Next Step in Vehicle Assist and Automation

Ann Guy, Wei-Bin Zhang

This March California PATH launched a two-year pilot program to demonstrate the technical feasibility of the vehicle assist and automation (VAA) system, a magnetic and GPS-based guidance system that allows buses to negotiate docking stations, tolling lanes, and right-of-way lanes with precision that adds significant efficiency and quality in a number of transit applications.

After one aspect of VAA’s transit technology was demonstrated on an urban test drive in November of 2008, the project could be found under nationwide headlines with the theme “Look Ma, No Hands!” because when performing its automated tasks, the driver lets go of the wheel as the automation takes over.

“The current deployment proposal seeks to show that VAA can improve transit agency efficiency, performance, and service,” said Jim Misener, PATH executive director. “These improvements are expected to increase the attractiveness of public transit services, reduce congestion, and reduce agency costs,” Misener said. Both PATH and AC (Alameda County) Transit expect project results to provide tangible examples for other transit operators throughout the country, encouraging more agencies to deploy VAA systems and thus creating a viable commercial market for the technology.

PATH submitted the project proposal in collaboration with AC Transit and the Lane Transit District (LTD) in Eugene, Ore., with support from TRW, ContainerTrac, and Integrated Motion Inc. This team combines public transportation stakeholders, technology developers, and technology implementers. The project is intended to leverage Federal Transit Administration funding, which will provide the majority of the resources needed to accomplish the proposed work.

Two Test Corridors

The test sites include a high-quality BRT corridor that was designed with VAA deployment in mind, and an express bus route that involves VAA applications for highways, tolling, and a major bus terminal. “The combination of two test sites provides the opportunity for field operational testing in two very different environments and for different types of bus operation,” said Wei-Bin Zhang, technical manager of the project. “The diversity of test sites will allow the team to achieve a broad assessment of VAA’s viability,” Zhang said.

continued on next page
According to Jim Cunradi, AC Transit Project Manager for BRT and for the VAA pilot program, AC Transit operates a complex combination of express Trans-Bay buses, conventional local feeder buses, and “Rapid” buses, and will begin operating a BRT service on a largely dedicated right of way in several years. “The agency’s initial need for VAA technology is for use on our TransBay express buses,” Cunradi said. The buses operate on HOV lanes approaching the San Francisco-Oakland Bay Bridge and the San Mateo-Hayward Bridge, where currently they must slow down to very low speeds to pass through the narrow toll booths without damaging the buses and their side mirrors. Cunradi says that the accurate steering control of VAA will make it possible for buses to negotiate the toll plazas at higher speeds, reducing operating delays and mirror damage – thus providing better customer satisfaction and avoiding the direct repair costs, driver stress, and lost bus service time associated with mirror damage.

If the VAA experience proves successful in this application, future applications for AC Transit include precision maneuvering of buses in the tight confines of the new Transbay Transit Center in San Francisco and precision docking on the planned BRT services. At the new Transbay Transit Center, which will replace the existing seismically unsafe Transbay Terminal structure, high land cost places a premium on the ability to operate within narrower operating tolerances.

The Lane Transit District (LTD) of Eugene, Ore., has been operating the Franklin EmX bus rapid transit (BRT) service for more than a year on an urban route with a largely dedicated right of way. This pioneering high-end BRT application could benefit immediately from the precision docking function enabled by VAA, reducing station dwell times and improving the quality of service to passengers. The VAA automatic steering between stations should improve safety in locations where the bus lane is immediately adjacent to mixed traffic, reduce stress on drivers, and further enhance quality of service by improving ride quality. A successful field operational test could lead to more economical implementations of future BRT lines by LTD, in narrower lanes occupying less right of way.

The proposed VAA system will be based on two mutually complementary technologies for vehicle guidance, magnetic marker sensing (see pg 6) and Differential GPS (see pg 10) combined with inertial sensors. The Differential corrections to the GPS signals will be provided using Vehicle Infrastructure Integration (VII) roadside equipment (RSE), representing a transit application of VII technology.

To facilitate the operational testing, the buses will be equipped so that they can be operated using only the magnetic system, only the GPS/INS system, or both systems together. For “GPS only” testing, PATH plans to use magnetic sensing as a backup because GPS is vulnerable to physical and electronic interference and requires a reliable sensing system to ensure that safety is maintained in the event of loss of GPS signals. “In this way,” said Wei-Bin Zhang, “it will be possible to understand the advantages and disadvantages of both technologies and how they can be combined to be mutually supportive.”

The proposal team has also discussed with Siemens the addition of their vision-based guidance system for precision docking as an option, pending availability of additional resources.
If you’ve seen an electronic message sign along the highway that tells you how long it will take to get downtown or to the airport, or paid your toll or your parking fees with an electronic tag, or ridden a bus that triggered the traffic lights to turn green as it approached them, then you have experienced some of the benefits of Intelligent Transportation Systems (ITS)—an umbrella term for a variety of new technologies and operations methods for highways and transit. Other on-the-ground ITS applications are less visible to the average traveler, but every bit as useful: they help traffic managers detect and respond to accidents promptly, handle the extra traffic that special events generate, and help state workers safely plow snow on mountain roads in blinding snowstorms.

ITS proponents see an even bigger future for new technologies in transportation—applications that could transform the way transportation systems are designed, operated, and used. To paraphrase one expert: Imagine that car crashes are rare events, traffic flows smoothly even in rush hour, travel times are reliable, up-to-the-minute travel information is ubiquitous, and pollution and wasted fuel from traffic jams are a thing of the past. This vision of Intelligent Transportation Systems has attracted billions of dollars of R&D funding and some of the best minds in the field, both in university research groups and in the private sector, over the past two decades.

Yet Intelligent Transportation Systems also face a host of barriers, only some of which are technological. Deployment costs, funding restrictions, liability concerns, uncertain demand, institutional inertia, and political challenges have limited ITS implementation in a number of cases.

To document the key accomplishments of ITS, find out what is on the horizon, and uncover the challenges to broader implementation of technology-based transportation improvements, we conducted a series of interviews with more than two dozen technical experts and policy makers, including academics and industry experts in California and elsewhere in the US. Here we present the highlights of our findings.

**Key Accomplishments of ITS**

Technological improvements that emerged from ITS research are now so ubiquitous that we take them for granted. They include objects like electronic tags on car windshields for paying tolls and parking charges and “smart cards” for paying transit fares. Travelers also benefit from ITS innovations such as real-time traffic and transit information systems, the national phone number 511 for travel information to map and directions applications for dashboard displays, cell phones, and PDAs. We barely notice that many traffic signal systems are coordinated along corridors and in grid networks, adjusting signals based on the actual numbers of vehicles present, both for daily traffic and for special events. Other ITS improvements we have come to rely on include safety technologies such as vehicle collision warning and avoidance systems and on-board driver monitoring systems for commercial vehicles, as well as freight identification and routing information systems that get baggage to the right airport and packages to the right address.

Technologies like these make travel easier and more convenient. Many of them also...
make the transportation system more efficient by increasing the number of people and vehicles that can be comfortably accommodated in a travel corridor. In addition, these technologies provide operators with information about the transport system that can be used for better planning, operations, and management. For example, the PeMS data management system, developed with Caltrans funding at California PATH, allows transportation agencies to store and process massive quantities of data from roadway sensors quickly and inexpensively. The resulting data sets measure traffic volumes and congestion levels, which planners use to analyze system performance and develop improvements. New sensors also instantaneously detect unusual delays and stoppages, allowing managers to dispatch emergency service vehicles far faster than previous methods of monitoring could do.

**Emerging Applications**

As computer and wireless technologies continue to improve, ITS researchers are finding new applications for them in transportation. Recent examples include smart parking applications that direct drivers to empty parking spaces so they don’t have to cruise around looking for parking. Travelers can use their cell phones and PDAs to find transit routes and schedules from their current location or from a proposed departure point to a planned destination, and to check the arrival time of the next bus or train. Detector systems are growing more sophisticated, and can now warn motorists of ice on the pavement, pedestrians in the crosswalk, and debris in the lane ahead. Dashboard displays can now tell drivers how much fuel they are using so that they can improve their driving efficiency.

Such technologies are already making travel safer and more environmentally friendly as well as easier and more efficient, and new applications currently under development have the potential to provide significantly enhanced benefits. For example, researchers are developing vehicle-to-vehicle communication systems that would automatically warn motorists that a vehicle ahead of them is braking. These systems could also automatically slow or stop a vehicle following one that puts on the brakes. Improved information technologies and vehicle routing and scheduling algorithms will reduce how far in advance paratransit services must be reserved, for example, from 24 hours to perhaps only two or three hours in advance. Integrated weather forecasting, hazard identification, and traffic management systems will allow traffic managers to adjust speed limits and signal timings, deploy emergency services and maintenance personnel, close threatened facilities, reroute traffic, disseminate information about conditions to the public, and if necessary provide information and support for evacuations. Corridor management systems will include information on transit travel times as well as highway times. And advanced electronic freight management systems will be able to provide a single manifest for shipments being transported by several different modes. Policy makers need a clear description of the benefits of new and proposed technologies.

**The Implementation Challenge**

Despite the proven success of many ITS applications and the promise of more to come, ITS continues to face a number of challenges. These range from communicating information about what new technologies can do, to expectations about the speed of implementation, to lack of funding for implementation and operations. We list several of the most common implementation challenges below.
Communicating the benefits of new technologies to decision-makers

Elected officials and agency leaders who must make decisions about whether to invest in new technology development and deployment complain about the jargon that technology developers often use—a host of abbreviations and details that busy decision-makers do not need to understand and do not want to learn. Policymakers are looking instead for a clear description of why the new or proposed technology would be beneficial: what outcomes it would produce and what it would cost compared to other ways of accomplishing the same results. Better communications would be aided by cost-benefit analyses comparing new technology to conventional approaches as well as independent evaluations of completed projects. This suggests there is a need for technology developers to partner with social scientists with expertise in evaluation methods.

Managing expectations for near-term results

Funders want to see results from their investments in ITS, but it can take years to move a technology from “proof of concept” to full deployment. In between these two stages, it’s typical to make many refinements to the technology to improve performance and reliability and to reduce costs. Realistically, not all research results are likely to be deployable in the short or even medium term, but this is not always understood by sponsors. Yet a push for quick results can undermine technology development and reduce the prospects for success: a focus on fast implementation could miss out on longer-term but much larger payoffs. A fine balance needs to be struck between the desire for results and the premature introduction of new technologies that need more development.

Finding an appropriate role for the private sector

The private sector often plays a key role in moving technology from “proof of concept” through development and on to implementation. Private sector interest is, of course, one test of the market for a new technology, and private partners can be a major source of funding for technology development and testing. Industry and business leaders can also play important advisory roles, helping researchers identify possible markets and applications, understand the competition, and develop realistic cost and performance criteria. On the other hand, private sector involvement raises questions about intellectual property ownership, publication rights, competitive bidding obligations, and more. Case-by-case consideration of the roles that private companies can play needs to be a key part of ITS implementation planning.

Involving Users and Stakeholders

Understanding the perspectives of likely users of a new technology can improve the chances of implementation—or lead to a reconsideration of the technology project before too much money is spent on a product that will not find a sufficient market. Owners and operators of public facilities often include the state department of transportation as well as numerous local governments, transit agencies, delivery services, and freight transporters, as well as individual drivers. Businesses and residents also have a stake in changes that affect the transportation systems they rely upon, and often will have a say in those changes. Early involvement of these diverse stakeholders can help in at least three ways: identifying likely supporters and early adopters; understanding concerns early enough to address them in product designs and deployment plans; and introducing new concepts far enough in advance that stakeholders can develop a degree of familiarity with them. On the other hand, broad-based involvement requires skills in public outreach that are quite different from those most technology developers hold. Early stakeholder involvement also may be problematic in cases where the objective is to create for-profit applications.

Developing Workable Business Plans

In some cases, the business plan for transportation technologies has been underdeveloped; in other cases it has been overly rigid. Moving new technologies from the lab to real-world deployment requires a detailed yet flexible business plan. Business plans can help temper unrealistic expectations. For example, public agencies have sometimes assumed that there would be a market for new technologies they develop or for data their systems produce, only to discover that other agencies are uninterested in paying for the new technology or expect data generated on public

continued on page 11

PATH researchers show new results to Caltrans.

Networked Traveler safety and traveler information applications.
PATH's Magnetic Marker Reference Sensing and Guidance System, now being implemented on highways for field operational tests, was designed by PATH researchers specifically for vehicle guidance and control. The system can provide very accurate measurements of vehicle position within a lane, absolute longitudinal location of a vehicle, and advance information about roadway characteristics.

The PATH magnetic guidance system comprises vehicle-borne sensing and processing units that obtain information from a series of magnetic markers that serve as a roadway reference. The markers are simple permanent magnets embedded in the center of a lane, about 1.2 meters apart, to indicate the lane center. Changing the magnetic polarities of the markers creates a binary code: "north pole up" equals a binary 1, "south pole up" a binary 0. The binary coding can be used to indicate roadway characteristics such as upcoming road geometry, speed limits, stop signs, and milepost locations, and to identify highway onramps and offramps. On average, it takes 25 markers taking up 30 meters' length of roadway to encode one binary-coded message. The elapsed time to read that message for a vehicle traveling at 100 km/h (60 mph) would be about a second.

Arrays of fluxgate magnetic sensors, mounted under a vehicle at front and rear, measure the magnetic fields on three axes. A computer, mounted on-board, processes the magnetic field data to derive lateral and longitudinal position measurements and to decode the binary information. (The same computer may also perform all other vehicle control functions.) A signal processing algorithm, by comparing the measured magnetic field strength to the "magnetic field map" of a magnet and eliminating the background noise, determines the position of the vehicle relative to the road center.

Over fifteen years of testing and evaluation, the PATH magnetic guidance system has demonstrated excellent performance: lateral position accuracy of 5 mm (root mean square), longitudinal position accuracy of 5 cm (root mean square), highly robust and reliable under realistic environmental conditions, and fail-safe.

The PATH magnetic system has been tested and proven to be robust under a wide variety of operating conditions. It is not affected by falling or accumulated rain or snow. It provides extremely accurate and repeatable measurements. The infrastructure cost is low, with magnets’ usable life exceeding pavement life, and no maintenance required. The combination of absolute position information with the system’s coded preview of roadway characteristics offers added functionalities and performance for vehicle guidance and control.

The PATH magnetic guidance system can be used for a variety of vehicle guidance and control applications, including:

- Automatic steering control reference for all vehicle classes
- Lane departure warning reference for all vehicle classes
- Precision docking reference for transit buses
- Guidance reference for snowplows
- Special applications in difficult environments (maintenance yards and shops, tunnels, mines, terminals, or ports)
- Automated Vehicle Location (AVL) for fixed route operations.

The PATH magnetic guidance system has demonstrated considerable potential application value, and is attracting worldwide interest from industry and government agencies. Several European, American, and Japanese automobile companies have contacted PATH about the possibilities of transferring magnetic marker reference sensing and guidance technology. PATH and IMRA America (a research subsidiary of Aisin Seiki) originally demonstrated a lateral guidance system using magnetic sensing between 1990 and 1993. Under the coordination of the Japanese Ministry of Construction, Toyota, Honda, Nissan, and Mitsubishi demonstrated fully automatic controlled vehicles using the PATH magnetic marker sensing approach in 1995 and 1996, both on a test track and on a segment of highway in Japan. The system was also used in 2000 during the SmartCruise-21 demo, also in Japan.
In 1997, the National Automated Highway Systems Consortium (NAHSC) conducted "Demo '97," a high-profile demonstration of automated highway systems. The PATH magnetic guidance system was one of the key technologies used by three demonstration systems at Demo '97 (PATH/GM, Honda/PATH, and Caltrans/Lockheed Martin). The eight-Buick platoon demonstration showed the technical feasibility of operating standard automotive vehicles under precise automatic control at close spacings at highway speeds. For Demo '97, magnetic markers were installed on two High Occupancy Vehicle (HOV) lanes of an eight-mile stretch of Interstate 15. Most markers used were ceramic magnets (2.4 cm diameter x 10 cm long, $0.90 each), with stronger neodymium magnets (2.5 cm diameter x 2.5 cm long, less than $10 each) used for special locations. The cost per lane mile of installation was less than $10,000. When the installation process is automated, this cost can be substantially reduced.

In 1998, the Netherlands Rijkswaterstaat (Ministry of Transport, Public Works, and Water Management) organized a large-scale European demonstration of Automated Guided Vehicle Technologies—"Demo '98." PATH, the only US organization to participate, demonstrated a fully automated platoon of passenger cars using the PATH magnetic guidance system that turned out to be the star attraction of the Demo. The PATH cars were the smoothest and most reliable of all sixteen vehicle demonstrations. Also at Demo '98, the Dutch consortium Combi-Road, formed to develop approaches for automated container transportation, demonstrated a heavy-duty automated, driverless, electric-powered truck for hauling shipping containers that steered itself within an accuracy of 5 cm using the PATH system.

Starting in 1998, the California Department of Transportation (Caltrans), in conjunction with the Advanced Highway Maintenance and Construction Technology Research Center at UC Davis (AHMCT) and PATH, demonstrated a snowplow guidance system using the PATH magnetic guidance system on a four-mile segment of Interstate 80 on Donner Pass under the most severe operating conditions, and the magnets remained in place through multiple freeze/thaw cycles each year. In 2004 the system was used to guide a rotary snowblower. The Arizona Department of Transportation demonstrated the system on US-180.

In 2003, two 40 foot CNG powered New Flyer buses and one 60 foot articulated diesel New Flyer bus were retrofitted with a magnetic guidance system. Precision docking and stopping maneuvers, both in-line and S-curve, were demonstrated successfully in Washington DC and San Diego by a 40 foot bus with 2 cm accuracy laterally and 15 cm accuracy longitudinally. Lane assist, lane change and automated/manual transitions were demonstrated on the I-15 HOV lane in San Diego. 15 cm lateral tracking accuracy was achieved up to 65 mph for both 40 foot single unit bus and 60 ft articulated buses.

Under an existing Caltrans-sponsored project, a magnetic test track about one mile long, with three S-curve station stops, was recently built by the project team along East 14th Street in San Leandro, CA for field testing a 60 foot articulated New Flyer bus with lane assist and precision docking. Field testing conducted by AC Transit and PATH began in January 2008.
The overall goal of the proposed project is to demonstrate the technical merit and feasibility of two VAA technology applications in transit revenue service, and to identify and document their costs and benefits. In order to maximize opportunities to collect meaningful evaluation data on this limited field test, PATH will collect baseline data during vehicle operations without the VAA technologies activated in order to provide a basis for comparison.

After the VAA technologies have been activated, new data will be collected to identify the differences. These will include: measuring the station dwell times, while also counting the number of passengers boarding and alighting at each station; measuring the bus speeds and travel times between fixed locations on the trips through the bridge toll plazas; surveying the bus drivers and passengers about their impressions of the bus rides they have taken.

The major technical uncertainties to be addressed in this project involve the robustness and reliability of the VAA systems for use on buses driving in daily revenue service, with long hours of service, diverse unexpected operating conditions, and non-specialist drivers. In order to resolve these uncertainties, the project team includes industrial partners with significant experience in implementing operational systems, who will develop the VAA hardware and lower-level software for the operational testing.

The Team

Caltrans, the research sponsor, has been sponsoring cutting-edge research and development on VAA technologies for 20 years. Research partners AC Transit and LTD are among the most innovative transit agencies in the United States and have real needs for VAA. The VAA technologies to be used on the buses will be based on 20 years of research and development by PATH, extended by the private industry partners into versions that are suitable for public revenue service.

These industry partners include TRW Commercial Steering Systems and Conekt, providing the steering actuation system and the safety case for its; ContainerTrac, providing custom-designed computer systems for signal processing and vehicle control; and Integrated Motions Inc. (IMI), providing CAN-based networking among all the add-on vehicle components.

Z. Sonja Sun, VAA project manager for Caltrans, has been managing research and development projects at the Caltrans Division of Research and Innovation for more than 10 years.

Graham Carey, project manager for LTD, has more than 20 years of transit experience, the last 10 years as LTD’s BRT Project Engineer. Under his leadership, LTD’s BRT has become a model deployment that considered lane guidance in the original design.

Jim Cunradi will be the project manager for the AC Transit work on the project, has managed AC Transit’s BRT program for eight years. Prior to that, he worked in transit and highway planning for 15 years, with ITS experience.

continued on next page
including engineering/design/estimating for the Traffic Operations System in Los Angeles County.

Technical manager Wei-Bin Zhang is the leader of PATH's Transit Program. He served as the Technical Director for the National Automated Highway Systems Consortium (NAHSC), providing oversight of the AHS development under this congressionally mandated national program. He was also the Program Manager for the development of the automated platoon system for the NAHSC Demo '97.

Looking Forward

The project is structured as a two-year operation test, with system refinement and integration primarily in the first year and the public operational testing in the second year. If the results are favorable, AC Transit and LTD plan to deploy the VAA system in revenue service buses. Both transit agencies intend to continue operating the VAA systems after the completion of the testing and, contingent on positive test results, plan to expand their use of VAA technologies to other applications.

PATH Executive Director Jim Misener said the pilot establishes the benefits (and potential limitations) of the VAA technology in both urban and highway applications, covering the diverse needs of low-speed precision docking and high-speed freeway operations. “The knowledge gained from this pilot about benefits and costs of VAA should be applicable to the widest possible range of transit operations around the country,” Misener said.

Differential Global Positioning System (DGPS)

The Global Positioning System (GPS) is a convenient and accurate method for determining vehicle position in a global coordinate system, and when combined with an accurate digital map it can determine the position of a vehicle relative to the lane boundaries. To increase the stability and accuracy of a normal GPS system an added signal will be incorporated.

DGPS is a method of improving the accuracy of your receiver by adding a local reference station to augment the information available from the satellites. It also improves the integrity of the whole GPS system by identifying certain errors. In DGPS operation a station, often called a beacon, transmits correction data in real time that is received by a separate box, called a beacon receiver, which sends the correction information to the GPS receiver. A GPS receiver normally calculates it position by measuring the time it takes for a signal from a satellite to reach its position. By knowing where the satellite is, how long it takes to send the signal, and knowing the speed of the signal it can compute what is called a pseudo range (distance) to the satellite. This range must be corrected before it is used to compute the final position. Corrections such as compensation for ionospheric errors due to the fact that the ionosphere slows down the speed of travel of the radio wave is one form of correction that can be applied. A DGPS beacon transmitter site has already calculated all of the pseudo range correction data based on the fact that it already knows exactly where it is and can compute the errors in the satellite computed position from its known location. Once the pseudo range correction data is computed it is sent to the GPS and used to compute a more accurate fix.

As part of the proposed system DGPS/Onboard Map Guidance, will be added and explored for its improved reliability and increased capabilities. The DGPS system will also be integrated with an INS (Inertial Navigation System) to remedy against satellite blockage and multi-path problems. In order to minimize the number of DGPS base stations to save costs, the installed Vehicle Infrastructure Integration (VII) network can allow correction signals from a single differential base station to be communicated to the vehicles all along the route by the local VII Roadside Enclosures (RSEs). The VII-enabled DGPS approach will help to improve the accuracy of GPS positioning while reducing the number of base stations required. This system will use the advantages of the DGPS/INS systems, such as lower-cost roadway infrastructure, path preview and digital map facilitating electronic guidance design and Bus Rapid Transit (BRT) operations, virtually unlimited sensor range, and the high frequency motion data from the INS. In addition, this integrated system provides a platform for performance and reliability evaluation of a variety of system configurations.

PATH researchers at U.C. Riverside and U.C. Berkeley have also conducted significant research on DGPS based vehicle control/guidance. Carrier phase (CP) GPS signal processing and ultra-tight DGPS/INS integration were investigated to address the problems associated with GPS based positioning systems such as accuracy, latency and low update rate. The integrated CP DGPS/INS system could provide vehicle position, velocity, acceleration, heading and angular rate at 150 Hz update rates with accuracies (standard deviation) of 1.5 cm, 0.8 cm/s, 2.2 cm/s/s, 0.1 deg and 0.1 deg/s. In [12, 15], a CP DGPS/INS based control system was tested on a PATH vehicle at the Crow’s Landing test facility. Decimeter accuracy was achieved at speeds up to 70 mph under the open sky. These GPS capabilities will be applied to the guidance of the AC Transit buses, in combination and comparison with the magnetic guidance system.

facilities to be available without charge. Business plans can also help develop suitable contract provisions for anticipated applications. Many public agencies are accustomed to detailed specifications, but with new technologies with as-yet-unknown applications, flexibility is a desirable contract characteristic. Planning ahead for this can help reduce delays and conflicts.

In addition, for technologies that will remain in the public sector, a long-term funding plan is needed. Although new technology applications often can be paid for using standard funding sources, funding for even well-proven technologies like highway monitoring systems has been far from a sure thing. In a number of cases, monitoring systems have been dropped from projects when budgets tightened. Maintenance funding has also been a problem. In particular, underfunding of sensor maintenance has reduced the effectiveness of this large investment in street and highway instrumentation. Making the funding plan part of the technology assessment and business plan could help overcome these difficulties.

Meeting the Challenges

The challenges to ITS implementation are serious, but they need not be barriers. The non-technological challenges can be addressed by planning and policy researchers, social scientists, and law and business experts whose know-how would complement that of the engineers and scientists who are creating new technologies. The transportation problems that new technologies aim to address have strong legal, institutional, social, environmental, and economic dimensions; research should likewise cover the broader planning and policy context as a complement to technology development. Greater attention to these complementary research needs can help move ITS technologies from special initiatives to the mainstream.

Further Reading


Pravin Varaiya, “What We’ve Learned About Highway Congestion,” Access, no. 27, Fall 2005.
Get on the Mailing List!
FAX, mail or e-mail us the following information for a free subscription to Intellimotion:
Name & Title
Address
E-mail address

If you wish to be notified by email when the next issue is ready online, and not receive a paper copy, please let us know.
See back page for our address and fax number.

Intellimotion
Keeping up with California PATH Research in Intelligent Transportation Systems
Intellimotion is a more or less quarterly newsletter edited and designed by the California PATH Publications Department.
Publications Manager  Bill Stone
Multimedia Specialist  Jay Sullivan
For more information or to offer comments about this newsletter, please write, call, fax or e-mail:
PATH Publications
1357 South 46th Street, Bldg. 452
Richmond, CA  94804-4648
Tel:  510/665-3406 FAX:  510/665-3537
e-mail: publications@path.berkeley.edu
http://www.path.berkeley.edu

Photos by Bill Stone, Jay Sullivan, Gerald Stone, iStockPhoto and Sensys Networks. Graphic pg 6 Jay Sullivan.

Caltrans Management Liaison  Homar Noroozi
Primary funding provided by:

©2009 UC Regents. All rights reserved. Unless permission is granted, this material shall not be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise.
ISSN-1061-4311
Printed on recycled paper