guarentees the accuracy of its AVL system to the nearest 150 feet. Due to south Florida's relatively flat terrain, the accuracy of the south Florida system is generlly within the nearest 50 feet. AVL systems which use augmented global positioning systems technology are generally accurate to within 16 feet.

The City of Miami was responsible for recruiting volunteer drivers. Many of the drivers were City of Miami or Dade County employees who live on the periphery of the city and commute to downtown daily, thus providing coverage of 5 of the 17 corridors in the peak direction during the peak period. Advantages to participation in the experiment included receiving a free vehicle breakdown and stolen vehicle recovery service for which many south Floridians pay over $300. Disadvantages included a certain loss of privacy which left some potential volunteers unwilling to make the tradeoff. CUTR, AirTouch Teletrac and the City assured volunteer drivers that their vehicles would be tracked only by its assigned number, and that all vehicle location information would be used only for the stated purposes of the study.

The AirTouch Teletrac AVL system polled the vehicles for their locations every 30 seconds when the vehicles were on and every 5 minutes when the vehicles were off. The vehicles' locations were recorded by the AirTouch Teletrac fleet management software FleetDirector™ at a workstation located at the City of Miami offices. FleetDirector™ wrote the vehicle location data to a file for 5-hour morning and afternoon peak periods on weekdays, plus a 4-hour period on Saturday. Every week City of Miami staff sent the latest copies of the files to CUTR in Tampa for analysis.

CUTR researchers wrote two software programs to analyze the vehicle location data. One derives average travel speed for an entire trip, from the moment the vehicle ignition is turned on to the moment the vehicle ignition is turned off. The other correlates the geographic coordinates of road segments to the vehicle's recorded locations to derive average speeds for particular segments of the commute trip. The FleetDirector™ software has never before been used to track vehicles to calculate their speed.

To determine if the system was producing valid data, CUTR researchers established a validation process to compare the observed values for average speed over a vehicle trip to values calculated by CUTR's data analysis software. City of Miami transportation planning staff, who were driving equipped vehicles, recorded the starting and ending times of their trips, plus the distance traveled as recorded by their car odometers.

Comparing the data collected automatically and manually for thirty validation runs, the mean difference was -1.07 mph for method 1 and +1.07 mph for method 2. The standard deviation of these differences was 4.06 for method 1 and 2.63 for method 2. Assuming that the differences between observed and calculated values follow a normal distribution pattern, we can be 95% confident that the calculated speed will be within -1.07 mph $\pm$ 1.45 mph of the observed value for method 1 and within 1.07 mph $\pm$ 0.94 mph for method 2.

In a future phase of this experiment, CUTR will use the data analysis software to compute average travel speeds for each of Miami's seventeen corridors in the peak direction during the peak period. The City Planning Division then has the option of incorporating those computed average speeds into its corridor level-of-service determination. In addition, District IV of the Florida Department of Transportation has evidenced interest in using the system to collect average travel speeds in either Broward or Palm Beach Counties for their ISTEA-mandated congestion management systems.

AirTouch Teletrac donated use of its AVL system to the City for minimal cost. CUTR paid AirTouch Teletrac $2,500 for installation and removal of the 25 transponders, workstation and FleetDirector™ software for 120 days. AirTouch charges its commerical customers $7,500 plus $250 per month for a similar equipment rental and services. The City of Miami paid CUTR $25,000 to set up the experiment and write data analysis software.

IV. OTHER U.S. APPLICATIONS

A. TravTek

When IVHS was first conceptualized in the late 1980's, the most popular application of technology to transportation was route guidance, (also called "in-vehicle navigation"). For a route guidance system, special computers are installed in vehicles. The computers contain map databases and have the ability to locate their own position. A driver inputs his desired destination, and the in-vehicle unit gives him directions on how to get there. Development of in-vehicle navigation units has progressed considerably in recent years. Oldsmobile will begin selling in-vehicle navigation units as an option in their Eighty Eight LSS performance sedan in California at the end of 1994.

Dynamic route guidance takes the navigation task one step further by receiving information about current traffic conditions on the road network. In giving directions to the driver, the in-vehicle unit allows the driver to avoid areas and roads with heavy traffic congestion. TravTek, a one-year operational test of IVHS technology conducted in Orlando, FL from March 1993 to March 1994, employed dynamic route guidance. TravTek obtained its information on current traffic conditions from loop detectors embedded in Orlando-area roads, video surveillance cameras installed along Interstate-4 and other stationary sensors. This information was collected and processed at a Traffic Information Center (TIC) staffed by the City of Orlando traffic engineers.

The American Automobile Association, Federal Highway Administration, Florida Department of Transportation, General Motors Corporation and the City of Orlando made financial or in-kind contributions to the test.

Each of the 100 vehicles TravTek was equipped with a computer, touch-screen display, map database on CD-ROM, on-board compass and odometer and global positioning system (GPS) receiver. The positioning system used a combination of GPS, dead-reckoning and map-matching to locate the vehicles.

Volunteer drivers rented the vehicles through Avis rental car agency, most of whom were tourists visiting Orlando. The American Automobile Association promoted the program to its members nationwide. Over 6,000 volunteer drivers had the opportunity to drive TravTek vehicles. Privacy concerns were not explicitly addressed as part of the project.

Using electronic maps from both Etak, Inc. and NavTech as a base, the TravTek project maintained an estimated travel time for each link in the road network. The map database covered a 1200-square-mile area of west central Florida, maintaining travel times on over 1,400 links. Traffic management software estimated link travel times from a variety of dynamic sources: surveillance cameras installed on Interstate-4, incident reports logged by the traffic information center operators, the city's traffic signal control software, the city's road maintenance and construction schedules, and probe data from the TravTek vehicles themselves. If no dynamic information on a link's travel time was available, the system used a historical estimate based on the time of day and day of week.

Each TravTek vehicle sent a report every minute to the TIC. Each probe reports contained the vehicle ID number, latitude and longitude of the vehicle's position, speed and direction, and the last three link traveled and their travel time.

Software developed by Farradyne Systems, Inc. fused data from these various sources into one travel time estimate for each link. Probe vehicles accounted for only about 10% of the estimated travel times for links on the road network. The city's traffic signal control software accounted for 28% of the estimates. The system relied on historical information for 56% of its estimates.

The dynamic estimates for link travel times were broadcast to the TravTek vehicles, in one-minute intervals, so that the navigation software could use this data in its calculation of the quickest route to each driver's destination. The dynamic link travel times were not used for any other purpose. Since the conclusion of the TravTek project in March 1993, software developers from Farradyne Systems have not trained Orlando city traffic engineers on use of the traffic management software, which still resides in the Orlando TIC. Although data from the TravTek probe vehicles is no longer being collected, data from other sources could still be used to estimate vehicle travel speeds on road segments. The City of Orlando is in negotiation with Farradyne on this matter.

TravTek was among the first large-scale field operational test of IVHS technologies. The total project cost was $8 million.

B. ADVANCE

Like TravTek, the ADVANCE project (Advanced Driver and Vehicle Advisory Navigation Concept) tests dynamic route guidance, but relies much more heavily on data from vehicle probes.

The Federal Highway Administration, Illinois Department of Transportation (IDOT), Northwestern University, University of Illinois at Chicago, and Motorola are participating in the project. Financial support for ADVANCE is provided by the FHWA, IDOT and other private commercial interests.

Each probe vehicle will be equipped with a Mobile Navigation Assistant (MNA). The MNA is composed of a computer, CD-ROM, driver interface, wheel speed sensors, a compass and global positioning system (GPS) receiver. Probe vehicles will report travel time for road links as they traverse the test area. The data will be collected by on-board equipment then transmitted to a Traffic Information Center (TIC). Information is also collected from loop detectors embedded in various parts of the roadway, plus anecdotal reports from drivers via cellular phone.

The project is intended to eventually include 5,000 private and commercial vehicles. Driver recruitment began in August 1994. The American Automobile Association (AAA) is assisting in the recruitment process. Each vehicle will be assigned a unique identification number, and vehicles will be tracked using only that number to maintain drivers' privacy.

The basic data set will be transmitted via RF signals, including vehicle number, location and time of each reading. The MNA also records the driver's interaction with the system, so that statistics can be compiled on the options selected, route taken, and frequency of use. Argonne National Laboratories will analysis this type of data.

ADVANCE has received substantial funding as part of the annual U.S. Department of Transportation appropriations process, with over $10 million earmarked for the project to date. The estimated total project cost is $52 million. At the conclusion of the test, IDOT will be left with state-of-the-art traffic surveillance equipment and Motorola will have developed an in-vehicle navigation unit which it can sell as an after-market product on passenger and commercial vehicles.

C. TRANSCOM

Unlike the ADVANCE project or the Miami Experiment, TRANSCOM will use technology developed and implemented for another purpose - electronic toll collection - to collect traffic information using probe vehicles. In electronic toll collection, vehicles are equipped with a transponder which communicates only when they pass near antennas installed at specific points along the roadway. This kind of system is called Automatic Vehicle Identification (AVI) to distinguish it from Automatic Vehicle Location (AVL) in which transponders constantly transmit their location to a central receiving point. Drivers who use the toll road regularly purchase or lease a transponder, plus make a deposit on a payment account of future tolls. Transponders can cost anywhere from $10 to $40. When the driver passes through a toll plaza, the AVI system automatically decrements the driver's balance. In this way, the driver pays his toll without having to stop at the toll gate. Toll authorities are turning to electronic toll collection as a way of reducing traffic congestion near toll plazas, and make traveling along those roads more appealing to drivers.

Seven toll authorities in Pennsylvania, New York and New Jersey have agreed to install the same ETTM system for all of their roadways. (Two thirds of all toll revenue collected in the United States is collected in these three states.) The coalition calls itself the Inter-Agency Group (IAG) and the electronic toll collection project "E-ZPass." The IAG recently selected Mark IV Industries as the ETTM vendor. However, prior to Mark IV's selection, two member agencies installed an ETTM system from another vendor - Amtech - for an initial feasibility test. The TRANSCOM project will use the 40,000 drivers who have purchased ETTM transponders as probe vehicles to determine traffic conditions on the New York State Thruway and Garden State Parkway.

When the system is operational, software developed by Farradyne, Systems, Inc. will randomly select a vehicle at a toll plaza equipped with an E-ZPass transponder. The vehicle will be assigned a random tracking code and tracked using RF antennas along the two participating toll roads. Tracking code, location and time will then be recorded and used for real-time incident detection. Farradyne has developed software to analyze vehicle location data, report on possible traffic incidents, and notify emergency response agencies.

TRANSCOM member agencies are currently installing roadside antennas. The system should be operational by October of 1994. However, according to the TRANSCOM office, the committee has no plans to make the travel time data available for transportation planning purposes.

Like ADVANCE and TravTek, TRANSCOM has received substantial federal funding and earmarking through the annual USDOT appropriations process. The estimated project cost for the ETTM portion of TRANSCOM is just over $2 million.

D. Houston AVI

The Texas Department of Transportation (TxDOT) is involved in two projects involving volunteer drivers as probe vehicles in the traffic network. The first project, entitled the "Cellular Telephone Demonstration Project," used calls from selected drivers via cellular telephone to monitor traffic conditions on a Houston-area travel corridor composed of parallel roads north of downtown Houston - the Hardy Toll Road, I-45 and State Road 59. Two hundred probe vehicle drivers were selected from a pool of drivers who use those routes as part of their normal daily commute. Volunteers received a cellular telephone free of charge. In return, drivers were required to call a central telephone number and report on traffic conditions and incidents that affected traffic flow. As a volunteer driver passed a designated receiving station, he was required to call the TxDOT control center and report the station number and identification number of his vehicle. The operator would record the information, plus the time and date of the call, entering it into a travel time analysis database.

Relaying the information and entering it into the database took 10 to 15 seconds per call. Each probe vehicle made between 10 and 12 reports per day.

Software written by the Southwest Regional Transportation Center of Texas A&M University analyzed the database and gave a report of current travel conditions on the selected roadways. TxDOT used the current travel conditions to update its network of eight variable message signs and to instruct its incident response teams. The information was also faxed to the broadcast studios of the three Houston-area traffic advisory services.

The second Houston-area project, like the TRANSCOM and Illinois Tollway projects, uses ETTM patrons as vehicle probes. TxDOT is installing readers at 2 to 4 mile intervals on over 120 miles of freeways and 100 miles of reversible HOV lanes. Installation of readers will be conducted in three phases. Phases I and II cover I-10, I-45, SR 59 and SR 290, and are nearly complete. Phase III will cover I-610 (the beltway) and the Sam Houston Tollway.

The 32,000 drivers who have already purchased ETTM tags will not be used because of privacy concerns. TxDOT has issued 1,000 transponders to drivers who travel I-10, SR 290 and I-45 as part of their normal daily commute. TxDOT plans to issue tags to an additional 3,200 volunteers. A clause in the volunteers' contract specifically states that the vehicle's travel time data will not be given to police for the purpose of issuing tickets to drivers. The Metro Transit Authority has also installed transponders on buses which use exclusive HOV lanes in these corridors.

As each vehicle passes a reader antenna, information on the location, time and vehicle identification number is collected at the roadside by the reader and transmitted by radio to nearby field stations equipped with modems and telephone lines. The information is then sent by telephone to the Central Control Facility (CCF). Using software similar to what was used in the Cellular Telephone Experiment, the travel time database is analyzed to product a summary of current travel conditions. The information is then distributed to various users of real-time information.

In an article published in *ITE Journal*, two of the Houston AVI project managers allude to using the travel time data to measure roadway performance, however no firm plans exist to date. "Since so many measures of effectiveness rely on the impact of speed and travel times, it is important to have the most reliable data available." stated Steve Levine of TxDOT and William McCasland of the Texas Transportation Institute.

The cost of Phase I installation was $2 million. The cost of the other two installation Phases are unknown.

E. Illinois Tollway

Along with the TRANSCOM committee and Harris County Toll Authority, the Illinois State Toll Highway Authority has plans to use patrons of an electronic toll collection system as traffic probe vehicles. In June 1994, the Illinois State Toll Highway Authority announced that it had selected AT/Comm as the technology vendor and Science Applications International Corporation (SAIC) as the systems integrator for an ETTM system - called "I-Pass" for over 200 lane miles of toll roads near Chicago. The Authority selected AT/Comm after the vendor had successfully completed a test of the technology on the North-South Tollway, involving 2,500 patrons. The contract requires installation of ETTM equipment on the entire North-South Tollway and on the central portion of the Tri-State Tollway, and involves the distribution over 10,000 electronic toll collection tags.

Following their interest in IVHS with the ADVANCE project, the Illinois DOT has reached an agreement with the Illinois State Tollway Authority that will allow IDOT to use motorists' I-Pass tags as traffic probes. IDOT is negotiating with SAIC to design the hardware and software to determine average vehicle travel speeds on the tollway, based on data obtained by the ETTM readers at the toll plazas.

SAIC's contract for the entire electronic toll collection system is worth about $12 million. The cost of the vehicle travel speed data collection portion of SAIC's work is unknown.

F. CAPITAL

Instead of ground-based radio-frequency signals, global positioning systems or automatic vehicle identification, the CAPITAL project will test the use of ordinary cellular telephones as AVL transponders. Engineering Research Associates (ERA), a subsidiary of E-Systems based-in Tampa, is developing a technology - called E-CPAS - which essentially turns any cellular telephone switched on to receive calls into an AVL transponder, and any vehicle with such a phone in it into a traffic probe. Bell Atlantic Mobile Systems is the vendor of cellular telephone services which has donated the use of its network for the test. The Maryland State Highway Administration and the Virginia Department of Transportation (VDOT) will make use of the traffic data gathered from probe vehicles.

The test will gather traffic data on portions of three interstate highways in Virginia and Maryland outside of Washington, D.C.: I-395, I-495 (the beltway), and I-270, plus some arterial streets which cross the interstates. The operational test is scheduled to begin in the summer of 1995 and last 90 days.

Farradyne Systems is developing software to convert the vehicle location data to real-time traffic data on traffic speed and incident locations. Farradyne will maintain a database of traffic conditions at its facility in Rockville, Maryland. Farradyne will make a graphic display of current traffic conditions available to VDOT and the Maryland State Highway Administration via a phone line and modem connection. Lines representing the highways on an electronic map will change color to indicate average vehicle speeds. The maps will also highlight the locations of incidents the system has detected.

Privacy concerns are an important issue, since all of the Washington, D.C.'s estimated 117,000 cellular telephone users are potential probe vehicles, but none have explicitly given their consent to participate in the test. ERA also provided documentation that their system will not violate the federal Telephone Disclosure and Disputes Resolution Act, which prohibits the use of scanners that intercept cellular telephone calls. The E-CAPS system only detects the location of the cellular phone, not the content of the calls. Vehicles are identified by number randomly assigned at the time the E-CAPS system locates the vehicle, not by the cellular phone's telephone number or serial number.

In addition to providing a traffic information database to transportation officials, Farradyne is also developing hardware and software to deliver the database over the cellular telephone communications network to special receivers installed in vehicles. Approximately 10 vehicles belonging to a delivery service that has agreed to participate in the test will receive Farradyne's traffic information via cellular telephone modems and laptop computers.

The Maryland State Highway Administration is currently installing new software that will use data from multiple sources - in-pavement loop detectors, overhead radar detectors and the cellular telephone probes - to monitor traffic flow in real-time. The agency expects this system to be operational in two to three years.

Federal Highway Administration is contributing $5.5 million of the total estimated project cost of $7.1 million, which includes equipment installation, software development, and actual day-to-day expenses of conducting the test.

IV. COST COMPARISON

The start-up costs of conventional travel-time studies and relatively low, while the day-of-day cost of conducting the tests - paying drivers, vehicle rental, gasoline, etc. - is relatively high. In an estimation of costs of different types of congestion management performance measures, JHK & Associates estimate that the start-up cost to be negligible and the operations cost to be $2 per vehicle mile of data collected.

Start-up costs of the Miami Experiment included the $25,000 contract to CUTR to set up the test, supervise installation of the vehicle and write the necessary data analysis software. Although Air Teletrac provided the use of its system at a discount, the Company usually charges its commercial customers $300 per vehicle start-up fee plus $10 per vehicle per 30 days rental.

Assuming that vehicles make two daily commute trips on weekdays with an average distance of 12 miles, the cost per mile of data collection using AirTouch's AVL system and 25 drivers would be:

$$= \left[\frac{\$32{,}500 + (\frac{\$10}{30 days})(25 vehicles)(duration)}{(\frac{4.3 weeks}{30 days})(\frac{5 days}{week})(\frac{2 commutetrips}{day})(\frac{12 miles}{commutetrip})(25 vehicles)(duration)} \right]$$

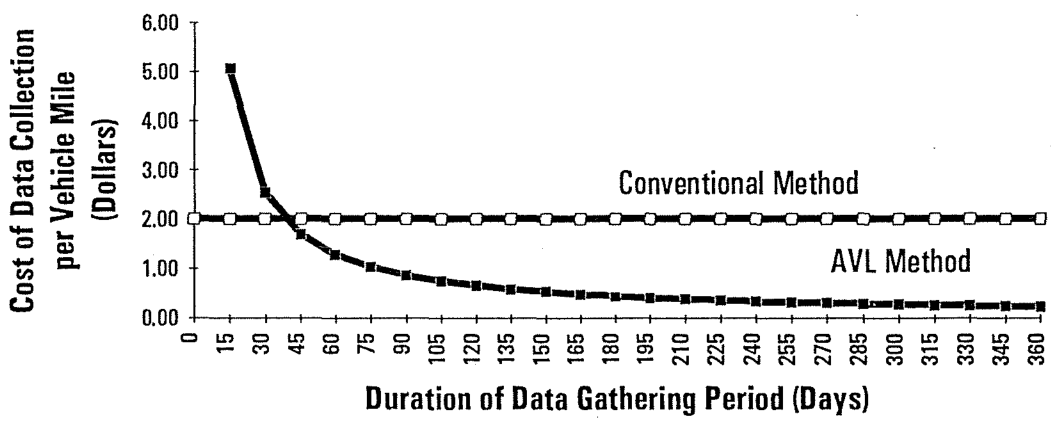
$$= \left[\frac{(\$32{,}500 + \$8.33 * Duration)}{(430 * Duration)} \right]$$

This modal also assumes that:

- no trips are recorded on weekends (including weekend trips would decrease the cost of data collection per vehicle mile even further.)
- drivers are volunteers and are not paid.

Figure 1 shows the cost of data collection for conventional and AVL methods versus duration of the data gathering experiment. The cost values for the AVL method was obtained using equation for the Miami Experiment described above. For data gathering periods of longer than 45 days, the AVL method is the least expensive. For data gathering periods of almost 1 year, the difference in cost is almost two ordersof magnitude.

Figure 1
Cost of Data Collection Using CONVENTIONAL and AVL Methods



IV. CONCLUSION

Five federally- and regionally-funded projects in the United States projects are using vehicles as probes to collect information on traffic conditions. In each of these five projects, the data is used to deliver real-time traffic information to various users: state department of transportation, incident management and emergency response teams, radio and TV traffic information broadcasters, and even drivers with dynamic route guidance units installed in their vehicles. Only the Houston AVI projects has considered the possibility of using the data collected to measure level-of-service. The Miami Experiment is the only IVHS project in the United States to use data gathered from an AVL system for transportation planning purposes. In addition, AVL systems are less expensive than conventional methods of collecting travel information for long-term data gathering periods.

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APPENDIX A
List of Contacts

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