

# California PATH Program 2002 Annual Report



# California PATH

## 2002 Annual Report

C A L I F O R N I A  
PATH

PATH—Partners for Advanced Transit and Highways—is a collaboration between the California Department of Transportation (Caltrans), the University of California, other public and private academic institutions, governmental agencies, and private industry.

PATH's mission: applying advanced technology to increase highway capacity and safety, and to reduce traffic congestion, air pollution and energy consumption



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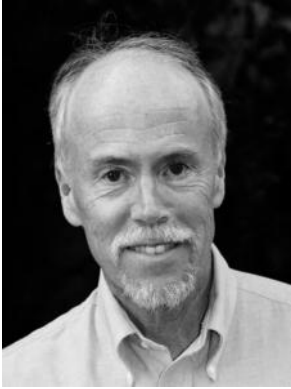
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# Director's Introduction



The California PATH Program, a collaboration between Caltrans and the University of California, is a unique multidisciplinary research program that seeks advanced technological solutions to our worsening transportation problems. PATH's researchers and staff come from many countries and academic backgrounds and are spread across California's college campuses and into private industry. They are united by the goal of fulfilling the promise of ITS, Intelligent Transportation Systems, and finding solutions for today and tomorrow.

PATH's research activities in the area of Advanced Traffic Management and Information Systems (ATMIS) have greatly expanded in the last few years. An exciting new Center for Commercialization of ITS Technologies (CCIT) opened in February 2002 near the Berkeley campus. CCIT is teaming up with University faculty and graduate students, private sector companies, and government transportation agencies in the new facility with the mission of facilitating the commercial deployment of advanced traffic information system technologies. A very successful application of ITS to traffic information and management is PeMS (Performance Measurement System). The intent of this project is to collect historical and real-time freeway data from freeways in the State of California in order to compute freeway performance measures.

PATH is internationally recognized as the leading research institution in vehicle automation to reduce congestion and to increase driving safety. PATH's demonstration of vehicle automation at Demo'97 was the highlight of the most successful demonstration of vehicle automation technology ever held. PATH has continued to participate in follow-up automation technology demonstrations, including Demo '98 in the Netherlands, Demo '99 in Ohio, and Demo 2000 in Japan. Caltrans and PATH are currently focusing their efforts in vehicle automation on heavy trucks and transit buses. The area of Bus Rapid Transit is becoming very attractive to many cities in the US and is an excellent application area for PATH's automated technology.

PATH brings together engineers and economists, geographers and urban planners, computer scientists and statisticians, among others. Its multidisciplinary atmosphere is responsible for shaping the "modern" transportation engineer, who is familiar not only with traditional disciplines but also with the emerging areas of sensors, communications, data structures, vehicle dynamics and control, and many other disciplines. We pride ourselves on the many students and postdocs who have "graduated" from PATH and gone on to influential positions at universities and in the public and private sectors, spreading the ITS vision. PATH's future looks bright as the need for intelligent transportation solutions becomes ever more clearly apparent. Bringing together the best minds in California to improve California's, the nation's and the world's transportation systems is PATH's goal!

Karl Hedrick  
California PATH Director

A handwritten signature in black ink that reads "Karl Hedrick". The signature is written in a cursive, flowing style.

# A Word from Caltrans

The California Department of Transportation strives to be the highest performing transportation agency in the country. In pursuit of our mission, we continue to strengthen ties with our partners. Caltrans and the California PATH Program continue to work together on research to create a transportation system that is both safe and efficient. The overall strength of our transportation system plays a crucial role in maintaining the livability and economic vitality of our state. It is a system of different modes, services and programs working together to provide access and mobility to support our daily lives and travel needs.



Caltrans and PATH are working on some very high profile research projects. One of those is the Intersection Decision Support Project. The Federal Highway Administration has encouraged us to find ways to reduce the frequency and severity of intersection crashes. Intersection crashes are among the most technically challenging types of crashes to prevent. We are designing a system that would monitor vehicle position relative to intersection geometry, observe relative speeds and positions of other vehicles in the vicinity of the intersection, and advise the driver, if necessary, of appropriate action in order to avoid a crash. Due to the complexity of the intersection collision problem, it is anticipated that a cooperative vehicle-infrastructure solution will be needed to fully address all the subsets of this problem.

Caltrans and PATH are working to improve the safety of public transportation. With support from the Federal Transit Administration, we developed a forward collision warning system for buses that has been placed into regular transit service by San Mateo Transit. These collisions account for about 30 percent of all transit bus accidents, and the project has enabled PATH researchers to better understand the conditions and maneuvers associated with imminent crashes and the requirements for warning drivers of dangers. Specific human factors research has included examination of visual and audible display methods, determination of warning thresholds, and the interactions with other bus driving tasks. This important work will enable bus drivers to safely negotiate the unpredictable environment on public streets and reduce injury-producing crashes.

Caltrans and PATH continue to prepare for Demo 2003, a demonstration and conference showcasing the benefits of transit bus automation. The vehicle testing for this demonstration in San Diego is now underway. Demo 2003 offers the opportunity to advance the state of the art in the control of heavy vehicles, while at the same time giving Caltrans and PATH the chance to present recent technological developments to possible early adopters of vehicle automation. Potential benefits of the technology include reduced fuel consumption and exhaust emissions, traffic congestion relief, enhanced quality of service and safer vehicle travel.

Despite our past successes, we know that further challenges remain ahead of us if we are to achieve our goals. To reach this end, the Division of Research and Innovation has recently made procedure changes to the research project selection process. One of the most significant changes in this philosophy is our commitment to conduct customer-focused research and to perform activities that help to meet departmental goals.

On behalf of the staff and management of the Division of Research and Innovation, I congratulate PATH on its considerable accomplishments during another successful year. We are very optimistic about 2003 and beyond. Congratulations on a job well done!

Greg Larson  
Caltrans Management Liaison

A handwritten signature in cursive script that reads "Greg A. Larson".

# Overview

## California PATH Program

Steven Shladover

The California Partners for Advanced Transit and Highways (PATH) Program has been leading the way in ITS (Intelligent Transportation Systems) research since PATH's founding in 1986, before the term ITS or its predecessor IVHS (Intelligent Vehicle Highway Systems) had even been coined. PATH's purpose is to develop foundations for the widespread adoption of advanced technologies that will improve the operation of California's surface transportation systems. PATH'S primary goals are to reduce traffic congestion and improve traffic safety. By succeeding at these, we also expect to help reduce travel stress, pollution, and energy consumption, and contribute to enhancing the strength of California's economy.

Caltrans provides the seed funding for PATH's core research, based on its goal of promoting the development of new knowledge and new technology that can improve the productivity, safety, and environmental impacts of California's surface transportation systems.

PATH's charter includes the missions of conducting leading-edge research, evaluating operational tests, developing public/private/academic partnerships, and educating students as well as practitioners about ITS.

PATH focuses on research with the potential for dramatic improvements in the operation of California's transportation system, rather than diffusing its efforts in areas where only incremental improvements are possible. California's population and its transportation demands are growing so rapidly that the effects of incremental solutions would likely be absorbed by the time they could be implemented. Hence, PATH emphasizes relatively long-term, high-impact solutions, while also addressing the progressive steps needed to achieve those long-term solutions. PATH research also attempts to identify impediments to progress, both technical and institutional, and to devise strategies for overcoming those impediments. Research and development done under PATH auspices include:

- identification of problems and needs
- basic research on enabling technologies
- applied technology research and development
- system-level design and evaluation
- experimental verification of design predictions
- evaluations of existing technologies or equipment
- evaluations of costs and benefits
- technology assessments
- predictions of users' behavioral responses
- predictions of the impacts of technologies' use
- evaluations of legal and institutional issues.

PATH is managed by the Institute of Transportation Studies of the University of California at Berkeley, which established the PATH Program Headquarters Office at the University's Richmond Field Station in 1986. Policy issues are addressed by the PATH Executive Committee, composed of representatives of the primary participating universities, and by the Caltrans-PATH Joint Management Team, composed of program managers from both Caltrans and the University. PATH's day-to-day operations are managed by the headquarters staff.

PATH headquarters has about fifty full-time staff members, including a core group of research staff members, plus program managers and administrators. A substantial body of research is done by the full-time research staff at PATH headquarters, but most PATH research work is done by faculty members employing graduate students on the campuses of the universities that form the PATH



partnership. This work is supplemented by subcontracts to private companies as needed, and by cooperative research agreements with a variety of organizations, including private companies as well as public institutions, both domestic and international. The product-development-oriented work of private companies complements the more basic work of the academic researchers, so that each group can concentrate on what suits it best. Publication of PATH research work is coordinated at PATH headquarters.

## **PATH Activities in National ITS Programs**

PATH has received substantial funding from the Federal Department of Transportation (USDOT), including support from the Federal Highway Administration and Federal Transit Administration. PATH participation in USDOT ITS programs during the past year includes several projects within the Intelligent Vehicle Initiative (IVI) program:

- Defining the requirements for an integrated transit bus Forward and Side Collision Warning System, with the San Mateo County Transit District (SamTrans), Caltrans, and bus manufacturer Gillig, together with partners in Pennsylvania..
- Transit bus Rear Collision Warning System requirements definition, with Ann Arbor Transit Authority and ERIM International.
- Development of an Intersection Decision Support (IDS) system to improve the safety of intersections, under the auspices of the IVI Infrastructure Consortium (California, Minnesota and Virginia, together with FHWA).

PATH and Caltrans continued to participate in the Multistate Operations Research Program (MORIP), which includes Minnesota, Texas, and Washington. MORIP provides an opportunity for operations practitioners and researchers to share information on ITS-related efforts in the four states.

PATH has worked closely with Caltrans on developing two multistate pooled fund projects to advance the state of the art of cooperative Advanced Vehicle Control and Safety Systems (AVCSS), with USDOT participation. In addition to the IVI Infrastructure Consortium mentioned above, Caltrans and PATH have attracted ten other states and Honda R&D North America, Inc. to join in a Cooperative Vehicle-Highway Automation Systems (CVHAS) program, under the sponsorship of which we are evaluating the effectiveness of bus and truck automation system in the Chicago metropolitan region.

## **State-Funded Core Program of ITS Research**

The core of the PATH program is its collection of research projects funded by Caltrans' Division of Research and Innovation. Currently there are about 80 such projects, selected on the basis of an annual Request for Proposals (RFP) and proposals submitted from throughout California. These involve the work of about 32 professors, representing 7 academic departments on 12 different university campuses, supervising the research of more than 90 graduate students and post-doctoral researchers. Projects are currently being conducted at: UC Berkeley, UC Davis, UC Irvine, UC Los Angeles, UC Riverside, California Polytechnic State University at San Luis Obispo, California State University San José, Ohio State University, San Diego State University, Stanford University, the University of Michigan, and the University of Southern California.

## **Other projects**

PATH attracted research support from a variety of other sources during the past year. Some of these projects, in addition to the IVI projects previously cited, include:

- A simulation and visualization model for evaluation of Bus Rapid Transit Systems (SmartBRT), under the joint sponsorship of the Federal Transit Administration and Caltrans.
- Development and evaluation of a variety of technologies for Bus Rapid Transit, under Caltrans sponsorship.
- New technology approaches for railroad crossing warnings at uncontrolled crossings in the San Joaquin Valley, under sponsorship of the Caltrans Division of Rail.
- A precision automatic steering control system for a Caltrans rotary snow blower,



under the sponsorship of Caltrans' Advanced Highway Maintenance and Construction Technology program (AHMCT).

- A project on distributed autonomous agent networks of aerobots for the Office of Naval Research.
- A testbed and automotive example application project for Model-Based Integration of Embedded Systems (MoBIES), under the sponsorship of the Defense Advanced Research Projects Agency (DARPA).
- A Border Crossing ITS Technology Demonstration Commercial Deployment, at the Otay Mesa Commercial Vehicle Point of Entry.

### **Other notable developments during the past year included:**

- PATH had an opportunity to explain its progress to Secretary Maria Contreras Sweet of the California Business, Transportation and Housing Agency during her visit to the Richmond Field Station.
- PATH Deputy Directors Steven Shladover and Hamed Benouar were both named to the ITS Caucus Advisory Committee, which is providing advice to the Congressional ITS Caucus during their deliberations about the reauthorization of the national surface transportation program.
- Jim Misener was appointed as PATH's first Business Development Manager to help consolidate activities associated with obtaining new research funding support
- Under the auspices of the Federal Transit Administration, PATH and the Institute of Transportation Studies of U.C. Berkeley joined forces with the Center for Urban Transportation Research of the University of South Florida to establish the National Bus Rapid Transit Institute (NBRTI). Wei-Bin Zhang is the Co-Director of the NBRTI, representing UCB/PATH.
- CCIT (Center for Commercialization of ITS Technologies) celebrated its official grand opening on February 7, 2002.
- In addition to his duties as CCIT Executive Director, Hamed Benouar was appointed as PATH Deputy Director in charge of Advanced Transportation Management and Information Systems. This was a new position created in an effort to re-organize PATH to promote transportation system management, transit, traffic as well as to accelerate the implementation of transportation innovations.
- Hamed Benouar, in conjunction with the PATH 2002 Annual Meeting initiated a re-organization plan in his area of responsibility to include clusters of expertise led by faculty and researchers working together. The new Innovative Mobility (IMR) Research Program was initiated under the leadership of Susan Shaheen at CCIT to serve as a model for such new programs. Other programs in System management/planning, Transit and Traffic Operations were also planned to follow IMR's model.
- CCIT continues to forge partnerships with industry and provide implementation support for Caltrans. With support from Caltrans and industry, it launched an effort to develop a strategic plan to include a new mission as well as a business and organization plan.



## 1. TRAFFIC SYSTEMS

### Traffic Management

#### Design, Field Implementation and Evaluation of Adaptive Ramp Metering Algorithms

Roberto Horowitz, Pravin Varaiya, UC Berkeley; Michael Zhang, UC Davis  
TO 4136

These new traffic-responsive ramp metering strategies are designed to optimize highway throughput while employing ramp metering policies that are perceived to be fair by all travelers.

Traffic data mining, and model validation of Highway I-210 in Caltrans District 7, is currently in progress. A computer simulation study, evaluating the performance of several local and traffic responsive ramp metering schemes will follow shortly. Years 2 and 3 of this project will be devoted to field-testing the ramp metering strategy that performs most favorably in the Year 1 simulation study, and developing and testing coordinated ramp metering policies.

#### Changeable Message Signs (CMS)

Alex Skabardonis, UC Berkeley  
TO 4306

When alternate routes are available, a CMS may be used to indicate which route is preferable at the current time. This study shows that selecting the preferred route based on real-time data, is more accurate than selecting a route based on historical data. Indeed, the predicted route is almost as good as the route that would be selected by a clairvoyant driver who knows the future! When only a single route is available, showing current estimated travel time on a CMS may reduce traveler anxiety. This study shows that basing the travel time estimate on real-time data has a much smaller uncertainty than basing it on historical data.

### Traffic Data Collection

#### Deployment and Evaluation of Real-time Vehicle Reidentification from an Operation Perspective

Pravin Varaiya, UC Berkeley, Benjamin Coifman, Ohio State University  
TO 4107

A previous project developed a prototype travel-time measurement system that utilized existing dual loop speed traps and “model 170” controllers to identify and reidentify vehicles on a freeway link. This research has advanced the work by improving the vehicle

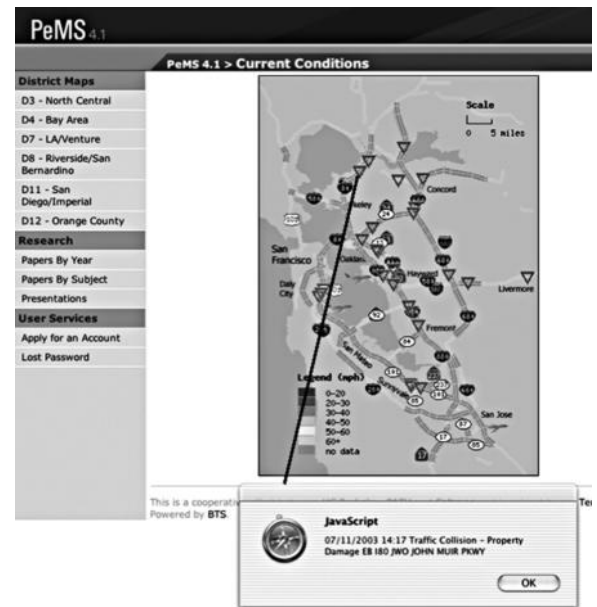
reidentification algorithms, extending them to single-loop-detector stations, and using the reidentified vehicles to extract both density and the net number of lane change maneuvers.

#### Freeway Performance Measurement System (PeMS) Version 3

Pravin Varaiya, UC Berkeley  
TO 4127

California freeways are least productive when the demand is greatest: they carry fewer vehicles at slower speeds during congestion. A PeMS application calculates decrease in total travel time compared to an ideal ramp-metering scheme.

(The metering scheme is ‘ideal’ because lack of ramp capacity is not considered.) The scheme holds vehicles behind the ramp whenever occupancy downstream of the ramp exceeds a critical level. As a result, traffic moves at free-flow speed and at maximum flow rate on the freeway. Analysis of freeway data from Los Angeles indicates dramatic improvement in productivity.



#### Freeway Performance Measurement System (PeMS) Version 4

Pravin Varaiya, UC Berkeley  
TO 4301

Loop detector data are not fully reliable: samples may be missing, or they may be incorrect. PeMS now subjects each sample to a statistical test that judges, in real time, whether the sample is valid. Invalid or missing samples are then replaced by imputed values. As a result, PeMS now provides a complete (and valid) loop detector data set. Applications may now safely assume that the data are complete and correct. This enormously simplifies the task of developing applications. PeMS maintains the original and the corrected data. Before relying on an application, the user can find out how much of the data used by an application is obtained via imputation.

**PeMS Deployment**  
**Hamed Benouar, California PATH/CCIT**  
**RTA 51A0221**

The California Center for Innovative



Transportation (known in 2002 as the Center for Commercialization of ITS Technologies, or CCIT) is under a Research Technical Agreement with Caltrans for deployment support, user fluency, training, and accelerating the commercial deployment of PeMS. PeMS 4, in the final phase of development, is being deployed in Caltrans districts 3,4,7,8,11, and 12. The ITS Office of Technology

Transfer has been awarded a contract by CCIT to develop PeMS training materials as well as delivering the training to the Caltrans staff.

**Berkeley Highway Laboratory (BHL) Project**  
**Adolf May, UC Berkeley; Benjamin Coifman,**  
**Ohio State University**  
**TO 4134**

The Berkeley Highway Lab (BHL) covers 2.7 miles of freeway with 4-5 lanes in each direction and eight paired “speed trap” inductive detector stations in each lane. The detector system is continuously maintained, collecting data that is provided to researchers. A link to Caltrans District 4 has also been maintained to allow the BHL loop detector stations to function as standard District 4 detectors.

Research on alternative detector diagnostic tests has been undertaken. Major short-term and longer-term accomplishments include the development and refinement of several single- and dual-loop detector data validation tests. Further research has been done on vehicle reidentification for travel time estimation. This has resulted in an increased frequency of vehicle identification, while simultaneously reducing the error rate.

## Traffic Theory

**Validation of Daganzo’s Behavioral Theory of Multi-lane Traffic Flow**

**James Banks, San Diego State University**  
**TO 4113**

This study was intended to validate Daganzo’s theory with empirical data. Some phenomena predicted by Daganzo were observed in the field but not at all locations. Phenomena predicted by Daganzo and observed at some locations include semi-congested states, fast waves, and an increase in average time gaps, indicating a “loss of motivation.” Phenomena predicted or assumed by Daganzo but not observed in the study locations include equalization of speeds in congested flow and distinct capacity and discharge flow states. Redistribution of flow among lanes was observed despite the absence of speed equalization, contrary to Daganzo’s behavioral assumptions.

**Field Investigation of Advanced Vehicle Reidentification Techniques and Detector Technologies – Phase 2/Year 2**

**Stephen Ritchie, UC Irvine; C. Arthur MacCarley, Cal Poly San Luis Obispo**  
**TO 4122**

This phase of the research is utilizing fully instrumented freeway and signalized intersection sites for field investigation of several emerging traffic sensor and detector technologies for vehicle reidentification (REID) purposes and real-time traffic performance measurement. A traffic detector and surveillance sub-testbed on North I-405 in Irvine became operational in August 2002, and REID-based real-time traffic performance measurement, including section travel times, traffic origins and destinations, and vehicle classification, was demonstrated in October 2002. Work on REID and detector technology assessment in the I-405 testbed is continuing with research partners Inductive Signature



Technologies, Inc., and the Caltrans Divisions of Research Innovation and Traffic Operations.

**Study of Traffic Dynamics and Management Strategies Using Berkeley Highway Lab Data**  
**Joy Dahlgren, California PATH**  
**TO 4141**

It was found that oscillations in flows in queued traffic increase when traffic passes off-ramps and shrink as it passes on-ramps. Oscillations also increase between two detector stations where there are no ramps, indicating that lane-changing alone induces oscillations. Between midnight and 4 AM, headways were between one and two seconds in most lanes at



most times, even though the mean headway was five or more seconds, perhaps indicating that desired headways range between one and two seconds in free flowing traffic. In slow, heavy traffic between 8 and 8:10 AM, minimum headways were from 0.5 to 0.8 seconds. HOV lane speeds are strongly affected by speeds in the adjacent mixed flow lanes, and to a lesser extent by HOV

lane volumes. When speeds in the mixed-flow lanes are 20 mph (32 kph) or less, HOV lanes speeds average around 40 mph (64 kph).

**2. PUBLIC TRANSPORTATION SYSTEMS**

**Demand-responsive Transit**

**Smart Demand Responsive Transit Feeder Systems**  
**Youngbin Yim, California PATH**  
**TO 4102**

Consumers are experiencing limited access to transit due to saturated parking at or around transit stations. Smart DRT Feeder systems can collect transit riders from neighborhoods and take them to transit stations. The goal is to provide easy access to transit and increase ridership. Market studies in the San Francisco

Bay Area indicated that nearly 60 percent of the participants would be interested in using a smart feeder service. A market study in Castro Valley suggested that 15 percent of solo drivers would ride transit if smart feeder service were offered. Field tests are planned for Castro Valley in Alameda County and the City of Millbrae. Vehicle tracking, real-time information, and automated dial-a-ride communication systems will be employed for the field tests.

**Benchmarking Best Practices of Demand Responsive Transit Systems**  
**Maged Dessouky, University of Southern California**  
**TO 4108**

We present the results of a nationwide study involving sixty-two large transit agencies and thirteen small transit agencies. We evaluate the impact of implemented technologies and practices upon productivity and operating cost. Our findings show that agencies that use Paratransit CAD Systems to provide the delivery are more productive than those that do not. Furthermore, the use of financial incentives is detrimental to productivity. We also found that the use of advanced communication can be beneficial in reducing operating cost while the use of financial penalties can increase it.

**3. BUS RAPID TRANSIT (BRT) SYSTEMS**

**Assessment of Bus Rapid Transit Opportunities in the San Francisco Bay Area**  
**Mark Miller, California PATH**  
**RTA 65A0141**

This project's objective is to investigate the feasibility of bus rapid transit in the Bay Area. The research team focused on state routes (both arterial roadways or freeways) to identify regional opportunities for innovative types of partnerships to help address unmet public transit service needs across jurisdictional boundary lines. Interconnectivity and regional aspects associated with bus rapid transit systems' deployment were considered. Five primary corridors with potential for further investigation of bus rapid transit feasibility were identified: Highway 101, Interstates 80, 580, 680, and 880.



Traffic Systems
Public Transportation
Bus Rapid Transit
Innovative Mobility
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Collision Warning
Automation Transportation
Driver Behavior
Enabling Technologies
Modeling and Simulation
Evaluation and Decision Support

**Adaptive Bus Signal Priority System**  
**Hongchao Liu, Chin-Woo Tan, Mark Miller,**  
**California PATH; Alex Skabardonis, UC Berkeley**  
**RTA 64A0026**

This system gracefully adapts traffic signals' cycles to the movement of buses in the system. The arrival of a bus at a traffic signal is anticipated using special bus loop detectors and using Advanced Vehicle Location /Global Positioning Satellite (AVL/GPS) systems to show bus location with respect to the traffic signal. The traffic detection system makes full use of traffic information from existing loop detectors to derive real-time traffic data from the loops. A well-defined priority algorithm, adaptive to real-time traffic condition, make decisions on priority strategy based on both traffic situation and bus priority request. Before going to the field, priority concepts can be evaluated and validated by both microscopic simulation model and hardware-in-the-loop tool.

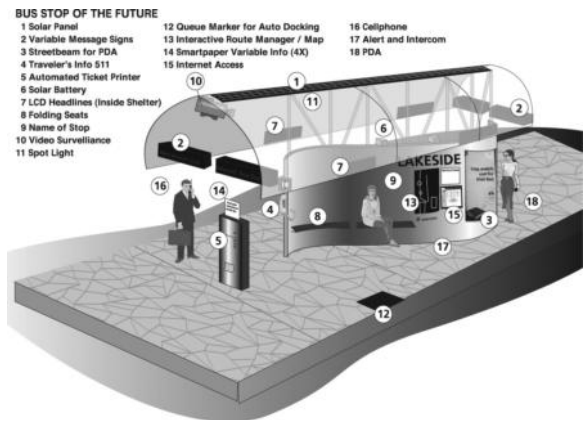
**Bus Precision Docking and Electronic Guidance System**  
**Wei-Bin Zhang, Han-Shue Tan, California PATH;**  
**Masayoshi Tomizuka, UC Berkeley**  
**RTA 64A0028**

Because a bus was unavailable for use as a test vehicle, a Buick LeSabre was used to advance the docking system development. Work included complete control analysis and integrated docking algorithm with lane-keeping algorithm, software development that integrated the modularized new signal processing algorithm with the docking control algorithm structure, steering actuator performance/ component requirements for the automated docking function, feasibility investigation of using driver guidance display for docking maneuver via a driver-in-the-loop display simulator, formulation of the automated-manual transitioning problem and the design of a transition controller, and demonstration of precision docking.



**Evaluation of Advanced Concepts for an Integrated Bus Stop Design**  
**Joy Dahlgren, California PATH**  
**RTA 64A0028 Task 3**

Improvements studied include improved approaches to delivering and updating schedule and route information, methods to facilitate faster boarding and alighting, and improved methods of monitoring operations and security at bus stops.



**Bus Rapid Transit (BRT) Evaluation Tools**  
**Jim Misener, Tunde Balvanyos, California PATH**  
**TO 4400**

SmartBRT simulates the operation of a Bus Rapid Transit (BRT) system and evaluates operation parameters and system performance measures. This will allow user-defined BRT concepts to be evaluated. The core of SmartBRT is a microsimulation, complete with appropriate bus and infrastructure geometric libraries and high-fidelity photo-realistic 3D graphics. This allows computation and visualization of the incremental effect of adding Intelligent Transportation Systems (ITS) technologies to BRT operation, but without the high capital investment of field tests. This project is funded by Caltrans and the USDOT (FTA).

**BRT Deployment Planning**  
**Mark Miller, California PATH**  
**RTA 64A0027**

We have conducted a macro-scale examination of bus rapid transit systems from technical, operational, institutional, and planning perspectives. We are currently performing an evaluation of BRT impacts in the context of a case study using Los Angeles Metropolitan Transportation Authority's Metro Rapid Bus Wilshire Blvd. corridor as the focus of the case study in which we are assessing the potential benefits, costs, and tradeoffs of alternative BRT systems. This evaluation has involved a large data collection effort and design of an evaluation test plan. The data collection process is complete and the test plan is nearing completion. We are also developing a deployment strategy framework or "route map" to assist transit properties in the decision-making process of selecting which bus rapid transit attributes work best in their environment.

**Planning Analysis for Bus Rapid Transit**  
**Martin Wachs, UC Berkeley; Jim Misener,**  
**California PATH**

**Sponsor: Riverside Transit Authority**  
 Initial focus of our 2002 work was on defining and proposing a near-term BRT demonstration project, slated for Western Riverside County.

Traffic Systems
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This involved identifying and defining various service and technological elements of the BRT demonstration, plus estimating travel demand, identifying supportive feeder service strategies, and generating farebox recovery estimates. The recommended strategies include an explicit preliminary layout concept, development of the phasing of design, and technological and operational features for the BRT and BRT-feeder system. Two main BRT routes were identified, as well as BRT-feeder routes that provide connective services into the main BRT services. The phasing plan recommends first upgrading existing local services into feeder routes with low-investment components similar to BRT characteristics.

## 4. INNOVATIVE MOBILITY

### CarLink II Susan Shaheen, California PATH/CCIT TO 4104

CarLink II was a pilot demonstration of a transit-based shared-use vehicle system, based in Palo Alto, that operated from June 2001 - June 2002. The PATH evaluation team is completing final project analysis. The evaluation methodology includes before and after questionnaires, interviews, focus groups, and automatically collected vehicle data. Operational analysis indicates that advanced carsharing technologies tested improved client satisfaction and expanded program capacity. Community support and local operational support were vital to program success. Early evaluation results indicate that transit mode



split increased and that vehicle miles traveled were reduced.

### Davis Smart Mobility Model Project Susan Shaheen, California PATH/CCIT TO 4144

The goal of this project is to optimize individual mobility options through improved

connectivity among modes, enhanced techniques to link land-use planning and transportation systems design, advanced information technologies, and clean fuel vehicles. The project is centered on reducing transportation impacts on the UC Davis Campus due to an anticipated additional 9,000 staff, students, and faculty on campus by the 2015 school year. PATH researchers met with campus partners representing transportation and parking, housing, transit, environmental planning and long-range planning to evaluate transportation needs and match the identified needs with innovations, such as carsharing, dynamic ridesharing, smart parking, and smart vending machines to improve access to campus.

### University of California, Davis Long-Range Development Plan: A Davis Smart Mobility Model Project Susan Shaheen, California PATH/CCIT TO 4302

The work completed under this project is part of a research, analysis, and modeling effort for the Davis region (continuation of TO 4144). The goal of the project is to optimize individual mobility options through improved connectivity among modes, enhanced techniques to link land-use planning and transportation systems design, advanced information technologies, and clean fuel vehicles. During 2002, PATH researchers focused on the UC Davis campus. Focus groups were conducted with UC students to introduce innovative transportation ideas and solicit feedback about selected innovations. In addition, an on-line transportation survey of students, staff, and faculty was administered to gain a stronger understanding of current transportation patterns.

### Smart Parking Management Pilot Project Susan Shaheen, California PATH/CCIT TO 4305

This project investigates whether transit use increases when parking information and overflow parking facilities are provided near transit stations. This project includes a literature review of smart parking approaches. A pilot program will launch in spring 2003 at the



Bay Area Rapid Transit (BART) District Dublin/Pleasanton station. It will include changeable message signs (CMS) located strategically on Interstate 680 to direct travelers to additional parking at adjacent business parks when BART lots are full. Participants will either walk or take a free shuttle bus to BART.

**Improving Bay Area Rapid Transit (BART) District Connectivity and Access with the Segway Human Transporter (HT) and Other Low-Speed Mobility Devices**  
**Susan Shaheen, California PATH/CCIT**  
**RTA 20833**

This project investigates improving transit connectivity with low-speed mobility devices such as bicycles and Segway Human Transporters (HT). The first year included a review of safety and pedestrian literature, national and state legislation, and existing HT pilot programs. In the second year, meetings and focus groups with stakeholders will be conducted to design an HT pilot program. The pilot will be conducted in a suburban transit setting to test commuter and day use applications at employment sites. The pilot evaluation will include a before-and-after behavioral analysis and will assess the economic potential of a shared-use HT business model.



**5. FREIGHT**  
**TRANSPORTATION SYSTEMS**

**Improved Grade Crossing Safety with In-pavement Warning Lights**  
**Theodore Cohn, UC Berkeley**  
**TO 4138**

The notion of employing in-pavement signals to create a 'visual gate' lies in cost between flashing roadside signals and full, lit gates. It could thus be an attractive upgrade at crossings that do not have gates, provided that it is effective. Our project aims to test its viability as a preventive strategy. During the past year, in-pavement signals from a manufacturer have been obtained and a method of exploring means of optimizing their visibility and attention getting qualities have been developed. Tests of optimization strategies in the lab are planned. Next year, the plan is to deploy such optimized signals at a test crossing in the San Joaquin Valley.

**Border Crossing ITS Technology Demonstration Commercial Deployment**  
**Hamed Benouar, Tony Brennan, CCIT,**  
**California PATH**  
**TO 4300**

The project's objective is to evaluate the systems application of proven ITS technologies to the efficient movement of trade through the international border at Otay Mesa, California. The technology evaluation will illustrate the application of electronic data interchange, electronic credentials, electronic pre-processing, and electronic screening to the efficient processing of commercial vehicles, drivers, and trade transactions. The results of the demonstration will illustrate and evaluate benefits associated with the application of ITS technologies to the international border processing function and the ability to ensure the clearance of safe and legal transactions across a secure border.

## 6. COLLISION WARNING AND AVOIDANCE, CONTROL ASSISTANCE SYSTEMS

### Technology Design and Development

**Innovative Grade Crossing Safety Measures for the San Joaquin Rail Corridor**  
**Theodore Cohn, UC Berkeley**  
**Sponsor: Caltrans Division of Rail**

This is a laboratory and field investigation of what causes grade crossing crashes along the San Joaquin corridor from two points of view, driver perception and driver cognition. The perception investigation consists of an investigation of the visibility of incandescent signals vs. LED, both in the laboratory and in the field. The cognition investigation consists of equipping a Caltrans-owned Amtrak locomotive with surveillance cameras to understand, then model, behaviors of drivers that immediately precede grade crossing incursions. We have completed an appraisal of LED replacements for railroad crossing signal lights, having measured their usability. We have installed and begun to test a system to monitor activity at crossings in advance of a locomotive that makes a daily round trip from Oakland to Bakersfield in the San Joaquin rail corridor. Completion of the monitoring system will enable us to develop a database of events that are precursors to collisions at crossings, to see what factors predispose to these events.

**Intersection Decision Support (IDS): A Systems Approach to Achieve a Nationally Interoperable Solution**

**James Misener, Steven Shladover, California PATH TO 4403**

The IDS system aids drivers trying to decide when it is safe to make a left turn across

approaching traffic. Our research in 2002 focused on the requirements, tradeoffs assessment, and technology investigations necessary to define an IDS. Our specific focus is on left turn movements, and in particular Left Turn Across Path/Opposite Direction (LTAP/OD), and Left Turn Across Path/Lateral Direction (LTAP/LD), urban scenario. We have also begun planning a naturalistic driving data collection system, inputting this into an overall driver model of nominal behaviors at intersections within an IDS simulation tool. A feature of our experimental approach is the construction of a four-way signal-controlled intersection at our Richmond Field Station facility, where we will also test our communication hardware and protocol development.

### Transit Applications

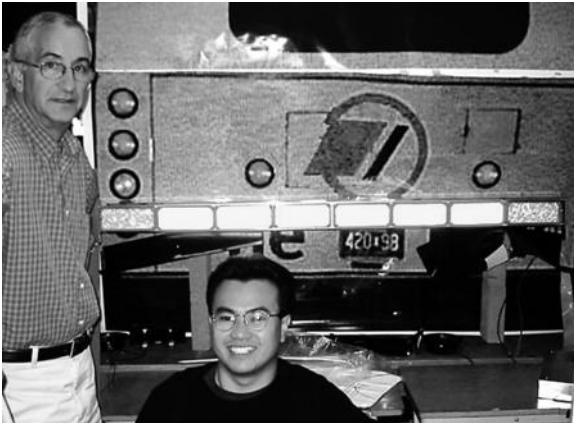
**Development of Performance Specifications for Frontal Collision Warning System (Year II)**  
**Wei-Bin Zhang, California PATH TO 4231**

A frontal collision warning system (FCWS) for transit buses uses advanced sensing and computer technologies to increase safety by giving advance warning to the driver about potential hazards. This project includes the development of a prototype system to validate the requirement specifications. A secondary goal is to explore smooth maneuvering as a result of collision warning, and to reduce tailgating. This project is a partnership of California PATH with the San Mateo County Transit District (SamTrans), and the Gillig Corporation. The FCWS system has been implemented on SamTrans buses and tested on SamTrans service routes. A Regional Advisory Committee has been formed for this project from selected transit agencies within the greater Bay Area, with the purpose of facilitating communication among the transit community and contributing to early development of a FCWS market.



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**Rear Impact Collision Warning System**  
**Theodore Cohn, UC Berkeley**  
**Sponsor: Federal Transit Administration/IVI Program**

Buses are hit from behind far more often than are passenger vehicles,

despite their large size, high visibility, and the fact that following vehicle (FV) drivers know them to be slow and to stop often. Suppose that the bus, the lead vehicle (LV) could detect the problem. How should the FV be signaled? We studied visual warning signals that were constrained to the form of an eight segment linear (horizontal) array of lights (8 cm x 150 cm). Experiments were conducted to compare reaction times of FV drivers when all light segments were illuminated simultaneously and when they were illuminated in a sequence representing a “looming” pattern.

**Transit Bus Collision Warning Integration Program**  
**Steven Shladover, Wei-Bin Zhang, California PATH**  
**Sponsor: Federal Transit Administration**

The operating environment for urban transit buses is much more complicated than the highway environment for which commercial collision warning systems are designed. This Intelligent Vehicle Initiative (IVI) project involves instrumenting a SamTrans (San Mateo County Transit Authority) bus with multiple sensors to develop a comprehensive characterization of its operating environment, and then using the extensive data gathered by those sensors to support development of prototype collision warning software, which can serve as the basis for defining the performance requirements for a deployable system.

**Evaluations of Effectiveness**

**Evaluation of the Effects of Intelligent Cruise Control (ICC) Vehicles in Mixed Traffic**  
**Petros Ioannou, University of Southern California**  
**TO 4217**

This project furthered research to evaluate the effects of intelligent cruise control (ICC) vehicles in a mixed traffic environment. Analytical and simulation results involving ICC vehicles in mixed traffic have been previously developed. This project carried out actual vehicle following experiments to validate the analytical and simulation results, and to quantify the benefits of ICC vehicles in mixed traffic.

**Conceptual Development and Performance Assessment for the Deployment Staging of Advanced Vehicle Control and Safety Systems**  
**Mark Miller, California PATH**  
**TO 4230**

This project investigated adaptive cruise control systems in the framework of deployment staging leading toward future automated highway systems. Strategies were proposed to advance step-by-step from today’s transportation system of manually controlled vehicles, to future systems of automated vehicles. Our work focused on three areas: evaluation of the effects of driver control assistance systems relative to human driving for multilane highways with light duty passenger vehicles, development of vehicle-highway automation system concepts for trucks and buses, and review of the state of international research, including simulation and evaluation as well as technology demonstrations of vehicle-highway automation systems.

**7. AUTOMATED TRANSPORTATION SYSTEMS**

**Concept Development and Evaluation**

**Definition and Evaluation of Bus and Truck Automation Operations Concepts**  
**Jan Botha, H.-S. Tsao, San José State University**  
**TO 4218**

This project developed and evaluated operating concepts for fully automated bus and truck transportation systems, as well as for the intermediate steps facilitating their deployment. We built on information from





prior research at California PATH and on information from truck and bus automation efforts around the world (e.g. the CHAUFFEUR project). The focus was on developing and evaluating concepts for transportation corridors, especially on identifying benefit-cost elements for a detailed comparison between urban bus automation and its conventional public-transit alternatives, and between inter-city truck automation and its conventional alternatives. Deployment sequences for the proposed operating concepts were developed to demonstrate the deployability of these concepts and to explain how they could be implemented.

**Evaluation of Truck and Bus Automation Scenarios**

**Jan Botha, H.-S. Tsao, San José State University; Randolph Hall, University of Southern California TO 4236**

Our goal was to quantify the benefits and costs of automating bus transit and road freight transportation, and to make a comparison with conventional systems. Among the information needed were benefit-cost comparisons between automated urban buses and their conventional public-transit alternatives, and between automated inter-city trucks and their conventional alternatives. The conventional public-transit alternatives included light-rail systems and bus-way systems. The project compared aspects of the implementation of an automated Bus Rapid Transit (BRT) system to their counterparts in an existing light-rail system. An automated BRT was also compared to a conventional busway. The conventional freight transportation alternatives included addition of a conventional lane, addition of a truck lane, and addition of an exclusive automated truck lane and intermodal rail.

**Cooperative Vehicle-Highway Automation Systems (CVHAS) Pooled Fund Study Case Study Analyses**

**Mark Miller, Steven Shladover, California PATH TO 4401**

California and ten other states have joined

with Honda R&D North America in a multi-state enterprise to explore CVHAS' potential for improving transportation system performance. Case studies of applications of CVHAS in specific sites were needed in order to shed light on important issues such as the definition of system operating concepts, system designs, institutional opportunities and constraints, and system benefits and costs to the various stakeholders, as well as to society as a whole. We conducted two case study analyses to explore the opportunities for CVHAS applications to trucks and buses, including a bus rapid transit circulator system and an intermodal freight interchange system, both in Chicago. Case studies focused on the solution of actual transportation problems provide a basis for focusing technical decisions and refining system design tradeoffs.

**Transit Applications (Bus Automation)**

**Automated Fault Tolerant Longitudinal Control of Transit Buses**

**Karl Hedrick, UC Berkeley/California PATH TO 4206**

Research focused on three main objectives: vehicle modeling, automated longitudinal control, and fault diagnosis and management. Vehicle modeling entailed the development of a realistic vehicle model of transit buses. The model was simulated and verified using experimental data. The mathematical model provided the first step in understanding the capabilities, limitations, and overall performance of transit buses. Results include the design of an automated longitudinal controller for a platoon of transit buses, and the design of a fault diagnostic and management system to detect, identify, and compensate for faults in all sensors and actuators involved in the longitudinal control system. Experimental validation of simulations will be carried out.

**Development of Heavy Duty Vehicle Automation Demonstration**

**Ching-Yao Chan, California PATH TO 4228, TO 4229**

California PATH is equipping three transit buses and three Class-8 tractor-trailer rigs for testing a variety of vehicle control and safety system concepts and technologies under realistic highway



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conditions. In 2002, system requirements for vehicle instrumentation were examined and evaluated. A new computer platform was selected for its robustness, small footprint, and increasing acceptance and usage by the industrial and academic communities. A suite of sensors, including accelerometer, yaw rate, range and range rate sensors, and GPS were tested. Working with Meritor-WABCO, an advanced version of electronic braking systems was implemented on the truck. Working with NSK, steering actuators for the trucks and buses were designed and implemented. These actuators were installed and validated. In initial road tests, longitudinal and lateral dynamics of heavy-duty vehicles were experimentally documented with a variation of trailer loads. Building upon these initial experiments, control algorithms with considerations for performance and robustness have been developed. Vehicle-to-vehicle communication through wireless links was also evaluated, investigated, and developed, using the wireless token ring protocol (WTRP) developed at California PATH.

**Coordination Layer Control Design for Automated Trucks and Buses**  
**Xiao-Yun Lu, California PATH**  
**TO 4237**

This project addresses the development of the higher-level coordination and link-layer control strategies needed to govern maneuvering interactions among vehicles, and between vehicles and the roadway infrastructure. Before this research was undertaken, these interactions had been defined in rather general terms in simulations, but had not been implemented experimentally. For example, the automated merge demonstrated in previous research was implemented entirely at the regulation layer. A complete implementation needs to include coordination layer interactions as well. The results of this research will be tested in a Bus Rapid Transit (BRT) system and in automated trucks.

**Freight Transportation Applications (Truck Automation)**

**Robust Lateral Control of Heavy Duty Vehicles**  
**Masayoshi Tomizuka, UC Berkeley**  
**TO 4201**

Work accomplished in 2002 included implementation and testing of previously developed lateral control algorithms for heavy trucks. A scanning laser radar sensor was used in implementing a vehicle following model. Simulation models were developed and used

to study the linear feedback controllers. An experimental setup was developed to characterize the scanning laser radar sensors, used to measure the relative distance and relative yaw angle of two vehicles closely traveling together.

Extensive experiments were conducted and valuable raw data was collected under different ambient light conditions, at different static distances and different angles, as well as for varying distances. The noise levels were characterized and algorithms to effectively process the time series to extract useful information were investigated. Enhancements to robustness and performance of the control algorithms were made. Previous research results were extended to include additional analytical and numerical work to handle uncertainties such as road-tire interaction and large-motion dynamics. Extensive experiments were conducted for various control strategies, and their performance was compared.

**Fault Tolerant Autonomous Following Lateral Control for Heavy Vehicles**  
**Masayoshi Tomizuka, UC Berkeley**  
**TO 4233**

Addresses the development of lateral vehicle following, both as a fault-tolerant method of lateral control of heavy-duty vehicles in a platoon, and as a backup system to magnetometer-based control. Intervehicle communication was included to reduce the propagation of lateral tracking errors throughout a platoon of heavy vehicles. Controllers that take advantage of the communicated information were developed. A vision-based lateral control was integrated with the existing magnetometer scheme to improve the performance, robustness and fault tolerance of current lateral control algorithms. The research covered analysis, simulation, and experimental verification of new lateral control algorithms. Experimental verification was also conducted with intervehicle communication.

**Integrated Longitudinal Control for Safe Automation of Commercial Heavy Vehicles**  
**Anna Stefanopoulou, University of Michigan Ann Arbor; Ioannis Kanellakopoulos, UC Los Angeles; Christian Gerdes, Stanford University**  
**TO 4202**

Addresses the integration of vehicle retarders for safe automation of commercial heavy vehicles. The project considered two issues. The first issue dealt with the robust longitudinal control design through on-line adaptation, so that the performance of the automated heavy truck was insensitive to varying load and road conditions (such as changes in vehicle mass,

load variations, road grade, wind gusts, and engine tuning). The second issue was the use of the engine brake and transmission retarder for braking, and the design of controllers that were capable of combining all the different brake actuators for optimal performance.

**Experimental Verification of Discretely Variable Compression Braking Control for Heavy-Duty Vehicles**

**Tsu-Chin Tsao, UC Los Angeles; Anna Stefanopoulou, University of Michigan Ann Arbor**  
**TO 4234**

The project’s goal was to develop a scheme to limit the use of service brakes on heavy duty vehicles. The developed splitting torque scheme uses the compression brake in conjunction with the service brake to maintain a desired speed. The compression braking capabilities of the Freightliner vehicle with an electronically controlled Cummins engine, a newly developed Jakobs braking mechanism, and an automatic transmission were tested and mapped. An evaluation was performed to determine if the compression braking torque quantization using the 6-stage discretely variable compression brake combined with multiple gear ratios is sufficient for a vehicle following scenario. The results were used to demonstrate heavy-duty vehicle (HDV) automation. A rigorous study of HDV parameter estimation, its impact on HDV safety, efficiency and driving ability was conducted.

**Control of Heavy-Duty Vehicles: Environmental and Fuel Economy Considerations**

**Petros Ioannou, University of Southern California**

**TO 4203**

Evaluated the environmental performance of existing heavy-duty vehicle-following control systems, developing modifications or new designs where necessary for environmentally efficient controllers. The research made use of an emissions and fuel consumption model for heavy-duty vehicles being developed at UC Riverside with support from California PATH and the US. Environmental Protection Agency. The controllers were designed to not only guarantee good fuel efficiency but also stability in close vehicle following. The theoretical findings were validated by experiments using actual vehicles. Tradeoffs among environmental efficiency, traffic flow stability, capacity, and vehicle stability were identified and quantified.

**Safety Performance and Robustness of Heavy-Duty Vehicles**

**Christian Gerdes, Stanford University**  
**TO 4211**

Developed a heavy truck model with a greater level of kinematic and dynamic fidelity than previous models. The research took into consideration the complexity of truck dynamics, which was important in order to establish what constitutes a safe truck. The project specified a set of metrics to quantify safety measures for heavy trucks, such as yaw stability, roll-over avoidance and stopping distance. Robustness of the safety claims was established by considering different operating conditions experienced by heavy trucks, variations in vehicle dynamic parameters arising through loading conditions, component choice and wear. Using a dynamic model, sensitivity analysis was performed to determine which parametric variations produce the most significant impact on the safety metrics. Experimental validation of the multi-body truck model was performed and suggestions were made on the redesign of existing heavy truck controllers for safety.

**Parameter Estimation of Heavy Vehicles for Regulation and Coordination Layer Control**

**Christian Gerdes, Stanford University**

**TO 4235**

Addressed the design and implementation of a robust real-time estimation scheme that estimates critical parameters affecting the performance of heavy-duty vehicles (HDVs). The scheme enabled estimation of mass, measurement of grade, estimation of roll resistance and estimation of aerodynamic drag force. The project focus was on the development of integrated regulation and coordination controllers capable of using the information provided by the real-time parameter estimation system and mapping out the forces on the truck and their implications in maneuver generation and closed-loop control.

**The Aerodynamics of Heavy Trucks**

**Fred Browand, University of Southern California**

**TO 4214**

This project addresses important aerodynamic drag issues for heavy-duty vehicles. Wind tunnel measurements were used to estimate drag and potential fuel savings for a single truck and were repeated for two scale-model tractor-trailers in tandem at short headway. The measurements were made on static tractor-trailer configurations, and yielded estimates of the quasi-steady limit forces. A goal of this

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project was to derive a sufficient vehicle roll stability margin for safe handling of Class 8 trucks at high speeds and under strong cross-wind and abnormal road conditions (such as a wet highway). Additional testing and analysis is underway.

### **Development of a Heavy-Duty Diesel Modal Emissions and Fuel Consumption Module for SmartAHS**

**Matthew Barth, UC Riverside  
TO 4215**

Heavy-duty vehicle modal emission models have not previously been developed, primarily due to the lack of appropriate second-by-second emissions data. Under a project sponsored by the US Environmental Protection Agency (EPA), an emission measurement trailer was developed at UC Riverside College of Engineering-Center for Environmental Research and Technology (CE-CERT) that could be attached to a number of heavy-duty rigs so that instantaneous emissions (including particulates) could be measured in situ. Using the emissions data, a heavy-duty diesel modal emissions/energy model was developed and verified. The model was integrated with California PATH's SmartAHS simulation tool to evaluate numerous automation scenarios that involved passenger cars, buses, and heavy-duty trucks. The model was combined with control simulation tools to evaluate ITS scenarios such as adaptive cruise control.

## **Snow Removal Applications**

### **Development of the Advanced Rotary Plow (ARP) for Snow Removal Operations** **Han-Shue Tan, California PATH**

**Sponsor: Caltrans Advanced Highway Maintenance and Construction Technology (AHMCT) Program**

Our goal is to design, implement and field-test a rotary snowblower under automated steering control with high robustness and accuracy, based on magnetic markers placed in the roadway along the guardrail. The conventional method for snowblowing operations along guardrails is to lean against the guardrail in order to prevent the "bleeding" of snow back on the roadway. The automated system can prevent expensive guardrail damage by controlling the distance between the blower head and the guardrail to within 2 to 4 inches (5-10 centimeters).



During 2002, California PATH equipped and tested a 20-ton rotary snowblower with the California PATH magnetic sensing system, a steering actuator, a driver-vehicle interface (DVI) (with lights and sounds), and associated control software. Operators from the Kingvale maintenance yard (near Donner Summit on I-80) have test-driven the automatic steering system and demonstrated that the system keeps the snowblower 5 to 10 cm away from the guardrail.

This project includes a collaborative effort between California PATH and the AHMCT Center at UC Davis. PATH is responsible for the development and implementation of the automated steering system, including system architecture, hardware installation, sensor signal processing, control algorithms, and DVI.

## **Automotive Applications – Automated Highway Systems (AHS)**

### **Enhanced AHS Safety Through the Integration of Vehicle Control and Communication**

**Karl Hedrick, UC Berkeley  
TO 4210**

Using communication systems the project implements dynamic position tracking of vehicles as well as fully coordinated platoon maneuvers. The project focuses on the development and experimental testing of an algorithm that exploits position tracking and communication capabilities to estimate friction characteristics of the road, constructing a map of these characteristics as a function of location. Results of this research were combined with existing and emerging work on emergency maneuvers to produce a detailed simulation of emergency stopping of a platoon of vehicles on slippery roads.

### **The Automated Highway Systems (AHS)/Street Interface: Effects of Capacity Concentrations on System Performance**

**Randolph Hall, University of Southern California  
TO 4216**

Investigates the design of an interface between the arterial street network and an automated highway system, evaluating ways to maximize the benefits that would accrue from the added capacity of the system. The project focused on understanding how to accommodate concentrations of capacity within narrow corridors or a limited number of interchanges, and the implications for the surrounding street system. Strategic modeling was used to create

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and compare models for generic scenarios, and to evaluate system performance under a range of strategies. Operational modeling was used to develop policies for controlling flows through, and queues at, interchanges and entry/exit points. Deployment modeling focused on a few sites in California, with detailed analysis of requirements for accommodating exiting and entering traffic at the particular location.

**Enhanced Coordination and Link Layer Control Algorithms for Improving AHS Capacity**  
**Roberto Horowitz, UC Berkeley**  
**TO 4239**

The current California PATH AHS architecture was designed to guarantee safety under normal and several degraded mode conditions, but is not necessarily optimal with respect to capacity considerations. This research aims to redesign and enhance existing coordination layer atomic maneuvers and their associated regulation layer controllers, so that flow capacity is dramatically improved, without sacrificing safety. Another goal is to formulate new coordination-layer protocols, consisting of atomic maneuvers that permit multiple vehicles within a platoon to simultaneously change lanes and permit platoons in adjacent lanes to simultaneously exchange multiple vehicles. A third goal is to refine the link-layer controller by incorporating the enhanced and newly designed coordination/regulation layers, and enhance the communication protocols to prioritize maneuvers, depending on the highway topology. The last goal is to evaluate the capacity of the enhanced architecture design and compare it to the previous design. A result of this project in 2002 was the design and stability analysis of the control laws required for the platoon-to-platoon lane change maneuver.

**Other Vehicle Control Systems (Defense Applications)**

**Model-Based Integration of Embedded Software (MoBIES)**  
**Pravin Varaiya, Karl Hedrick, UC Berkeley**  
**Sponsor: DARPA**

California PATH is part of the UC Berkeley "Automotive Open Experimental Platform" prime contract within the MoBIES program, sponsored by the Defense Advanced Research Projects Agency. The goal of MoBIES is to develop theory and technology for composing large embedded software applications subject to real world constraints – e.g., noise, synchronization, and dependability. In 2002 PATH addressed "vehicle-to-vehicle"

experiments. We posed and implemented a baseline solution, carrying from simulation to real-time code generation, with concomitant verification and timing tests, a multiple-processor "cooperative adaptive cruise control" (CACC) problem that leverages current adaptive cruise control (ACC) technologies and emerging vehicle-vehicle cooperative technologies that could be of considerable interest to the light vehicle industry. In addition to the safety and capacity benefits traditionally studied at PATH, we foresee benefits in the engineering process due to the concept-to-code integrated development environment for embedded processors.

**Distributed Autonomous Agent Networks**  
**Raja Sengupta, UC Berkeley**  
**Sponsor: Office of Naval Research**

This project is developing wireless ad hoc networking and service networking technologies for the cooperative operation of unmanned air and ground vehicles, under the sponsorship of the Office of Naval Research (ONR). The project is also developing a theory of networked control, i.e., multi-vehicle control that is robust to the uncertainties inherent in wireless data communications.



**8. DRIVER BEHAVIOR**

**Driver Modeling**

**Detection and Avoidance of Collisions: the Assessment of Collision Threat (ACT) Model**  
**George Andersen, UC Riverside**  
**TO 4220**

Investigates the visual information (e.g. angle of collision) used by human drivers to detect and avoid collisions. The research involved conducting experiments, using a driving simulator, to derive the relevant model parameters of a general collision detection model referred to as the Assessment of Collision Threat (ACT) model. Based on the results of the experiments, microsimulations of the ACT model were performed to evaluate the viability of the model to detect collisions in the car following and lane changing scenarios. The ACT model was integrated with the human driver model being developed at California PATH. Validation of the simulation-based results was performed by comparing driving performance from simulation studies with data from extant studies on real-world driving behavior.

### **Human Driver Model Development Delphine Cody, California PATH TO 4222**

Our goal was to provide other researchers with a tool for analyzing the effects of Intelligent Transportation Systems (ITS) systems on conventional driving performance in terms of throughput by reproducing the information processing string developed by the driver. The research extended and refined the capabilities of the human driver model by developing more processing mechanisms that assess the effectiveness of other driving assistance systems. The project also increased the number of driving parameters that the model should incorporate. The development of the model included the identification, adaptation and refinement of relevant models for describing drivers' cognitive and perceptive activity. The project included a simulation model using the SmartAHS framework, as well as validation and calibration of the model using data collected during actual driving.



### **Development of a Vehicle Data Acquisition System for Naturalistic Driving Data Collection Scott Johnston, California PATH TO 4223**

The vehicle data acquisition system (DAS) was developed to collect data about how human drivers actually drive. The data is used to help calibrate and validate the human driver model described above. The DAS was designed to be unobtrusive to

the driver of the test vehicle and drivers of other vehicles. It is capable of recording many driving parameters, such as throttle position, acceleration, longitude and latitude, range rate, and presence of adjacent vehicles. Under this project, the needed components for the DAS were purchased, data collection and analysis software was developed and refined, and all were integrated on a late model passenger car on loan from Caltrans.

## **User Interfaces**

### **Automated-Manual Transitions: Human Capabilities and Adaptive Cruise Control Theodore Cohn, UC Berkeley TO 4221**

This project dealt with automated-to-manual transition (A-MT) of an adaptive cruise control (ACC) vehicle when the vehicle in front suddenly applied maximum braking. It developed experiments, using a driving

simulator, to investigate the ability of a human operator to detect the closing intervehicle spacing, time to collision, and conditions required for a safe and smooth A-MT. The study focused on those visual capabilities required by the human operator to determine the need to assume manual control, and those features of an in-vehicle warning signal (initiated by either vehicle) that could reliably prompt appropriate human operator action. The research supplied a model for how to study A-MT in other settings, for example, longitudinal control of a platoon of vehicles.

## **9. ENABLING TECHNOLOGIES**

### **Vehicle Sensor Technologies and Sensor Fusion**

#### **Analyses of the Response of Pavements Containing Plugs for Vehicle Guidance John Harvey, Carl Monismith, UC Berkeley TO 4219**

Examines the influence of magnetic markers on pavement performance, specifically cracking, by considering the effects of traffic loading and temperature changes through a series of pavement simulations of representative pavement structures with magnets currently in use. Three-dimensional finite-element idealizations of the selected pavement structures and sensor sizes and locations were developed for the pavement simulations. A range of temperature conditions was examined, and the effects of rate of loading (truck speed) were also evaluated. The simulations were validated by a series of loading tests conducted with the Heavy Vehicle Simulator at the Richmond Field Station.

#### **Cooperative Multiple-Sensor Fusion for Automated Vehicle Control Karl Hedrick, UC Berkeley TO 4243**

Studies how sensor fusion techniques improve the performance and effectiveness of vehicle control using numerous sources of information. The project focused on completing the development and implementation of a modular sensor-fusion architecture for the longitudinal control system. The development process entailed gathering experimental data to accurately model the statistics of the sensors and closed-loop dynamics for the design of the Kalman filters used in each operating mode. A

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deliverable of the project is a Matlab/Simulink representation of the sensor models, the closed loop vehicle models, and the mathematical framework of the sensor fusion architecture. This framework will be used to analyze the performance of the proposed system. Another deliverable is a cost-benefit analysis of the various possible sensor combinations, which will be performed in order to determine the minimal set of sensors needed for automated operation and to provide reliable sensor measurements.

## Vehicle Positioning Technologies

### California PATH Inertial Navigation Laboratory Chin-Woo Tan, California PATH TO 4224

The ultimate objective of the project is to develop a gyro-free inertial navigation system (INS) with global positioning system (GPS)-based error correction algorithms. Research in 2002 continued to design and deliver an improved testing and laboratory environment. The algorithms were simulated and experimentally tested. The communication channel architecture and protocols designed by the wireless communications laboratory, also under this task order, were used for the delivery of differential correction information.

### Magnetometer/ Global Positioning System (GPS)/ Inertial Navigation System (INS) Integration and Mitigation of GPS Signal Blockage Research

Jay Farrell, UC Riverside  
TO 4232

Addresses the development of an integrated magnetometer/GPS/INS system for reliable centimeter-level accuracy vehicle control. Specifically, closed loop advanced maneuvers (e.g. passing, merging) were performed at arbitrary locations along a trajectory; driver assistance technologies, such as lane departure warning, were demonstrated; and vehicle positions and arrival times were communicated back to the loading area. The objective of this project was to design, develop and evaluate algorithms to address the issue of GPS signal loss following temporary signal blockages (e.g. inside a tunnel). The algorithms were designed to decrease the time required for a GPS receiver to re-acquire phase lock and estimate the integer ambiguities following a temporary loss of GPS signal.

## Wireless Communication Technologies

### A Robust Communication Link and Architecture Design for the Automated Highway System (AHS)

Andrea Goldsmith, Stanford University  
TO 4212

Extends previous investigations of the communication requirements and quality of service for data access in AHS communications. An example of quality of service is data access for messages of varying lengths and priorities. One goal was to design a robust communication link and data access protocols. We considered the problem that the overall communication architecture for an AHS is complicated by the propagation environment of the signals, the existence of multiple interference signals, and the mobility and dynamic character of platoons. Given the inherent difficulties, existing and emerging commercial technologies were evaluated to determine if they could fulfill the communication requirements of an AHS. The project focused on designing a hierarchical communication system architecture that supports all different layers (application, transport, network, data link, physical) and fulfills the communication requirements.

### California PATH Wireless Communication Laboratory Raja Sengupta, UC Berkeley TO 4224

Addresses a major category of Intelligent Transportation Systems (ITS) enabling technologies: wireless communication. Our work extended and leveraged California PATH's research on the design of automated highway systems communication architecture and protocols by integrating it with emerging mobile data access products and standards. A mobile data access architecture and protocols were designed to facilitate the deployment of vehicle-vehicle and vehicle-roadside cooperative systems, and partially or fully automated vehicle highway systems. The vehicle location (global positioning system (GPS)/ inertial navigation system (INS) system designed by the inertial navigation laboratory, also under this task order, was used to solve a First Contact Problem in communication architecture.





## **Fault Detection And Identification And Fault-Tolerant Control**

### **Vehicle Lateral Control Under Fault in Front and/or Rear Sensors**

**Masayoshi Tomizuka, UC Berkeley**  
**TO 4204**

This project evaluated the performance and robustness, both analytically and experimentally, of the magnetometer-based lateral control system when either the front or rear set of magnetometers failed. The autonomous lateral control (ALC) system, used to measure the lateral error and yaw error relative to the vehicle in front, was studied and combined with the magnetometer-based lateral control system to enhance safety and reliability performance.

### **Fault Tolerant Lateral Control for Transit Buses and Trucks**

**Masayoshi Tomizuka, UC Berkeley**  
**TO 4205**

Previous research on magnetometer fault tolerance recommended modifications of lateral control lane-keeping algorithms. However, results worked well only at lower speeds. In this project, fault-tolerant controllers that guarantee safe vehicle operations at high speeds were developed, simulated, and experimentally tested. The research involved developing a control strategy that incorporated considerations of safety, performance, and cost, geared towards implementation on transit buses. The new lateral controllers were integrated with existing higher-level fault detection and identification algorithms. Yaw-rate sensors, gyroscopes, and accelerometers were also included to provide fault-tolerant capabilities.

### **Development and Implementation of a Vehicle-centered Fault Diagnostic and Management System for the Extended California PATH- Automated Highway System (AHS) Architecture**

**Karl Hedrick, Roberto Horowitz, Masayoshi Tomizuka, UC Berkeley**  
**TO 4207**

This project extended and integrated existing results on fault diagnostic and fault management research, and developed a comprehensive fault management system. Features included a multi-layer fault diagnostic and management system, diagnosis of faults in the sensors and actuators of the lateral and longitudinal control systems, detection of faults

in the most vital sensors and actuators, and development of a systematic methodology for processing diagnostic residues. Experimental implementation and testing of the completed system began. This work was important because fault diagnostics and management appear to be the most important technical issues remaining to be resolved before vehicle automation can be implemented.

### **Development of Integrated Meso/Microscale Traffic Simulation Software for Testing Fault Detection and Handling in Automated Highway Systems (AHS)**

**Roberto Horowitz, UC Berkeley**  
**TO 4208**

This project furthered research on the analysis and simulation of AHS feasibility by making available a platform for performing exhaustive simulations of a large-scale AHS. These simulations provided information for the different degrees of precision (micro and macro levels) required for the evaluation of AHS feasibility. The objective was to integrate the California PATH micro-simulation SmartAHS and the meso-simulation SmartCAP software packages into a coherent programming platform for efficient simulations of a large scale AHS at the physical, regulation, coordination, and link layers. The resulting integrated simulation package has the capability of simulating vehicle faults at the micro level, the impact of a fault on the overall AHS response, and the way that a fault could be handled at the macro level.

### **Testing and Evaluation of Robust Fault Detection and Identification for a Fault Tolerant Automated Highway System**

**Jason Speyer, UC Los Angeles**  
**TO 4209**

This project performed experimental implementation and verification of the fault detection and identification (FDI) algorithms, including data fusion approaches (fault detection filter and residual processing) developed under previous California PATH projects. A deliverable was a robust fault monitoring system, implemented to monitor failures in any actuator or sensor for a single vehicle in both longitudinal and lateral modes. The residual processes were evaluated to determine the probabilities of false and missed alarms for the fault monitoring system. The fault monitoring system was simulated, tested and fine-tuned in the presence of sensor noise and process noise such as road slopes and wind gusts. The monitoring system was also evaluated using empirical vehicle data recorded at PATH's Crow's Landing facility.

## 10. MODELING AND SIMULATION TOOLS

### Traffic simulation

#### Bay Area Simulation and Ramp Metering Study Joy W. Dahlgren, Yonnel Gardes, California PATH TO 4106

Research objectives were to assess the capabilities of the Paramics microsimulation model in evaluating a range of alternative traffic management strategies, and to analyze the impact of these strategies on traffic conditions. The area studied was a section of the I-680 freeway between I-580 in Pleasanton and SR 237 in San Jose during the southbound morning peak period. The Paramics core model, supported by a set of supporting modules (APIs) developed at PATH, was found to be a reliable tool to evaluate the potential benefits of adding HOV lanes or implementing the ALINEA local traffic responsive ramp metering strategy.

#### Large Scale Traffic Simulation Through Parallel Computing Henry Liu, ATMS Testbed, UC Irvine, California PATH TO 4142

Develops a software system to enable Paramics users to distribute the computation load demanded by large-scale microscopic traffic simulation by using a network of PCs connected via Ethernet. Instead of expensive supercomputers or multi-processor workstations, this system uses low-cost, readily available PCs. Common Object Request Broker Architecture (CORBA) middleware is adopted as a general infrastructure for communicating between distributed simulation environments, aiming to satisfy the future online simulation needs, which may demand communications with multiple types of traffic surveillance systems.

#### Real-time Traffic Information Estimation Through On-line Simulation and Hybrid Data Fusion System for Advanced Traffic Management Systems (ATMS) Applications Lianyu Chu, UC Irvine/California PATH TO 4143

This project has two goals. First, to link the Paramics simulation model with real-world loop data. A freeway network can thus be simulated in Paramics without having dynamic Origin-Destination (OD) tables, which are

difficult to obtain based on current theoretical methods. Second, to investigate how to fuse probe vehicle data with historical and real-time loop data in order to provide travel time information for real-time traffic control and management. Paramics simulation is used as an evaluation tool to evaluate the proposed artificial-intelligence based data fusion method.

#### California PATH Paramics Development and Support Henry Liu, Lianyu Chu, UC Irvine/California PATH TO 4304

Our goal is to provide Caltrans with Paramics-related assistance in three broad categories: on-call direct support, technical guidance, and research related support. On-call direct support involves providing technical support, maintenance, and functionality enhancement of UC Irvine-developed application program interfaces (APIs), as well as developing new APIs, such as the SWARM ramp metering algorithm, for Caltrans. Technical guidance involves providing guidance and evaluation for simulation studies relative to traffic modeling, and peer review of Caltrans micro-simulation model guidelines. Research related support includes the development of the interface between the four-step model and traffic micro-simulation models, and evaluation of validation/calibration techniques for micro-simulation.

## 11. EVALUATION AND DECISION SUPPORT

### General Evaluation Methodology

#### Maintain and Enhance ITS Decision Website Joy W. Dahlgren, California PATH TO 4140

Since 1996, material on various ITS services and technologies has been continually added and updated to this website. Two new tools have now been developed to add to the site. The first is case-based reasoning, to assist potential ITS implementers in assessing the potential performance of various ITS strategies in their particular situations. Case-based reasoning systems are now being developed for freeway service patrols, automatic vehicle location, computer-aided dispatch for transit, and traffic management centers. The second tool helps visitors to the website find ITS services that will address specific problems or goals, saving them the trouble of reviewing all of the ITS services.

Traffic Systems
Public Transportation
Bus Rapid Transit
Innovative Mobility
Freight Transportation
Collision Warning
Automation Transportation
Driver Behavior
Enabling Technologies
Modeling and Simulation
Evaluation and Decision Support

## Traffic Applications



### Assessing the Value of TMCs and Methods to Evaluate the Long-Term Effects of ITS Implementation David Gillen, UC Berkeley TO 4132

This project has two stages. In the first, the value added of traffic management centers (TMC) was explored. We try to understand where and how TMCs add value, over and above the value added by the individual ITS technologies including the

networks of loop detectors, ramp meters and variable message signs. In the second stage, we develop some general equilibrium models, well suited to assess the impact of new technology, specifically ITS, on the transportation sector and also on other sectors of the economy. Next year, a database will be developed to test and calibrate these models so they can be used for economic assessments such as benefit-cost analysis, and for looking at different transportation strategies individually or as a set.

### A Tool for the Incorporation of Non-Recurrent Congestion Costs of Freeway Accidents in Performance Management Tom Golob, UC Irvine TO 4137

We are developing and testing a statistical method of measuring recurrent and non-recurrent congestion. We used 2001 and 2002 data from the major freeways in Orange County, encompassing the area covered by the ATMS Testbed at UCI, to compute the parameters of the distributions of performance data for all traffic detection locations and all times of the week. These data are filtered for bad data and then converted into five-minute observations of performance. Then the distributional parameters of these performance measures are computed for each location for each five-minute interval during the week. These distributions provide comparative measures of recurrent congestion for all locations and time periods for which there is sufficient detector data. Finally, we compare performance at periods and locations affected by traffic accidents to the distributions of recurrent congestion in order to estimate the extent of non-recurrent congestion due to accidents.

## Automated Transportation Applications

### Safety Assessment of Advanced Vehicle Control and Safety Systems (AVCSS): A Case Study Ching-Yao Chan, Wei-Bin Zhang, California PATH TO 4225

Continues the collaboration between California PATH and the French Institut National De Recherche Sur Les Transports Et Leur Sécurité (INRETS) in performing safety analysis and evaluation of advanced vehicle control and safety systems (AVCSS), such as vehicle longitudinal and lateral control systems. The goal of the research was to identify errors in the process of specification, design, development and integration prior to the implementation of the new technologies, thereby preventing hazardous consequences. PATH contributed expertise in vehicle control and failure analysis to identify, analyze, and classify the risks inherent in each part of an AVCSS system. INRETS provided expertise in safety analysis and assessment. The project also considered sensor reliability and diagnosis, and developed a system architecture to include fault tolerance and fault detection. As a case study, a transit bus was used as a study platform.

## Institutional and Societal Issues

### Institutional Aspects of Multi-Agency Transit Operations Mark Miller, California PATH TO 4105

Investigates institutional changes that transit agencies have recently undertaken to work in partnership and coordination (rather than in competition) with other regional public agencies to address mutual transportation problems from a regional (rather than parochial) perspective. The investigation included case studies both within and outside of California. In analyzing the case studies, both formal and informal mechanisms are seen to forge strong regional coordination linkages. Several key factors help to create an environment that makes interagency coordination possible, including an established common vision among the agencies, good leadership from individuals within agencies, persistence by the participants to overcome institutional and operational barriers, and availability of technologies to encourage and enhance the coordination process.

**Institutional, Organizational, and Market Aspects of Successful ITS Deployment**  
**Pat Conroy, Caltrans; Jean-Luc Ygnace, INRETS**  
**TO 4157**

In the course of prior work, it became clear that political/ institutional, organizational and market environments in Europe, as they relate to transport, system management and ITS deployment, are comparable to those of the US and California. Issues, policy objectives, processes, and the stages of ITS research and deployment are quite similar, even though some interesting and informative differences exist. Key findings include: European partners feel that ITS is contributing to building a seamless Trans-European Road Network, and there is an expectation of significant capacity enhancements; medium-sized urban areas can enjoy benefits from ITS applications similar to larger regions and may have an advantage with less complex institutional environments. A significant factor for successful ITS deployment is the provision for operations and maintenance (O&M) funding, and delineation of O&M responsibilities within and among partner agencies.

**Commercialization of Intelligent Transportation Systems Technologies (CCIT)**  
**Hamed Benouar, Tony Brennan, California PATH/CCIT**  
**TO 4126**

CCIT is a program to organize, manage, staff, and provide facilities necessary to further the development, commercialization, and deployment of promising transportation technologies and systems originated through past and ongoing PATH research. CCIT forms partnerships with industry, academia and public agencies to solve difficult transportation problems. It provides facilities for research, development, testing, commercialization and deployment of transportation technologies and systems. CCIT provides support to the following projects: the Berkeley Highway Lab, Border Crossing ITS Technology Demonstration, CarLink II, PeMS Freeway Performance Measurement System, and the Innovative Mobility Research Program. CCIT's name will be changed to California Center for Innovative Transportation in 2003.



Traffic Systems
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Collision Warning
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Driver Behavior
Enabling Technologies
Modeling and Simulation
<b>Evaluation and Decision Support</b>

# Recent Publications

Available online at  
[www.path.berkeley.edu/PATH/publications](http://www.path.berkeley.edu/PATH/publications)

## Traffic Systems

### Traffic Management

#### Ten Strategies for Freeway Congestion Mitigation with Advanced Technologies

*Carlos F. Daganzo, Jorge Laval, Juan Carlos Muñoz*

Presents ten strategies for improving freeway performance that have become feasible with the advent of new software and hardware technologies for traffic control. Most of the strategies can be applied with advanced implementations of existing hardware. The presented strategies can be rigorously tested. Their measures of performance can be reliably obtained and do not depend on the accuracy of data-hungry, large-scale models. UCB-ITS-PRR-2002-3  
January 2002, 24 pp., \$5

#### TRICEPS: An ATMIS Field Implementation for Control and Evaluation: Final Report

*MG McNally, C. Rindt, F. Logi*

TRICEPS (Testbed Realtime Integrated Control and Evaluation Prototype System) was implemented in a sub-area of the Advanced Testbed network at the UC Irvine campus. Initial implementation focused on CARTESIUS, a real-time, multi-agent decision support system that integrates real-time control and simulation elements. Our report describes the genesis of TRICEPS, an overview of its major components and of the system architecture, the results of a system evaluation study, and a sample application of the model system. UCB-ITS-PRR-2002-9  
March 2002, 89 pp., \$15

#### Study of Traffic at a Freeway Merge and Roles for Ramp Metering

*Michael J. Cassidy, Jittichai Rudjanakanoknad*

This report presents a study that examines freeway traffic flows departing from a merge bottleneck and looks at the potential for increasing the merge area's service rates by metering its upstream onramp. Findings show that this might be realized by limiting the rate that onramp vehicles join the freeway's traffic stream. UCB-ITS-PWP-2002-2  
May 2002, 20 pp., \$5

### Traffic data collection

#### Improving Operations Using Advanced Surveillance Metrics and Existing Traffic Detectors

*Benjamin Coifman, Pravin Varaiya*  
This research improves the vehicle reidentification algorithms of an existing prototype travel time measurement system that utilizes existing dual loop speed traps and "model 170" controllers. The improved travel time measurement system is then

applied over seven freeway links in real-time. The report also describes the development of the Berkeley Highway Laboratory (BHL), which was designed to meet several goals, including: collecting traffic data for research, extracting meaningful information from the data, and furthering traffic flow theory and improving traffic control strategies. UCB-ITS-PRR-2002-2  
January 2002, 65 pp., \$15

#### Field Investigation of Advanced Vehicle Reidentification Techniques and Detector Technologies – Phase 1

*Stephen G. Ritchie, Seri Park, Cheol Oh, Carlos Sun*

This research focused on expanding the ILD-based vehicle reidentification system at an intersection in Irvine to address reidentification of turning vehicles; estimating of real-time traffic parameters from single loop detector inductive signatures, on developing a prototype real-time web-site for internet-based access to performance data from the study intersection; and on studying video image processing for future detector data fusion of video and loop signature data. UCB-ITS-PRR-2002-15  
March 2002, 100 pp., \$15

#### Field-Deployable Real-Time Laser-Based Non-Intrusive Detection System for Measurement of True Travel Time on the Highway

*Harry H. Cheng, Ben Shaw, Joe Palen, Zhaoqing Wang, Bo Chen*

This report presents a roadway detection system that can directly determine origin/destination data non-intrusively without violating privacy. Using a previously developed real-time laser based non-intrusive detection system, a feedback loop, using microchip control, is introduced into the system. The real-time device driver, data acquisition software, and microprocessor closed-loop control unit are described, and test results are presented. UCB-ITS-PRR-2002-23  
August 2002, 64 pp., \$15

#### Deployment and Evaluation of Real-Time Vehicle Reidentification from an Operations Perspective

*Benjamin Coifman, Pravin Varaiya*

This report presents an extension to previous research work on travel time measurement system. Because travel time provides information over an extended freeway link, rather than at a single point, it is a key parameter for ATIS applications and it is a powerful tool for ATMS. We have previously developed a prototype travel time measurement system that utilizes existing dual loop speed traps and "model 170" controllers. The research presented here improves the vehicle reidentification algorithms,

extends them to single loop detector stations, and uses the reidentified vehicles to extract both density and the net number of lane change maneuvers. UCB-ITS-PRR-2002-37  
December 2002, 54 pp., \$15

#### GPS/GIS Technologies for Traffic Surveillance and Management: A Testbed Implementation Study

*M.G. McNally, J.E. Marca, C.R. Rindt, A.M. Koos*

Studies applications of GPS that may be relevant to the ATMS Testbed, such as the implementation in probe vehicles to deliver real-time performance data to complement loop and other sensor data, and the implementation in vehicles from sampled households to record route choice behavior. We have designed a flexible GPS-based data collection unit. It incorporates GPS, data logging capabilities, two-way wireless communications, and a user interface in an embedded system which eliminates (or minimizes) driver interaction. UCB-ITS-PWP-2002-7  
August 2002, 68 pp., \$15

### Traffic Theory

#### Identifying Density-Flow Relations on Arterial Surface Streets

*Soyoung Ahn, Michael J. Cassidy*

In this report, a simple car-following rule was verified by studying vehicles discharging from long queues at signalized intersections. The report includes observations that the time-space trajectory of a *j*th vehicle discharging on a homogeneous intersection approach was essentially the same as the *j*-1th vehicle except for a translation in space and time. The observations were in agreement with a simplified theory proposed by G.F. Newell. The findings indicate that the congested branch of a density-flow curve is linear in form. UCB-ITS-PRR-2002-26  
August 2002, 18 pp., \$5

#### Validation of Daganzo's Behavioral Theory of Multi-Lane Traffic Flow: Interim Report, Work Accomplished at SDSU

*James Banks*

Documents the results of the first year of a research project designed to validate a behavioral traffic-flow theory recently proposed by Carlos Daganzo. The theory deals with traffic flow occupancy, headways, and queue discharges. The research includes a review of past empirical work related to the theory and verification of a set of predictions or hypotheses. Two case studies are presented. Through their results, the author discusses the conclusions reached for the various hypotheses. UCB-ITS-PWP-2002-1  
March 2002, 26 pp., \$10

#### Testing Daganzo's Behavioral Theory for Multi-lane Freeway Traffic

*Koohong Chung, Michael J. Cassidy*

This report presents a preliminary study of traffic on stretches of two different freeways that are plagued by merge bottlenecks. Using traffic data from a site on the Gardiner Expressway in Toronto, Canada, and a site on westbound State Route 24 near the Caldecott Tunnel in Berkeley, California, the authors tested Daganzo's behavior theory of drivers. In addition to verifying Daganzo's theory, the authors found that discharge flows increased when changes in traffic conditions caused the bottleneck to move upstream of the merge. UCB-ITS-PWP-2002-9  
November 2002, 22 pp., \$5

## Public Transportation Information Systems

### Transit Management and Information Systems

#### Evaluating the Impact of ITS on Personalized Public Transit

*Maged M. Dessouky, Majid Aldaihani, Rutvij Shah*

This report reviews available and emerging ITS technologies that have been deployed or are being considered for personalized public transit and demand responsive systems such as paratransit. Also included is a statistical analysis of travel patterns of a paratransit provider in Los Angeles County. We compare the performance of a strictly curb-to-curb system with a hybrid system that is a mixture of curb-to-curb and fixed route. UCB-ITS-PRR-2002-27  
September 2002, 78 pp., \$15

### Demand-responsive Transit

#### Assessing the Role of Automatic Vehicle Location (AVL) in Demand Responsive Transportation Systems

*David Gillen, Julie Raffailac*

The authors develop an algorithm for measuring the contribution of AVL technology to both passenger welfare and supplier efficiency. They present results of a literature review of dial-a-vehicle operations, noting that simulation models or empirical models based on simulated or real data appear to be the only options open to planners. They conclude that stated-preference surveys are needed to reveal the willingness to pay for a variety of different service levels. UCB-ITS-PRR-2002-16  
April 2002, 18 pp., \$5

## Bus Rapid Transit (BRT) Systems

### Bus Rapid Transit and the Use of AVL Technology: A Survey of Integrating Change

David Gillen, Doug Johnson

This report examines employee and organizational reactions to technical change in manufacturing and information management sectors. Concerns regarding change have critical real-world effects on firms. The authors examine the nature of change, its implementation, and its eventual consequences, thus leading to an understanding of employee resistance as well as to approaches for overcoming it. Reasons for pursuing AVL technology are examined, focusing on expected and realized benefits.

UCB-ITS-PRR-2002-17

April 2002, 24 pp., \$5

## Freight Transportation Systems

### Deployment Paths of ATIS: Impact on Commercial Vehicle Operations, Private Sector Providers and the Public Sector

Amelia C. Regan, Thomas F. Golob

This report addresses multivariate demand models which used large-scale surveys of commercial vehicle operators in California to determine the current use and perceptions of advanced information technologies, especially advanced traveler information systems (ATIS). Data were used to identify organizational and operational characteristics that made these technologies more or less attractive, and to predict potential adoption of the technologies by carrier type.

UCB-ITS-PRR-2002-31

October 2002, 36 pp., \$10

## Automated Transportation Systems

### Concept Development and Evaluation

### Definition and Evaluation of Bus and Truck Automation Operations Concepts

H.-S. Jacob Tsao, Jan L. Botha

This report describes a project that developed and evaluated operating concepts for urban bus automation and inter-city truck automation. A few of the most promising concepts were selected, with variations and intermediate deployment steps. For urban bus automation, an unprotected automated busway system (ABUS) was selected. For truck automation, a protected inter-city truck-automated highway system (AHS) was selected. Deployment sequences were devel-

oped for these operating concepts in order to demonstrate their potential.  
UCB-ITS-PRR-2002-8  
March 2002, 50 pp., \$10

## Transit Applications: (bus automation) – Freight Transportation Applications (truck automation)

### Identification and Integration of Commercial Heavy Vehicle Retarders

Maria Druzhinina, Lasse

Moklegaard, Anna G. Stefanopoulou

Describes development and validation of a coordination scheme between friction and discretely variable compression brakes for a truck. A coordination scheme that maintains the speed tracking performance of the nominal PID controller is developed. Through the coordination scheme, the command of the nominal PID controller is split into a friction brake command and a compression brake command. Validation of the coordination scheme revealed a sizable reduction in the friction brake usage during braking maneuvers, leading to a prolonged service life.

UCB-ITS-PRR-2002-14

March 2002, 34 pp., \$10

### Longitudinal Control of Commercial Heavy Vehicles Equipped with Variable Compression Brake

Lasse Moklegaard, Maria

Druzhinina, Anna G. Stefanopoulou

This report presents new results on research developing longitudinal control algorithms that coordinate the variable compression brake with conventional service brakes and gear selection. Specifically, we present the integration of the compression brake actuator with the service brakes and the design of a PID controller that emulates the driver's actions on long grades. The controller uses engine speed measurement to activate the service brakes only when the retarding power of the compression brake is insufficient.

UCB-ITS-PRR-2002-13

March 2002, 88 pp., \$15

### Longitudinal Control of Commercial Heavy Vehicles: Experimental Implementation

Yaolong Tan, Ioannis

Kanellakopoulos

This report describes research which examined the effectiveness of nonlinear spacing policies in improving the vehicle following performance of relatively simple PID and PIQ controllers. Through experiments, it was shown that system responses and performance were improved without adding significant complexity to the controller design. The closed-loop experiments also showed that simple PID and PIQ controllers are able to achieve good performance when

combined with nonlinear spacing policies.

UCB-ITS-PRR-2002-25

August 2002, 28 pages, \$10

### Truck Scheduling for Ground to Air Connectivity: Final Report

Randolph W. Hall, Shih-Che Lo

Critical to the overnight package business is the on-time arrival of trucks at airport terminals. Truck delays can delay package sorting, which can in turn delay aircraft departures. We model the airport terminal as a queueing process with random bulk arrivals. The models have been implemented in a web-based decision support tool (Truck to Air Dispatch, TAD, available at the website ger309-pc16.usc.edu), which provides real-time predictions for the status of the sort operation, plus decision support for scheduling dispatches.

UCB-ITS-PRR-2002-33

November 2002, 57 pp., \$15

## Automotive Applications – AHS

### Vehicle Sorting for Platoon Formation: Impacts on Highway Entry and Throughput

Randolph Hall, Chinan Chin

This report presents the evaluation of various strategies that were evaluated for organizing vehicles into platoons by sorting vehicles on entrance ramps. Performance was evaluated with respect to platoon sizes, highway throughput, and queueing characteristics or waiting time. The strategies included random, destination group (DG), dynamic grouping (DYG), and dynamic grouping and platoon splitting (DGPS). The evaluations showed that the dedicated assignment strategy performed better than dynamic assignment with respect to platoon ratio and throughput. Average waiting time at the entrance, however, was somewhat longer.

UCB-ITS-PRR-2002-7

March 2002, 38 pp., \$10

## Enabling Technologies

### Vehicle Sensor Technologies and Sensor Fusion

### System Review of Magnetic Sensing System for Ground Vehicle Control and Guidance

Ching-yao Chan

This report contains results of studies on magnetic marker systems used as a position reference system for Advanced Vehicle Control and Safety Systems. Effects of external objects and earth background fields on such systems are investigated with experimental measurements. Results show that signal processing techniques must be adopted in field applications to improve the accuracy and robustness of sensing algorithms.

The report contains experimental results from an evaluation study of the PATH marker system and the 3M Tape system. It was found that the PATH marker system offers a stronger signal-to-noise ratio and provides a more accurate position measurement.

UCB-ITS-PRR-2002-20

May 2002, 87 pp., \$15

## Vehicle Positioning Technologies

### Design and Error Analysis of Accelerometer-Based Inertial Navigation Systems

Chin-Woo Tan, Sungsu Park

This report examines the feasibility of designing an accelerometer-based (or gyroscope-free) inertial navigation system that uses only accelerometers to compute the linear and angular motions of a rigid body. The effects of accelerometer location and orientation errors are analyzed. Algorithms that identify and compensate these errors are developed.

UCB-ITS-PRR-2002-21

June 2002, 30 pp., \$10

### GPS-Aided Gyroscope-Free Inertial Navigation Systems

Sungsu Park, Chin-Woo Tan

This report studies gyroscope-free inertial navigation systems that use only accelerometers to compute navigation trajectories. Such navigation systems are low-cost, but their output error diverges at a rate that is an order faster than that of conventional gyroscope-based systems. So integration with an external reference system, such as the Global Positioning System, is necessary for long-term navigation applications. In this paper, an integrated GPS and gyroscope-free INS system is designed to achieve stable long-term navigation. The linear and nonlinear error models of a gyroscope-free INS are derived and are used as Kalman filter equations to estimate the errors in the gyroscope-free INS data. The effects of gyroscope-free inertial measurement unit errors are also analyzed. By using computer simulations, the performance of the integrated GPS and gyroscope-free INS system is verified.

UCB-ITS-PRR-2002-22

June 2002, 27 pp., \$10

### Integration of GPS/INS and Magnetic Markers for Advanced Vehicle Control: Final Report for MOU 391

Jay Farrell, Matthew Barth

This paper describes a triple redundancy navigation system which incorporates magnetometer, inertial, and carrier phase differential Global Positioning System (GPS) measurements for vehicle lateral control. The system is designed to operate reliably whether or not GPS and magnetometer measurements are available. It

provides vehicle position, velocity, acceleration, attitude, heading, and angular rates at 150 Hz with accuracies (standard deviation) of 1.5 cm, 0.8 cm/s, 2.2 cm/s/s, 0.03 deg, 0.1 deg, and 0.1 deg/s.  
UCB-ITS-PRR-2002-32  
October 2002, 18 pp., \$5

#### **Adaptive Control for Conventional Modes of Operation of MEMS Gyroscopes** *Sungsu Park, Roberto Horowitz, Chin-woo Tan*

In this report, we present adaptive control algorithms for conventional modes of operation of Micro-Electro-Mechanical Systems (MEMS) z-axis gyroscopes. For an open-loop mode of operation, an off-line self-calibration method is proposed for initial estimation and compensation of fabrication imperfections. For a closed-loop mode of operation, an adaptive add-on control method is proposed. This adaptive algorithm can estimate the angular rate and simultaneously identify and compensate quadrature error, and may permit on-line automatic mode tuning.  
UCB-ITS-PRR-2002-10  
March 2002, 36 pp., \$10

#### **Adaptive Control for MEMS Gyroscopes** *Sungsu Park, Roberto Horowitz, Chin-woo Tan*

In this report, we present a new adaptive operation strategy for Micro-Electro-Mechanical Systems (MEMS) z-axis gyroscopes. This gyroscope is self-calibrating, compensates for friction forces and fabrication imperfections that normally cause quadrature errors, and produces an unbiased angular velocity measurement that has no zero-rate output (ZRO). Convergence and resolution analysis show that adaptive control offers advantages over conventional modes of operation. These include greater operational bandwidth, absence of zero-rate output, self-calibration, and high robustness to parameter variations caused by fabrication defects and ambient conditions.  
UCB-ITS-PRR-2002-11  
March 2002, 34 pp., \$10

#### **Digital Implementation of Adaptive Control Algorithms for MEMS Gyroscopes** *Sungsu Park, Roberto Horowitz, Chin-woo Tan*

In this report, we present a hybrid discrete/continuous time version of the observer-based adaptive control system for micro-electric-mechanical systems (MEMS) gyroscopes that can be easily implemented using digital processors. We describe the dynamics of MEMS gyroscopes by accounting for the effect of fabrication imperfections. The observer-based adaptive control algorithm is then reviewed, followed by the development of a hybrid adaptive control law. The performance of the hybrid adaptive

controlled gyroscope is analyzed.  
UCB-ITS-PRR-2002-12  
March 2002, 35 pp., \$10

#### **Wireless Communication Technologies**

#### **WTRP—Wireless Token Ring Protocol** *Mustafa Ergen*

This report studies WTRP, a medium access control protocol for wireless networks. The report shows that WTRP is efficient, it reduces the number of retransmissions due to collisions. The report also shows that WTRP is fair, stations take turn to transmit and are forced to give up the right to transmit after transmitting for a specified amount of time. Not all stations need to be connected to each other or to a central station. WTRP has applications to inter-access point coordination in ITS DSRC, safety-critical vehicle-to-vehicle networking, and home networking.  
UCB-ITS-PRR-2002-29  
September 2002, 128 pp., \$20

#### **Fault Detection and Identification and Fault-Tolerant Control**

#### **Testing and Evaluation of Robust Fault Detection and Identification for a Fault Tolerant Automated Highway System**

*Robert H. Chen, Hok K. Ng, Jason L. Speyer, D. Lewis Mingori*  
This report describes a vehicle fault detection and identification system that can detect and identify actuator and sensor faults using fault detection filters, parity equations, and an approach based on analytical redundancy. It is shown that the fault detection filters can detect and identify actuator and sensor faults as expected, even under various disturbances and uncertainties such as sensor noise, road noise, system parameter variations, unmodeled dynamics and nonlinearities.  
UCB-ITS-PRR-2002-24  
August 2002, 152 pp., \$25

#### **Development and Implementation of a Vehicle-Centered Fault Diagnostic and Management System for the Extended PATH-AHS Architecture: Part I**

*Jingang Yi, Shashikanth Suryanarayanan, Adam Howell, Roberto Horowitz, Masayoshi Tomizuka, Karl Hedrick, Luis Alvarez*  
This report integrates existing results on fault diagnostics and fault management for passenger vehicles used in automated highway systems (AHS). These results have been combined to form a fault diagnostic and management system for the longitudinal and lateral control systems

of automated vehicles which has a hierarchical framework that complements the established PATH control system. Simulation and limited experimental results are provided.  
UCB-ITS-PRR-2002-34  
November 2002, 118 pp., \$20

#### **Development and Implementation of a Vehicle-Centered Fault Diagnostic and Management System for the Extended PATH-AHS Architecture: Part II**

*Jingang Yi, Shashikanth Suryanarayanan, Adam Howell, Roberto Horowitz, Masayoshi Tomizuka, Karl Hedrick*  
This project addresses four aspects of safety in the PATH AHS architecture: (1) a multi-layer fault diagnostic and management system, (2) diagnosis of faults in the sensors and actuators of the lateral and longitudinal control systems, (3) detection of faults in the most vital sensors and actuators, and (4) development of a systematic methodology for processing diagnostic residues. Experimental implementation and testing of the completed system is described.  
UCB-ITS-PRR-2002-35  
November 2002, 54 pp., \$15

#### **Integration of Fault Detection and Identification into a Fault Tolerant Automated Highway System: Final Report**

*Robert H. Chen, Hok K. Ng, Jason L. Speyer, D. Lewis Mingori*  
Describes a vehicle health management approach based on analytic redundancy. It also describes a point design of fault-detection filters and parity equations that are developed for the vehicle longitudinal mode. A preliminary design of a range sensor fault monitoring system is outlined as an application of a new decentralized fault detection filter. This system combines dynamic state information already generated by existing filter designs with inter-vehicle analytic redundancy.  
UCB-ITS-PRR-2002-36  
December 2002, 69 pp., \$15

#### **Modeling and Simulation Tools**

#### **Traffic Simulation**

#### **Modeling the Santa Monica Freeway Corridor: Simulation Experiments**

*Alexander Skarbardonis*  
This project created one of the largest freeway corridor networks coded for the CORSIM microscopic simulation model, about 10 miles of I-10 freeway and a surface street network with 75 signalized intersections. Results from the simulation experiments indicate that several CORSIM model param-

eters need to be adjusted in order to accurately simulate freeway facilities for California conditions. Recommendations are provided for developing a comprehensive simulation testbed for the study area including data collection requirements, model application, model calibration and validation and analysis of alternative ATMS strategies.  
UCB-ITS-PRR-2002-1  
January 2002, 71 pp., \$15

#### **Bay Area Simulation and Ramp Metering Study**

*Yonnel Gardes, Adolf D. May, Joy Dahlgren, Alex Skarbardonis*  
This report focuses on the investigation of a portion of the southbound I-680 freeway, between I-580 in Pleasanton and SR 237 in San Jose, during the morning peak. The project provided an opportunity for testing Paramics model capabilities to replicate freeway traffic conditions, and assess the extent to which the existing model can simulate various operational strategies such as HOV lanes and ramp metering.  
UCB-ITS-PRR-2002-6  
February 2002, 95 pp., \$15

#### **Enhancements of ATMS Using Artificial Intelligence**

*Henry X. Liu, Will Recker*  
Summarizes research conducted in three projects on real-time management of freeway systems. The first project led to the development of a library of plug-in modules to enhance the capabilities of PARAMICS simulation. The second introduced an adaptive signal control system utilizing an on-line signal performance measure. The third presents a model that captures travelers' decision making among discrete choices in a probabilistic and uncertain environment.  
UCB-ITS-PRR-2002-30  
October 2002, 54 pp., \$15

#### **Implementing A Dynamic O-D Estimation Algorithm within the Microscopic Traffic Simulator Paramics**

*Reinaldo C. Garcia*  
Addresses the implementation of a dynamic origin-destination (O-D) estimation algorithm for the Paramics microscopic simulator. Paramics offers important features such as high performance and scalability to handle realistic traffic networks. However, Paramics has its limitations, especially relating to the model's ability to interface with dynamic O-D estimation. This study attempts to make Paramics a more complete tool for evaluating the expected net benefits of Advanced Traffic Management Systems (ATMS) applications.  
UCB-ITS-PWP-2002-4  
June 2002, 16 pp., \$5

### **Analytical Dynamic Traffic Assignment (DTA) Model with Probabilistic Travel Times and Travelers' Perceptions**

*Henry X. Liu, Xuegang Ban, Bin Ran and Pitu Mirchandani*

Dynamic Traffic Assignment (DTA) which, despite its maturing stage, still needs improvements, especially regarding its formulation and solution capabilities under the transportation environment impacted by Advanced Transportation Management and Information Systems (ATMIS). Our proposed model captures travelers' decision making among discrete choices in a probabilistic and uncertain environment, in which both probabilistic travel times and random perception errors that are specific to individual travelers, are considered.

UCB-ITS-PWP-2002-6  
July 2002, 24 pp., \$5

### **Adaptive Signal Control System with On-line Performance Measure for Single Intersection**

*Henry X. Liu, Jun-Seok Oh, and Will Recker*

Addresses a signal control system that, unlike conventional signal control systems, employs real-time delay estimation and an on-line signal timing update algorithm. A description of the overall control system architecture and the optimization algorithm is addressed. Performance of the proposed system is evaluated with a high-performance microscopic traffic simulation program, Paramics. Preliminary results have proven the system's promising properties.

UCB-ITS-PWP-2002-5  
July 2002, 17 pp., \$5

## **Evaluation and Decision Support**

### **General B/C evaluation methodology**

### **Freeway Safety as a Function of Traffic Flow: The FITS Tool for Evaluating ATMS Operations**

*Thomas F. Golob, Wilfred W. Recker, Veronica Alvarez*

This report addresses FITS (Flow Impacts on Traffic Safety), which uses relationships between traffic flow and crash characteristics to assess safety benefits that are likely to be realized under specific ATMS implementations. Using observations from single-loop detectors, FITS forecasts the types of crashes most likely to occur for the flow conditions being monitored. In this report, conditions for a thirty-minute period preceding more than 1,000 crashes on six major freeways are analyzed against the crashes' characteristics.

UCB-ITS-PRR-2002-28  
September 2002, 96 pp., \$15

## **Traffic applications**

### **San Gabriel Valley Smart Shuttle Technology (SGVSS) Field Operational Test Evaluation: Final Report**

*Genevieve Giuliano, James E. Moore II, Thomas O'Brien, Jacqueline Golob*  
The SGVSS attempted to integrate services of three local municipal public transit operators and a regional fixed route operator via networked computer-assisted dispatching, automated vehicle location, and mobile data terminals. The integrated system was never fully deployed. The portions of the SGVSS that were deployed are evaluated, with special emphasis on one public transit operator. We conducted an institutional analysis of the FOT; institutional issues largely explain project outcomes.

UCB-ITS-PRR-2002-5  
February 2002, 130 pp., \$20

## **Transit applications**

### **Public and Private Benefits in Intelligent Transportation Systems/Commercial Vehicle Operations: Electronic Clearance and Supply Chain Management**

*David Gillen, Matt Haynes*  
Describes how ITS applications are classified in the area of commercial vehicle operations. Electronic clearance applications are then presented as a type of case study. This is followed by a look at supply chain management, its development, definitions, and potential applications to public sector operations.

UCB-ITS-PRR-2002-18  
April 2002, 16 pp., \$5

### **Intertechnology Effects in Intelligent Transportation Systems**

*David M. Levinson, Seshasai Kanchi, David Gillen*

Analyzes simulated results of a stylized network in a microscopic traffic simulator. The traffic network includes parallel roadways, ramp meters, Freeway Service Patrol, and changeable message signs. We have tested these technologies in various combinations. We measured effectiveness and defined a measure of inter-technology economies. In brief, it is found that additional technologies are sub-additive, and more benefits come from each technology in isolation than when it is bundled with other technologies.

UCB-ITS-PRR-2002-19  
April 2002, 15 pp., \$5

## **Institutional and societal issues**

### **Lessons in Network Management: Cross-Industry Comparisons, and Implications for ITS Development**

*Thomas A. Horan, William Reany*

This report provides an historical and case study analysis of policies aimed toward the management of complex systems, with specific reference to the role of public policy and technology in balancing surface transportation system demand and supply. Three case studies form the crux of the paper: energy management, airport management, and Internet growth. Lessons from these case studies are then applied to the circumstance of ITS deployment to manage surface transportation in California.

UCB-ITS-PRR-2002-4  
February 2002, 135 pp., \$20

### **Investigating Institutional Aspects of Multi-Agency Transit Operations—Review of the Literature**

*Amy Lam, Mark A. Miller*

Presents findings from a literature review that examined the motivation for fundamental change in transit operations, the need to enhance coordination among transit agencies, significant institutional barriers to coordination, and the role of various stakeholders in facilitating (or inhibiting) interagency coordination among transit operators. It also discussed the role that Intelligent Transportation Systems (ITS) play in bridging these gaps and resolving the issues across different transit operational systems.

UCB-ITS-PWP-2002-3  
May 2002, 66 pp., \$15

### **Summary of Selected, Significant ITS and ITS-related Policies and Programs in Europe and the US (with Japan Supplement): ITS from Research to Deployment: Global Thinking and Local Action—A Case Study Analysis**

*Pat Conroy, Jean-Luc Ygnace*

Results from a comprehensive internet/literature search on the status of ITS programs in Europe and the US, and responses from interviews with principals involved in ITS deployment at both the policy and project levels, and both the public and private sector, were analyzed to identify critical institutional and organizational factors for successful deployment and operation of ITS systems and services.

UCB-ITS-PWP-2002-8  
August 2002, 55 pp., \$10



# PATH Bibliographic Database

The California PATH Bibliographic Database provides access to the largest and most comprehensive collection of bibliographic information on Intelligent Transportation Systems (ITS). The Database is accessible on the Internet through a partnership established between the California PATH Program and the Transportation Research Board.

The Database, created in 1989, is sponsored by the California Department of Transportation (Caltrans) and the U.S. Federal Highway Administration. It is maintained by the Harmer E. Davis Transportation Library (HEDTL) at the Institute of Transportation Studies, University of California at Berkeley. The web site is administered by the Transportation Research Board and updated monthly.

## SCOPE AND COVERAGE

The Database contains references to all aspects of Intelligent Transportation Systems, ranging from historical materials dating back to the 1940s to topics of current and international research and applications. It reflects a wide coverage of information on ITS, including monographs, journal articles, conference papers, technical reports, theses, web sites, and selected media coverage. Currently there are over 26,500 records with abstracts contained in the Database. Full bibliographic information is provided, and URLs are included for documents that are available full-text in electronic format.

## ACCESS AND AVAILABILITY

To access the California PATH Bibliographic Database, go to:

**<http://www4.nationalacademies.org/trb/tris.nsf/web/path>**

To access a list of new records that have been added to the Database in the previous month, go to the "Recent Additions in Intelligent Transportation Systems Added to the PATH Database" web site at:

**<http://www.lib.berkeley.edu/ITSL/newpath.html>**

To access the Harmer E. Davis Transportation Library web site, go to:

**<http://www.lib.berkeley.edu/ITSL/>**

While the majority of the indexed items in the Database are held at the HEDTL, some items are references from off-site sources. The availability statement in each citation gives information on actual holdings. Loans and photocopies of materials are available to persons affiliated with the University of California and California PATH affiliates. For others, further information is available at the HEDTL web site. Questions regarding the Database may be directed to:

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