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Transit Research Issue

PATH – Partners for Advanced Transit and Highways – is a joint venture of Caltrans, the University of California, other public and private academic institutions, and private industry, with the mission of applying advanced technology to increase highway capacity and safety and to reduce traffic congestion, air pollution, and energy consumption.

CALIFORNIA PATH

Automating Bus Docking to Improve Transit Service

J. Bret Michael, PATH / Naval Postgraduate School

The technology needed to build automated buses has matured and been demonstrated, but transit operators still need to determine specific ways in which automating buses can improve service. Improved service should result in increased ridership, especially from people who ride buses by choice rather than out of necessity. For instance, service can be improved by increasing accessibility and by integrating bus operation with other modes of transportation, such as subways and light rail transit.

Low-floor buses were a major advance in improving bus accessibility. These buses, pioneered by the German manufacturer NEOPLAN, permit passengers to board and alight on the level, without stepping up or down from the sidewalk at the bus stop docking platform. Level boarding also reduces dwell time — the time a bus spends at a stop. However, if the bus pulls up too far from the curb, and the horizontal gap between bus door and curb is too wide, passengers must first step down to the pavement, rather than across to the bus. Even a small gap could lead to a passenger's falling between the bus and platform, or tripping on the edge of the bus or curb. For some transit users, such as the vision impaired, children, the elderly, or people in wheelchairs, any gap could be a hazard. By automating the docking process whereby a bus pulls up to a bus stop, buses can be made to dock consistently at precisely the desired distance to the curb. This article describes two types of automated docking systems, and summarizes the safety research on this topic conducted by the California PATH Program.

Automated Docking Systems

Two types of systems have been developed to eliminate the horizontal gap between bus and docking platform. One, a docking assistance system, tells the driver where the bus is with respect to the docking point. For example, the French National Institute for Transportation and Safety Research (Institut National de Recherche sur les Transports et leur Sécurité — INRETS) has evaluated, as part of the GIBUS (Guidage des autobus en station) project, an electronic horizontal display mounted on the dashboard of the bus. This display indicates the lateral distance from bus to docking point, and has been field tested in Grenoble.

The other type of docking system provides for full or partial-authority automatic control of the bus during docking: the bus driver lets the automated system drive, or at least steer, the bus. The VISEE system developed by Renault, for example, uses a partial-authority, vision-based control system to

continued on page 2

continued from page 1

steer the bus into the desired docking position. While the system steers, the driver controls the throttle and brakes. Renault, in cooperation with MATRA, is also working on a full-authority electronic-vision based system known as Civis, with testing underway in Paris and other French cities. Cegelec AEG has adapted the fully automated vehicle technology it developed for Channel Tunnel service vehicles for use by full-size transit buses. The bus follows two electronic guide wires embedded in the roadway. Speed is controlled either by the system (using a pre-programmed profile) or the driver. The Cegelec system has been field tested in Newcastle, England, on a Mercedes-Benz bus.

PATH is experimenting with a precision docking system, in which the vehicle follows magnets buried in the pavement. PATH researchers have demonstrated the ability to maneuver a passenger car (Buick LeSabre) very accurately at low speeds, as a kind of simulation of a docking maneuver. The car follows an S-shaped trajectory, analogous to that of a bus approaching a curbside bus stop, with a consistency of better than 1 cm (Figure 1). Researchers expect to be able to repeat this precision docking with a bus as soon as one becomes available. PATH is also investigating design alternatives for fully automated busways (automated highway system lanes dedicated to carrying bus traffic).

The systems mentioned above are based on the concept of electronic guidance, but mechanically based bus guidance systems are still being refined. In the 1980s, the O-Bahn automated bus system, which uses guide wheels with mechanical arms for lateral control, drew the attention of the transit community and was put into service in Essen, Germany, and Adelaide, Australia. The system was not widely deployed, primarily for nontechnical reasons. In 1997, Bombardier introduced a light transit vehicle guided by a single central rail, instead of costly, load bearing double tracks. The Bombardier GLT, like the Civis system, can be operated under manual steering control. Both systems compete with light-rail systems (or trams). Scott McIntosh of London Transport Planning has pointed out that although trams have many appealing characteristics, such as predictable paths of travel, electronically guided rubber-tired buses can provide the same service at less cost.

Safety Concerns

The systems mentioned above are not considered to be mature in terms of operational experience: docking systems' safety must still be evaluated in the environment of their intended use. For example: in the United Kingdom, the certification and regulation of signaling systems for electronically controlled rubber-tired buses falls under the jurisdiction of Her Majesty's Railway Inspectorate (HMRI), which bases its decisions about certification and other safety matters on its evaluations of "safety cases." A safety case consists of recommendations as to a system's fitness for use in specific operational contexts. The system's fitness is presented in terms of arguments as to how well safety issues have been assessed, and to what extent the implementation of the system addresses safety concerns. Each safety case also includes all evidence supporting the arguments, such as a safety plan, results from a preliminary safety analysis, and records of safety reviews and incidents.

Safety Cases

PATH has investigated ways to collect, manage, and present safety information about automated docking systems to regulatory, certification, and other decision-making bodies. The work to date has focused on French and British standards, practices, techniques, and tools for constructing and main-

Left to right:
Figure 1—PATH automated test car follows magnets in roadway to simulate bus docking.
Figure 2—Near-side bus zone with illegally parked car.
Figure 3—Nub stop and queue-jumper lane (ahead of stop). Note truck parked in bus zone.
Figure 4—Passengers boarding bus in street.
Figure 5—Buses arriving in tandem.

taining safety cases for driverless subway systems. Key findings include:

• Because each safety case may need to be presented to different audiences, a “pre-safety case” could be used to pre-plan the structuring of the safety case to support the generation of different views that could then be addressed in an effective presentation tailored to a specific audience. The Human Communication Research Centre at the University of Edinburgh has done extensive research on this topic.

• Each safety case is a “living” record: it must document all changes to the system, all incidents, and other safety-relevant information. Paper-based safety cases have been difficult and tedious to assemble and maintain over the lifetime of a system, but computer-based tools have now been introduced for constructing, storing, and managing safety cases. The Safety Argument Manager developed at the University of York (England) consists of a suite of tools for inputting safety analysis information and tracing this information back to system requirements and designs.

• Partitioning system functions into different categories can be a useful way of focusing the safety case on a system’s most critical functions. Safety cases for French driverless subway systems center on the automatic train protection system, which is responsible for hazard monitoring, emergency braking, and power shutdown, as opposed to automatic train operation and other functions.

• In France, system developers of fully automated subways work directly with independent evaluators appointed by the Ministry of Transportation, who provide the developer with non-binding suggestions for improving the safety case. After this feedback process, the evaluators recommend that the Ministry either approve or deny certification. The Ministry does not dictate, via standards or other means, the contents of the safety case or the manner in which it is presented: this is left up to the independent evaluators and system developers.

• In the United Kingdom, by contrast, there are standing regulatory and certification authorities for all rail-based systems, in addition to a large body of industry standards and guidelines. However, standards for certain aspects of such novel systems as automated buses do not exist. They are expected to be developed as the systems are introduced.

Field Observations

To develop an initial set of safety considerations upon which to build safety cases for automated bus docking systems, field observations of manual bus docking were made in downtown San Francisco. This area has a high volume of transit bus and other traffic, including pedestrians and bicyclists. Five sites were chosen to observe bus docking for different docking configuration-location pairs: near-side at curb (Figure 2), far-side at curb (see cover photo), nub with queue-jumper lane (Figure 3), and open bay.

Some hazardous conditions observed included: vehicles parked illegally in the bus docking zone (Figure 2), bus drivers permitting passengers to board and alight in the street (Figure 4), vehicles making U-turns, construction barriers forcing drivers to approach a bus stop at a sharp angle, resulting in a large gap between bus and curb, vehicles pulling out of driveways that are partially screened from the driver’s view, a truck stopped in front of a nub stop (Figure 3), pedestrians jaywalking as a bus approaches a far-side stop (see cover photo), and buses arriving in tandem with pedestrians standing at the edge of the curb (Figure 5).

continued on page 15

Improving Transit Access for the Blind and Vision Impaired

James R. Marston and Reginald G. Golledge, Geography, UC Santa Barbara

Our research identifies and evaluates a new technology to allow safe and easy access for the blind and vision impaired.

Signs, both written and iconic, guide us through unknown environments. We use them to identify street intersections, buildings, transit stops, different transit vehicles, and amenities such as telephones, fare, and information booths. People who can't read signs — the dyslexic, the illiterate, the developmentally disabled, people with brain trauma — experience difficulty traveling through unknown territory. The 8-9 million blind and visually impaired people in the United States face greater problems. They do not get the information embedded in signs, and receive few other cues to the environment around them. They are denied cues about pathways and traffic flows, both vehicle and pedestrian. They can't see buses or other transit vehicles, can't find doors, elevators, and other building amenities. This lack of easy and safe access to urban travel and public transit is certainly one reason why only 26 percent of working-age people who can't read newsprint are employed.

How can we improve access for these groups? The Americans with Disability Act of 1990 mandated equal access for all to transit and public buildings. Ramps, curb cuts, and lifts have replaced structural barriers, such as stairs and curbs, for those in wheelchairs. But print-handicapped and vision-impaired people still face functional barriers to equal access. How do blind people find their way, facing these problems of mobility, wayfinding, and exploration? Long canes and guide dogs help a person avoid objects and danger within a few feet, but give no cues to the more distant environment. If a person can't find a bus stop, identify a transit vehicle, or find a building or its entrance, they are denied equal access to transit and public buildings.

Our research identifies and evaluates a new technology to allow safe and easy access for the blind and vision impaired, Remote Infrared Signage Systems (RISS), or Talking Signs®. Each of these signs consists of an infrared transmitter that continuously beams a signal. A hand-held receiver picks up the beam and converts it into a spoken message that can be heard when the receiver is pointed at the transmitter. This gives the user a directional beam to the sign, as well as the sign's content or name.

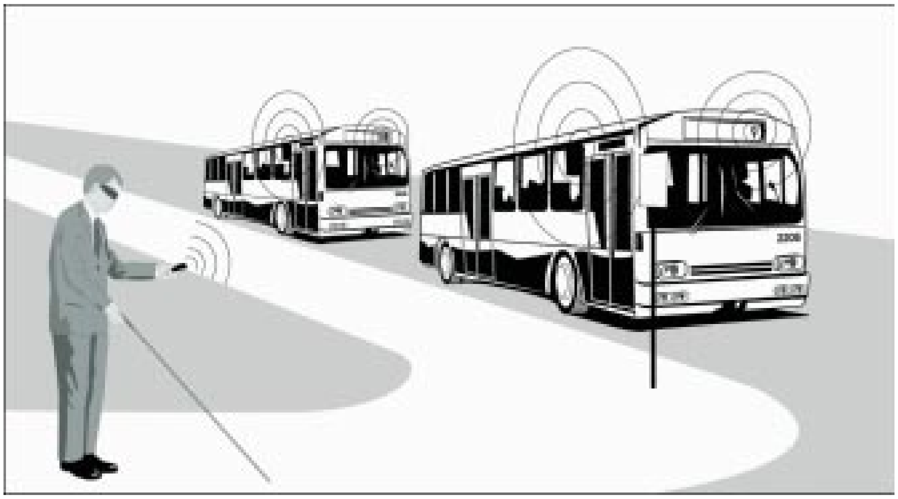
Test 1-A

We conducted two tests, using 10 blind subjects and 10 blindfolded sighted subjects. The first involved walking around a simple geometric path, either a 60' x 60' (18m x 18m) square or a 60' x 30' (18m x 9m) rectangle. A 36" (1m) high stanchion marked each corner of the shape. Subjects were led around the path three times using sighted guide techniques. Subjects swung a long cane ahead as they walked in order to help find the stanchion. Subjects identified the shape as they walked, and then were asked to walk the path on their own. They were pointed at the first stanchion, but received no further information during each attempt. People in the baseline condition made two attempts to recreate the path in a forward direction and one attempt in the reverse direction. If the stanchion was not found within 60 seconds, subjects were told to stop and search for the next stanchion. Response times, angle, and distance errors were recorded for all stanchions.

The blindfolded sighted subjects found 14 stanchions out of a possible 120 (10 subjects x 4 stanchions x 3 attempts). The blind subjects found 35 out of a possible 120 stanchions. Most successes occurred on the first leg, after the subjects had been pointed toward the first stanchion. We examined the response time, distance and angle error, means, and variance between the blindfolded sighted and the blind, and found no significant differences, although the means for the blind were often less than the means for the sighted.

Test 1-B

We next tested our 20 subjects using a Remote Infrared Signage System (Talking Signs®). After five minutes of hands-on training, the subjects were led around a different geometric shape one time and identified the shape. They were then given the receiver and retraced their path on their own. After one forward path retrace, they retraced the path in the reverse direction. The results were very significant: all 20 subjects found every stanchion. There



was therefore no angle or distance error. Average response times for retracing the rectangle were 205 seconds without Talking Signs (R) and fell to 71 seconds with them, a difference of 134 seconds or 65% less time to walk the same path. The results were significant at the 0.0001 level.

Bus Test

The next day, our subjects were blindfolded and taken to the university's bus circle. This busy bus stop is used by over 5000 riders per day and is served by nine different bus lines, so there are often several buses waiting at the circle. Three RISS transmitters were set up to guide subjects around the test path, halfway around the circular sidewalk. All subjects were walked around the half circle two times for practice. This task was made more difficult because there were no straight lines, and a planter and tree were in the middle of the path. The subjects also had to cross two access drives.

Two buses on the Number 9 line were equipped with RISS transmitters, which were installed on the front and side window, directly to the rear of the door. Subjects were told where on the bus the two receivers were located, but were not given any practice in locating the door. In the first trial, subjects waited at the start position, and as each bus was heard coming into the circle they pointed the receiver at the sound. When their receiver picked up the message from the Number 9 bus, they began walking toward the transmitters that guided them along the sidewalk. The verbal message broadcast by those signs said "Sidewalk to Bus Stop." When the subjects got to the bus stop area, they began to scan for the transmitter on the side of the bus. The task ended when they reached the proper bus and put their cane inside the doorway. Response times from first identifying the bus to reaching the doorway were recorded.

In the second bus trial, subjects used their normal techniques, which meant asking a passerby (the researcher) which bus was coming. Subjects then walked from the start position to the bus stop. Here they had to find the door and then ask the driver which bus it was. If it was the proper bus, the trial stopped. If it was the wrong bus, they walked to the next bus in line and asked again for confirmation. (This is what happens in real life at busy bus stops. A blind person must approach each bus and ask the driver which bus it is.)

The third bus trial was identical to the first. Table 1-A shows the number of people that found the proper bus. The success rate when using the Remote Infrared Signage System is clearly evident. A nominal logistic model (Table 1-B) comparing success rate

continued on page 11

Table 1-A
Success at Finding Proper Bus (Success / Attempts)

	Blind	Blindfolded
Trial 1 (RISS)	10/10	5/9
Trial 2 (No RISS)	8/10	2/9
Trial 3 (RISS)	10/10	7/9

Table 1-B
Nominal Logistic Model
Success by Vision (Blind/Sighted) and Aid (RISS/No RISS)

Both	DF =2	Chi Sq = 22.24	Sig=<0.0001
Vision	DF =1	Chi Sq = 10.08	Sig=0.0015
Aid	DF =1	Chi Sq = 6.80	Sig=0.0091

Left: Bus test–Talking Signs® transmitters were installed on front and side of buses on the #9 line at UCSB. Blind or blindfolded subjects used receivers to find the correct bus.
Above: Prof. Golledge and PATH researcher Robert Tam demonstrate Talking Signs® system.

Control Strategies for Transit Priority

Alexander Skabardonis, Institute of Transportation Studies, UC Berkeley

New technological approaches for improving urban transportation systems are being given considerable attention by transportation managers because of limited funding and concerns about the environmental effects of constructing new highway facilities. One viable approach is implementing advanced control strategies on roads controlled by traffic signals to give priority to transit vehicles. Transit, for the purposes of this study, is defined as buses (and light rail) that share the roadway with other vehicles. The objectives of this study are to examine strategies for transit priority in arterials and grid systems controlled by traffic signals.

Giving priority to transit reduces unnecessary delays and stops at traffic signals, improves transit travel times, and cuts fuel consumption and emissions. As a consequence, it would improve service reliability, increase ridership, reduce transit agencies' operating costs, and maximize the passenger-carrying capacity of urban arterials and networks. Advanced control strategies could also improve the ability of surface streets to serve as alternate routes for freeways during major incidents.

Transit Priority Strategies

Infrastructure design for transit priority normally involves exclusive lanes for transit on arterials, as well as street designs to facilitate transit movements. Examples include bus bays and bus bulbs (widened sidewalks at bus stops) to facilitate safe loading and reduce conflicts with other vehicles.

Proposed strategies were evaluated through simulation on a test segment of San Pablo Avenue in Berkeley.

On-street parking management must ensure the availability of adequate curb space for buses. The effectiveness of such measures is largely site specific. Bus bulbs, for example, can work well if there is sufficient road capacity for other traffic to pass a stopped bus, but can contribute to long queues and delays if the bus blocks traffic.

Traffic signal timing for transit priority is coordinated using fixed-time timing plans prepared off-line based on historical data. Transit priority is provided in off-line systems by determining the signal settings (cycle length, green times, and offsets) to favor bus movements. Figure 1a shows a time-space diagram between successive signalized intersections and the trajectories of both a vehicle platoon and bus. To provide priority for buses, the offset between signals must be adjusted to account for the slower speed of the bus and the midblock dwell time. These strategies may also involve bus stop relocation (Figure 1b). If possible, bus stop locations should alternate between the near side and far side of the intersection at successive intersections, so that buses do not have to stop at both the stopline (when the signal is red) and the bus stop.

Signal preemption, where the approach of a bus changes the timing of a traffic signal, is implemented by several methods: using strobe light emitters on the transit vehicles and special light detectors at the signal, radio control, or special loop detectors that recognize bus signatures. Phase extension holds the green until the bus clears the intersection. Phase advance starts the green phase for the bus early. Other options may include a phase activated by the bus, or skipping a phase for traffic in other lanes. Signal preemption has been widely applied at isolated signals and for light rail, but several operating agencies have resisted the implementation of bus preemption in coordinated systems because of the potential adverse impacts to the rest of the traffic stream. For example, phase skipping or red truncation could result in loss of coordination and high delays to the traffic stream. Changes in signal phasing during preemption may potentially cause confusion to motorists. Another issue is the assignment of priorities between intersecting transit lines in a grid network.

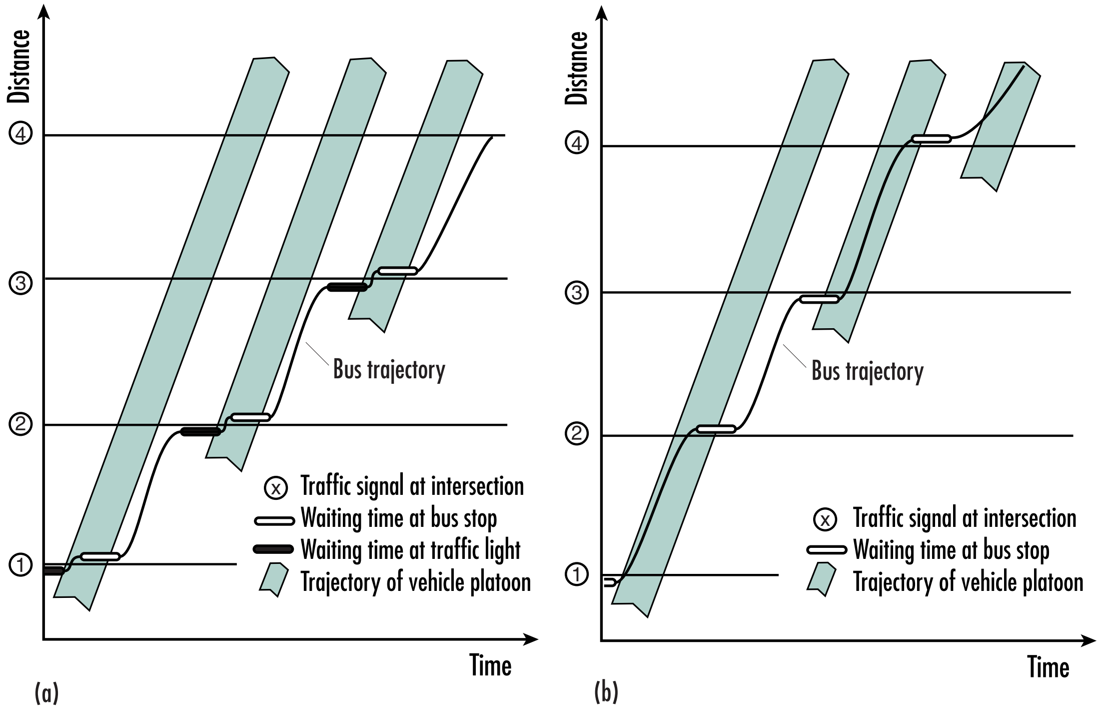


Figure 1. Trajectories of a vehicle platoon and a bus between successive signalized intersections.
1a–Bus stops at far side of intersections.
1b– Alternating near-side and far-side bus stops.

Automatic Vehicle Location (AVL) provides the transit vehicle's location and speed via transmissions from on-board or off-board equipment. Interfacing AVL with signal control systems theoretically permits anticipation of preemption needs and real-time signal control adjustments from the transportation management center (TMC). Currently, there are a total of 64 AVL systems being implemented in the United States. In Turin's UTOPIA system, the AVL system monitors the bus location and requests signal priority from the TMC for buses that are running late. Estimated bus arrival time at the intersection is relayed to the controller and the signal settings are adjusted on-line to provide transit priority. Reported benefits include a 20 percent increase in bus speeds without disbenefits to the rest of the traffic.

Proposed Strategies

In developing transit priority strategies (as well as techniques for their evaluation where appropriate) for buses traveling along arterials, we assume that there are no conflicting bus movements at the intersection approaches (i. e., that buses share the roadway with through traffic, and there are no buses on the cross-streets).

Passive Priority Strategies. The generation of fixed-time timing plans to favor transit vehicles can be accomplished either by manually modifying the background timing, or by using a signal timing optimization algorithm. We used the TRANSYT-7F model, which simulates the movement and interactions of traffic platoons, and optimizes the signal settings to minimize a combination of delays and stops in the network. TRANSYT-7F can be used to develop timing plans for transit priority as follows: bus movements are coded as separate links. Delay and stops weighting factors are then coded for the bus links so that the signal optimizer favors the transit vehicles. The weighting factors are determined through an iterative process based on bus frequency and network characteristics, subject to minimum adverse impacts to the auto traffic.

Active Priority Strategies. Proposed strategies for signal preemption and system-wide on-line adjustment of timing plans consist of a) criteria for selecting specific intersections in the system to provide transit priority, and b) procedures for minimizing adverse impacts to the rest of the traffic stream. The following criteria were used for signal preemption:

- Spare green time: signal preemption should be granted at an intersection if there is sufficient spare green time in the system cycle to avoid congestion or loss of coordination when extra green time is allocated to buses.

- Bus route progression: The decision to grant preemption at an intersection should consider predicted

continued on page 10

PATH Makes Big Splash at Netherlands Demo

Steve Shladover, Deputy Director, PATH

PATH's automated Buick LeSabres commanded the spotlight at Demo '98, held from 15-19 June in Rijnwoude, the Netherlands. From the time that the vehicles and PATH researchers arrived through the full week of demonstrations, they were the subject of intense interest by the Dutch media and public. By the end of Demo '98, they may well have been the most famous cars in the Netherlands. The country's major and local newspapers ran photos of the LeSabres and PATH researchers, television crews from several European countries clamored for chances to tape the demonstration, and ordinary citizens came by the hundreds to see the cars. Dutch Minister of Transport, Public Works and Water Management Mrs. Annemarie Jorritsma and her entourage rode in the PATH platoon. Her comment: "It's better than my chauffeur!"

Above: PATH cars demonstrate Automatische Voertuiggeleiding (Automated Vehicle Guidance) at highway speed. Counter-clockwise from left: entrance to Demo '98 exhibit hall; researcher Han-Shue Tan installs computer hardware in trunk; AVCSS Program Manager Steve Shladover interviewed in rain; researcher Wei-Bin Zhang demonstrates hands-off driving on wet road; Rijksweg 11 demo lanes; media day draws European press; precision lateral control on mini-demo track.

The star attraction was the three-car automated platoon demonstration on the 5.5 km section of still-under-construction Rijksweg 11. Over 800 people rode in the cars, and even visitors who did not get a ride were very impressed as the platoon whizzed past them in the viewing area, with the cars maintaining their 6 m separation at 90 km/h. The middle car of the three split from its neighbors, changed lanes, and decelerated until it was behind the other two, then changed lanes again to join itself to the end of the platoon, all under fully automatic control. This demonstration was a microcosm of the NAHSC platoon demonstration of Demo '97, in San Diego, with fewer cars and a slightly lower speed, based on the limits appropriate for this different road.

Technically, a low-speed mini-demo on a half-kilometer track was particularly challenging. The track featured much sharper curves than these PATH cars have steered through in the past, and the team had less than two days between track completion and media preview day to implement the demo. Nevertheless, it provided a very smooth, precise, completely automated ride with high-g curves. PATH researchers Han-Shue Tan and Benedicte Bougler spent a full month in the Netherlands preparing the demonstrations. They were joined at various times by David Nelson, Wei-Bin Zhang, Rajesh

Rajamani, Farokh Eskafi, Duke Lee, and Jay Sullivan, all of whom worked long and hard to ensure success. The challenges were considerable and the pressure intense, since the demonstration site was still under construction during most of the preparation period, the weather was cold, windy, and wet (the wettest spring on record in the Netherlands, thanks to El Niño), and their colleagues and families were nine time zones away.

An automated truck demonstration staged by the Combi-Road consortium took place at Ridderkerk, near Rotterdam, during the same week. PATH researcher Hung Pham implemented PATH's magnetic marker guidance system on the Combi-Road truck, in collaboration with researchers from TNO/TPD (Netherlands Organization for Applied Scientific Research) giving it the capability of steering itself to within an accuracy of 5 cm. The Combi-Road demonstration was also very successful in showing how PATH's vehicle control technology can help solve traffic congestion and safety problems.

The platoon demonstration attracted the lion's share of attention at Demo '98 because it was the most dramatic demonstration of the possibilities of vehicle control technology. It represented the greatest advance from today's driving conditions, and the most polished presentation in terms of user interfaces, packaging, and smoothness of ride. It was also probably the most reliable and available of the 16 vehicle demonstrations. Demo '98 certainly put the concept of the truly automated highway system, and PATH's research, on the map in the minds of the European transportation community, who were well represented among the visitors.

Control Strategies for Transit Priority

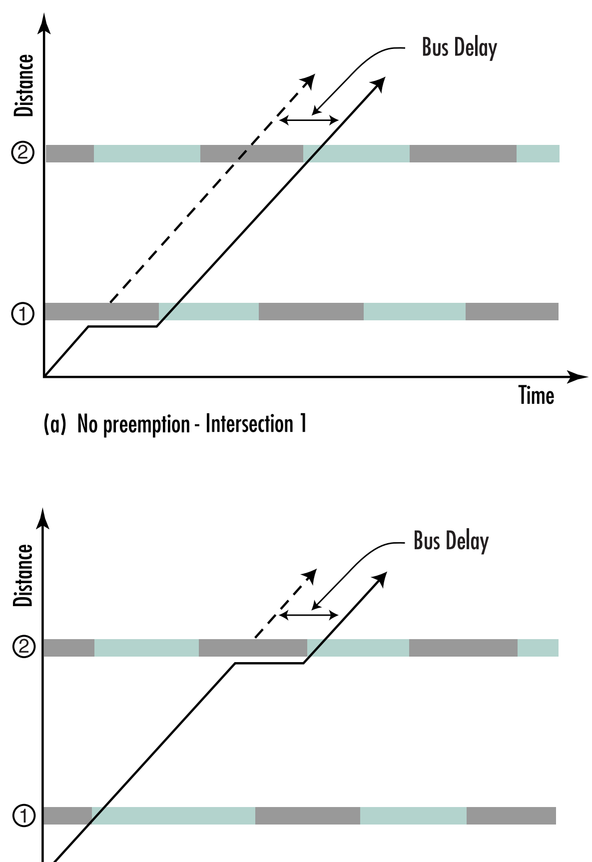
continued from page 7

arrival times of the bus at downstream intersections, and their signal settings. If, for example, advancing the green time at an upstream intersection results in additional bus delay downstream, there is no net benefit to the buses, but there is a disbenefit to the rest of the traffic. This "wasted" preemption is illustrated in Figure 2.

• Schedule adherence: transit priority should be given only to buses that are behind schedule. However, favoring a late-running bus may not be beneficial if it is empty and near the end of a route, with an out-of service period to follow. Using this criterion requires either an AVL system or action by the driver.

Evaluation

Our proposed strategies were evaluated through simulation on a segment of San Pablo Avenue, a major urban/suburban arterial in the San Francisco Bay Area. The test segment is 6.7 km (4.2 miles) long and includes 21 signalized intersections. Basic data on the study area and information about transit service were assembled and verified through field checks, and were coded into the TRANSYT and CORSIM simulation models. Comparisons of simulation runs with field measurements on critical intersections along the study segment indicate that the models reasonably represent existing operating conditions. The proposed strategies were then simulated. Optimal timing plans to favor buses along the arterial reduced the delay to buses by 14 percent and improved the average bus speed by 3.4 percent. This translates into delay savings of about 2 seconds/bus/intersection. The impacts on the rest of the traffic stream were marginal (a 1 percent increase in total delay). Sensitivity analyses showed that the estimated transit improvements are insensitive to a range of bus volumes up to 30 buses/hr.



(a) No preemption - Intersection 1

(b) Bus preemption - Intersection 1

Figure 2. Wasted preemption. If advancing the green time at an intersection to give a bus priority results in delay to the bus downstream, there is no net benefit.

Bus preemption at specific signals produced bus time savings ranging from 0 to 6 seconds per intersection, with typical savings of 2 seconds. Over the study area, the savings from preemption at the selected intersections would be about two minutes, without increase in delay to the rest of the traffic stream. It should be noted that on the study corridor, buses travel through on the cross streets as well as along San Pablo Avenue, which offsets some of the benefits of priority to the San Pablo Avenue buses. Also, the analysis of sample field data on individual arterial links showed that signal delay was only about 20 percent of total bus delay. In many cases, much of the bus delay would not have been avoided by signal preemption.

Conclusions

The proposed priority strategies placed major emphasis on systemwide improvements to the transit movements, and on minimizing adverse impacts to the rest of the traffic stream. Higher benefits from preemption would result if buses would preempt any of the intersections that are delayed. However, tests of this approach showed that it produced excessive queues on several side streets, as well as moving buses out of the front of one queue only to deliver them to the back of the next queue.

The application of the proposed strategies on a major arterial with 21 signalized intersections showed modest improvements to the movement of transit vehicles. Passive priority strategies improved bus delay by 14 percent, and signal preemption reduced delay by up to 6 seconds/intersection/bus, without adverse impacts to the auto traffic. These results apply to the test segment, and could be higher on routes with higher bus frequencies.

Improved capabilities in traffic control and transit systems offer considerable potential in developing effective control strategies for transit that outperform existing signal preemption techniques. There is a need to develop improved algorithms to take advantage of such technological advancements, to develop comprehensive simulation tools for thorough laboratory evaluation of proposed strategies, and to perform field demonstrations.

For further reading:

Skabardonis, Alexander. 1998. Control Strategies for Transit Priority. University of California, Berkeley: Institute of Transportation Studies, California PATH Program. UCB-ITS-PRR-98-2.

Improving Transit Access for the Blind and Vision Impaired

continued from page 5

to vision (B/S) and aid (RISS/No RISS) was highly significant. This model shows the significance of the success rate compared to the person's sight, the use of the Talking Sign® aid, and the combination of both of these variables.

Most of our blind subjects had been blind most or all of their lives and were very experienced and independent travelers, with their own tested mobility procedures. The blindfolded sighted subjects were more like newly or untrained blind people. The mean response time for the blindfolded sighted without the aid was 243 seconds and 172 seconds using the RISS.

The quantitative portion of the experiment showed that there is a significant difference in response times and performance when using a Remote Infrared Signage System. The last part of our experiment was to collect qualitative data from post-test interviews. We first asked general questions about how subjects felt about using the Talking Signs® RISS. Using a five-point scale for agreement or disagreement, we asked if the system relieved stress or reduced cognitive load; if the signs were helpful when navigating known and unknown spaces, identifying street corners, and finding bus stops and buildings; and finally, if the subjects would use such a system if installed. Ninety-five percent (95%) indicated agreement. Next we asked about the ease of understanding and finding the signs, if the subjects would use them at bus stops, and if finding unfamiliar bus stops was easier than by the subjects' usual method. We also asked if the bus auditory messages were easy to pick up, if the messages made it easy to find the right bus, if the subjects would use them on buses, and if it was easier to find the right bus than by using their usual method. On a five point scale from "strongly agree" to "strongly disagree," no subjects indicated disagreement on any of these points.

We also asked open-ended questions. The first was "Where would you like to see Talking Signs® used?" One subject, an Orientation & Mobility (travel techniques for the blind) instructor, summed it up by saying, "Wherever visual signs are used." All subjects made many suggestions, including all forms of transit, intersections, and many kinds of buildings. We then asked, "What was your opinion of Talking Signs®?" The results were extremely positive. Subjects called the signs great, superb, the best thing yet for the blind, and so on. Many people mentioned how they gained confidence and independence using them.

Our last question was "How does using Talking Signs® differ from your regular method of mobility?" Responses to this question were also very positive; many people said how much easier the system was, that they felt less stress, and mostly they mentioned how much more independent they felt, not having to ask others for help.

Our quantitative results show strong significant results when using a RISS. User feedback was overwhelmingly positive. We conclude that Remote Infrared Signage Systems should be adopted to erase the functional barriers that the blind, dyslexic, developmentally disabled, illiterate and others face daily when trying to access the built environment.

PATH Presentations

Recent and Upcoming Presentations of PATH Sponsored Research

ITS America 8th Annual Meeting, Detroit, Michigan, May 4-7, 1998.

• Datta N. Godbole, Raja Sengupta, "Rear-end Crash Mitigation Benefits of an Automated Highway System", presented by Datta Godbole.
• Datta N. Godbole, Raja Sengupta, "A Method for Design and Specification of Longitudinal Controllers for Vehicle Automation", presented by Datta Godbole.
• Datta N. Godbole, "A Framework for the Analysis of Crash Avoidance Systems", invited presentation.
• Thomas Horan, panelist "ITS and Environmental Sustainability: What's Missing?"
• Ronald Koo, Youngbin Yim, "Traveler Response to Traffic Information on an Incident", presented by Youngbin Yim.
• Mikhail A. Kourjanski, Jim Misener, "Modeling the Driver: A Microsimulation Approach".
• Raja Sengupta, panelist "Modeling to Determine the Benefits of Collision Avoidance Systems".
• Susan Shaheen, "Smart Car Linking in the San Francisco Bay Area: A Market Evaluation".
• Steven Shladover, panelist "Societal Issues: What the Intelligent Vehicle Initiative Has to Learn from the Experiences of the Automated Highway System".
• Steven Shladover, moderator "User and Societal Acceptance of AVCSS".
• Steven Shladover, panelist "Industry Perspectives on the Intelligent Vehicle Initiative".
• Youngbin Yim, Ronald Koo, Jean-Luc Ygnace, "TravInfo Evaluation: A Study of the TravInfo Transit Information Callers", presented by Youngbin Yim.
• Youngbin Yim, Ronald Koo, "A Revealed Preference Study of Automated Vehicle and Highway Systems", presented by Youngbin Yim.

5th World Congress on Intelligent Transportation Systems, Seoul, Korea, October 12-16, 1998.

• Youngbin Yim, Ronald Koo, "Automated Highway Systems Evaluation: A Survey of AHS Demo Riders", presented by Youngbin Yim.
• Jean-Luc Ygnace, Youngbin Yim, "User Response to the Telephone Assisted Traveler Information System in the San Francisco Bay Area", presented by Jean-Luc Ygnace.
• Ryuichi Kitamura, Cynthia Chen, Jiayu Chen, "Multimodal Daily Travel Planner".
• Steven Shladover, "Future Directions for Automated Highway Systems".
• Seungmin Kang, Stephen G. Ritchie, "Freeway Traffic Prediction with an Adaptive Autoregressive and Moving Average Model".

1998 SAE FTT Future Transportation Technology Conference, Costa Mesa, California, August 11-13, 1998.

• Youngbin Yim, Ronald Koo, "The Benefits of Advanced Traveler Information Systems", presented by Ronald Koo.

ASCE 5th International Conference on Advanced Transportation Engineering, Costa Mesa, California, April 29, 1998.

• Jim Misener, panelist "Practical Issues Learned and the Future of AHS".

8th Chilean Transportation Engineering Conference, Santiago, Chile, December, 1997.

• Carlos Daganzo, "La asignacion de trafico con almacenamiento limitado" (Traffic Assignment with Limited Storage Space), plenary lecture given as a video-conference.

Center for Transportation Studies, Northwestern University, Chicago, Illinois, March 1998.

• Carlos Daganzo, invited lecture "Traffic Assignment with Limited Storage Capacity".

University of California, Berkeley, California, April 18, 1998.

• Carlos Daganzo, "Urban Traffic Gridlock and What to do About It", featured presentation for the College of Engineering, Cal Day.

3rd Symposium on Transportation Engineering, Politechnic University of Catalunya, Barcelona, Spain, June 16, 1998.

• Carlos Daganzo, "Modern Methods of Highway Traffic Network Analysis, Design and Control", (6 hour workshop).

Car-Sharing Workshop, Seattle, Washington, May 29, 1998.

• Susan Shaheen, "Smart CarLinking".

Hybrid System Workshop, University of California, Berkeley, California, April 14, 1998.

• Sergio Yovine, Tunc Simsek, Marco Zandonadi, "SHIFT, Smart-AHS and KronoSHIFT".

Women's Transportation Seminar (Sacramento, California Chapter) Afternoon Seminar, April 30, 1998.

• Susan Shaheen, "Evolutions and Adaptations in Car-Sharing Markets in Europe and North America".

ZEUS (Zero and Low Emission Vehicles in Urban Society) Project, Bremen, Germany, March 12, 1998.

• Susan Shaheen, "Car-Sharing Research and Implementation in the USA" (expert seminar).

Aerospace Lighting Institute, Advanced Seminar, Los Angeles, California, February 1998.

• Theodore E. Cohn, "Looking Beyond Photometry: What Can We Predict About the Effect of Light on the Human Eye?".

2nd IFAC Workshop on Advances in Automotive Control, Mohican State Park, Loudonville, Ohio, February 1998.

• Ioannis Kanellakopoulos, "Intelligent Sensors and Control for Commercial Vehicle Automation".
• R. Rajamani, B. Law, S.B. Choi and J.K. Hedrick, "Design and Experimental Implementation of a Fault Management System for Longitudinal Control of Automated Vehicles".
• H.-S. Tan, J. Guldner, S. Patwardhan, and C. Chen, "Changing Lanes on Automated Highways with Look-Down Reference Systems".

1998 American Control Conference, Philadelphia, Pennsylvania, June 24-26, 1998.

- L. Alvarez, R. Horowitz, S. Chao, "Optimal Traffic Flow Patterns".
- C. Chen (presenter), J. Guldner, I. Kanellakopoulos, M. Tomizuka, "Nonlinear Damping in Vehicle Lateral Control: Theory and Experiment".
- K.-T. Feng, H.-S. Tan, and M. Tomizuka, "Automatic Steering Control and Validation of Vehicle Lateral Motion with the Effect of Roll Dynamics".
- H.-S.Tan, R. Rajamani, and W.-B. Zhang, "Demonstration of an Automated Highway Platoon System".

IEEE Conference on Decision and Control, San Diego, California, December 8-12, 1997.

- L. Alvarez, R. Horowitz, "An Activity Based Traffic Flow Controller for AHS".
- J. Yi, L. Alvarez, R. Horowitz, "Design and Implementation of Fault Tolerant AHS Control Systems".

8th IFAC / IFIP / IFORS Symposium on Transportation Systems, Chania, Greece, June 1997.

- R. Horowitz, "Automated Highway Systems: The Smart Way to Go", (plenary presentation).
- L. Alvarez, R. Horowitz, P. Li, "Traffic Flow Control in Automated Highway Systems".

International Workshop on Fault Tolerance in Autonomous Systems, Denver, Colorado, August 11-12, 1998.

- R. Rajamani, A. Howell, C. Chen. J.K. Hedrick, M. Tomizuka, "A Complete Fault Diagnostic System for Automated Vehicles".

Center for Autonomous Systems, Royal Institute of Technology, Stockholm, Sweden, January 1998.

- Ioannis Kanellakopoulos, "Nonlinear and Adaptive Control for Advanced Vehicles". (invited seminar)

Institute for Nonlinear Science, University of California, San Diego, La Jolla, California, April 1998.

- Ioannis Kanellakopoulos, "Nonlinear Control for Autonomous Vehicle Systems".

ASME International Mechanical Engineering Congress, Symposium on Transportation Systems, Dallas, Texas, November 1997.

- R. Rajamani, J.K. Hedrick, A. Howell, "A Complete Fault Diagnostic System for Longitudinal Control of Automated Vehicles".

Association for Research in Vision and Ophthalmology, (Annual Meeting Poster Session), Fort Lauderdale, Florida, May 1998.

- Daniel Greenhouse, Theodore E. Cohn, "Ommatometry: an Evolutionary Extension of the Science of Photometry".

ASME International Mechanical Engineering Congress, Symposium on Transportation Systems, Anaheim, California, November 1998.

- R. Rajamani, S.B. Choi, J.K. Hedrick, B. Law, R. Prohaska, P. Kretz, "Design and Experimental Implementation of Control for a Platoon of Automated Vehicles".
- C. Toy, K. Leung, L. Alvarez, R. Horowitz, "Emergency Vehicle Maneuvers and Control Laws for Automated Highways".

Society for Disability Studies 11th Annual Meeting, Oakland, California, June 4, 1998.

- Jim Marston, Reginald Golledge, "Toward an Accessible City: The Use of Auditory Signage for the Vision and Print Handicapped", presented by Jim Marston.

FISITA World Automotive Congress , Paris, September 27 - October 1, 1998.

- Steven E. Shladover, "Intelligent Transportation Systems and the Automobile: Recent History and Future Prospects".

International Conference on Advances in Vehicle Control and Safety (AVCS), Amiens, France, July 1998.

- J. Guldner, H.-S. Tan, C. Chen, and S. Patwardhan, "Robust Steering Control for Automated Highway Systems".

In the Dutch Combi-Road project, freight containers on semi-trailers are pulled by automatically controlled tractors powered by an electric rail. Combi-Road is now testing PATH'S Magnetic Marker Guidance System, which will do away with the need for a separate infrastucture with guide rails.

PATH on Paper

An Updated List of Recent PATH Sponsored Research Publications

A complete list of PATH publications that includes research reports, working papers, technical memoranda, and technical notes can be obtained from the:

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An increasing number of papers are available on-line at:
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Publications/index.html

Design of Fault Tolerant Control Systems for AHS, S. Sastry, R. Horowitz, K. Hedrick, April 1998, $15.00
UCB-ITS-PRR-98-16

Intelligent Diagnosis Based on Validated and Fused Data for Reliability and Safety Ehnancement of Automated Vehicles in an IVHS, Alice Agogino, Susan Chao, Kai Goebel, Satnam Alag, Bradly Cammon, Jiangxin Wang, April 1998, $20.00
UCB-ITS-PRR-98-17

Analysis, Design, and Evaluation of AVCS for Heavy-Duty Vehicles with Actuator Delays, Diana Yanakiev, Jennifer Eyre, Ioannis Kanellakopoulos, April 1998, $20.00
UCB-ITS-PRR-98-18

Alternative Traffic Signal Illumination, Theodore E. Cohn, Daniel Greenhouse, Richard Knowles, April 1998, $5.00
UCB-ITS-PRR-98-19

ITS Information and Services to Enhance the Mobility of Disabled Travelers, Wan-Hui Chen, Rochelle Uwaine, Kelley Klaver, Ken Kurani, Paul P. Jovanis, May 1998, $5.00
UCB-ITS-PRR-98-20

Advanced Information Techniques and Paratransit Services to Enhance Mobility of Elderly and Disabled Travelers, Wan-Hui Chen, Kelley Klaver, Rochelle Uwaine, Paul P. Jovanis, May 1998, UCB-ITS-PRR-98-21

The ISTEA/ITS Connection in California: The State of the Relationship and Opportunities for Productive and Beneficial Linkages, Mark A. Miller, Wenyu Jia, May 1998, $20.00
UCB-ITS-PRR-98-22

Why ITS Projects Should be Small, Local and Private, Stein Weissenberger, June 1998, $15.00
UCB-ITS-PRR-98-23

Definition and Measurement of Transportation System Performance, Joy Dahlgren, June 1998, $15.00
UCB-ITS-PRR-98-24

Models of Vehicular Collision: Development and Simulation with Emphasis on Safety IV: An Improved Algorithm for Detecting Contact Between Vehicles, Oliver M. O'Reilly, Panayiotis Papadopoulos, Gwo-Jeng Lo, Peter C. Varadi, June 1998
UCB-ITS-PRR-98-25

Implementation of the Regulation Layer Using SHIFT, David Gulick, Luis Alvarez, Roberto Horowitz, July 1998,
UCB-ITS-PRR-98-26

A Review of the Optimized Policies for Adaptive Control Strategy (OPAC), Lawrence C. Liao, April 1998, $5.00
UCB-ITS-PWP-98-09

Videobased Vehicle Signature Analysis and Tracking Phase 1: Verification of Concept and Preliminary Testing, Art MacCarley, May 1998, $10.00
UCB-ITS-PWP-98-10

Impacts of Computer-Mediated Communication on Travel and Communication Patterns: The Davis Community Network Study, Prashant Narayan Balepur, May 1998, $20.00
UCB-ITS-PWP-98-11

Estimation of Travel Time Distribution and Detection of Incidents Based on Automatic Vehicle Classification, V. Anantharam, June 1998
UCB-ITS-PWP-98-12

Decision Support Systems for Managing and Applying ITS Research, Joy Dahlgren, Mohamed AlKadri, Rosella Picado, July 1998, UCB-ITS-PWP-98-13

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PATH Database

The PATH Database, the world's largest on Intelligent Transportation Systems, is now accessible at:

http://www.nas.edu/trb/about/path1.html

It currently lists over 13,000 bibliographic records with abstracts.

Automating Bus Docking to Improve Transit Service

continued from page 3

Other features of bus stop design and location that may affect automated docking were noted. At one site, metered parking ran right up to the beginning of the bus zone, but the bus zone was not long enough to accommodate the bus. The current design and location of the other sites would necessitate extreme vigilance by the bus driver in a partially automated system, and very effective and reliable avoidance systems for detecting pedestrians, bicyclists, and other obstacles. The necessary dimensions of bus stops have been published by the International Union of Public Transport (UITP), including pull-in and pull-out angles as a function of bus length and speed, but these guidelines are sometimes not followed due to considerations such as technical feasibility, cost, or acceptability (in terms of public policy) of modifying the existing infrastructure or vehicles. As a basis for recommending changes for the location and design of bus stops to the Institute of Transportation Engineers and the UITP, field studies based on formal protocols should be conducted to identify special docking requirements for partially and fully automated docking.

Unresolved Issues

Other aspects of automated bus docking than safety remain to be investigated. The safety and technical constraints associated with obstacle avoidance of an automated docking system could possibly result in high development, operation, or maintenance costs. Will bus drivers in Germany, who tend to be well-trained and very experienced, or in London, where there is a high turnover of drivers, accept partial or full automation? Can designs of automated docking systems be developed that will be usable on a wide range of bus chassis, and result in operating costs that are lower than costs for trams? How will automated docking systems interact with collision warning and avoidance systems? These and other issues are fertile areas for further research and development.

Dr. Michael, until recently a PATH researcher, is now Visiting Associate Professor of Computer Science at the Naval Postgraduate School in Monterey, California. Email: bmichael@cs.nps.navy.mil

For information about the other technologies showcased at Demo '98, please visit the Netherlands Ministry of Transport Automated Vehicle Guidance Web site: http://www.minvenw.nl/rws/wnt/avg/index-uk.html

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PATH Welcomes Greg Larson as New Caltrans Management Liaison

I am pleased and excited to serve as the management liaison between Caltrans and PATH. While working on the National Automated Highway System Consortium, I had an opportunity to work side-by-side with many of the PATH researchers, and I was always impressed by their dedication, knowledge, and professionalism.

Although I already know many of the people at PATH, I have not previously been directly involved with the PATH Program. As a result I'm still learning about my duties as the management liaison. Fortunately, my predecessor Hamed Benouar and PATH management have developed an effective process for managing the unique research performed by PATH.

I received my Bachelor and Master of Science degrees in Electrical and Electronic Engineering from the California State University, Sacramento. I am a registered professional Electrical Engineer in California and have worked in the engineering field for 16 years, including over eight years with Caltrans. I currently serve as the Acting Chief of the Office of Advanced Highway Systems in the New Technology and Research Program.

I look forward to working with the PATH team to find solutions to our ever-growing surface transportation problems.

Intellimotion

Intellimotion is a quarterly newsletter edited and designed by the California PATH Publications Department.

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