

# CALIFORNIA PATH PROGRAM

*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, and private industry.*

## ANNUAL REPORT



Partners for Advanced Transit and Highways



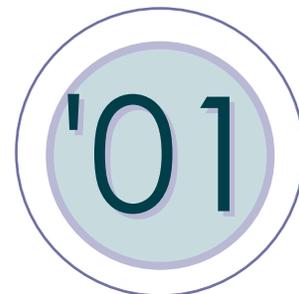
# '01

# CALIFORNIA PATH PROGRAM

Partners for Advanced Transit and Highways

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## ANNUAL REPORT



# Director's Introduction

**KARL HEDRICK** 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. In the coming decade, the population of California is expected to increase by 18 percent (6 million) with a corresponding 27 percent increase in vehicle miles of travel. In order to accommodate this increasing population and demand for mobility, California's transportation system (both private and public modes) will need to operate at optimum efficiency, using advanced information technologies in traditional formats and in creative applications that will change the face of transportation.



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.

Caltrans and PATH share a vision of congestion relief through highway automation. PATH's demonstration of an eight-car fully automated platoon was the highlight of the most successful demonstration of vehicle automation technology ever held: Demo '97. PATH has since participated 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 planning for a major demonstration in August of 2003 that will showcase automation technology for heavy trucks and buses.

PATH's research activities in the area of Advanced Transportation Management and Information Systems (ATMIS) have greatly expanded in the last few years. The development of advanced traveler information systems and innovative bundles of technology will enable travelers to take a proactive role in their mobility choices each day. An exciting new Center for Commercialization of ITS Technologies (CCIT) opened in 2001 near the Berkeley campus. CCIT is teaming up University faculty and graduate students, private sector companies, and government transportation agencies in a new facility with the mission of facilitating the commercial deployment of intelligent transportation system technologies.

PATH brings together engineers and economists, geographers and urban planners, computer scientists and statisticians—and many more. 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. 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, Director, PATH

A handwritten signature in black ink that reads "Karl Hedrick".

# A Word from Caltrans

Caltrans and the California PATH Program continue to work together to create a transportation system that is both safe and efficient. We have taken the national lead in performing research to discover new methods for improving traveler safety, reducing traffic congestion, enhancing the mobility of people and goods, and promoting the transportation system's economic productivity. PATH research continues to focus on areas of particular concern in California. PATH is an important element of the national program to develop, evaluate and facilitate the deployment of Intelligent Transportation Systems (ITS), and as such receives federal funding and industry support in addition to its primary funding from the state of California. Caltrans and PATH are devoted to utilizing all possible resources to improve the safety and efficiency of our California surface transportation system.

GREG LARSON



Despite our past successes, we know that further challenges remain ahead of us if we are to achieve our goals. To this end, the Division of Research and Innovation (DRI), formerly the Division of New Technology and Research, has recently made some structural changes by reorganizing. One of the most significant changes in philosophy is our commitment to conduct customer-focused research and to perform activities that help to meet departmental goals. In addition, in order to achieve the best research results across all universities, we are now identifying PATH as the focal point for all Caltrans-sponsored university ITS research.

Caltrans and PATH continue to prepare for Demo 2003, a demonstration and conference showcasing the benefits of transit bus and heavy truck automation. The vehicle testing for this demonstration in San Diego is now underway. This event will be a big step toward widespread deployment of Advanced Vehicle Control and Safety Systems that support all vehicle types. 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 showcase recent technological developments to possible early adopters of vehicle automation. Some potential benefits of the technology include better delivery time and reduced fuel consumption, traffic congestion relief, enhanced quality of service, and safer vehicle travel.

Together, Caltrans and PATH are working to encourage the use of public transportation. We continue to research innovative ways of enhancing the public transportation experience. From our advanced carsharing projects, such as CarLink I and II, to our Smart Parking project investigating the use of technology to provide valuable "space available" information to drivers entering public parking facilities, we are pushing the frontiers of ITS. Our goal is to make it easier to choose public transportation over single-occupancy vehicles for all or part of our daily commute.

On behalf of the Division of Research and Innovation, I congratulate PATH on its considerable accomplishments during another successful year. I hope that next year will continue to be a period of intellectual accomplishments and important contributions to transportation productivity in California, the nation, and the world.

Greg Larson, Caltrans Management Liaison

A handwritten signature in black ink that reads "Greg A. Larson".



# California PATH Program

**OVERVIEW** 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. But PATH also addresses 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 a transit bus Forward Collision Warning System, with the San Mateo County Transit District (SamTrans), Caltrans, and bus manufacturer Gillig.
- Transit bus Rear Collision Warning System requirements definition, with Ann Arbor Transit Authority and ERIM International.
- Development of threat assessment simulation software for Automotive Collision Avoidance System (ACAS) field operational test with General Motors and Delphi Automotive Systems.

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. In 2000, the group developed a business plan that, among other items, identified areas of common research interest. Subsequently, PATH and the Texas Transportation Institute (Texas A&M University) have launched a joint investigation of the state of the practice in three areas: transportation



systems performance measurement and data collection technology needs, data sharing policies and practices, and highway maintenance management systems. 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. Within the IVI Infrastructure Consortium, Caltrans and PATH have teamed with counterparts in Minnesota and Virginia to develop a cooperative intersection decision support system. Separately, as an outgrowth of the Phoenix Project, 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) project, which we hope will revive national interest in automated highways.

### 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 ninety-five 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 forty professors, representing fifteen academic departments on fourteen different university campuses, supervising the research of more than one hundred 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.



### New projects

PATH attracted research support from a variety of sources during the past year. Some of the new 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's Center for Commercialization of ITS Technologies (CCIT) moved into its new office space on Bancroft Way in downtown Berkeley.
- PATH completed its first Strategic Plan, under the guidance of a statewide university steering committee, and a Research Roadmap identifying research issues to pursue during the coming decade.
- The Carlink II project received the President's Award for Intermodal Transportation from the American Association of State Highway and Transportation Officials (AASHTO).
- PATH took delivery of three Freightliner Century Class trucks, which its experimental staff is now equipping for automated driving for Demo 2003.
- A technical paper describing the NAHSC platoon demonstration system by current and former PATH researchers Rajesh Rajamani, Han-Shue Tan, Boon Kait Law, and Wei-Bin Zhang was awarded the 2001 Outstanding Paper Award for the IEEE Transactions on Control System Technology.
- Caltrans was sufficiently impressed with the progress on PATH's Performance Measurement System (PeMS) that it decided to advance it from development to statewide deployment.
- PATH/CCIT were named to the Traveler Information Partnership Advisory Committee, a new industry/academia advisory committee formed by Caltrans under recommendation from the legislature. It held its first meeting at CCIT.



## RESEARCH:

# Transportation Management and Information Systems

## Advanced Traffic Management

### Access Control Strategies to Manage Traffic Backups and Increase System Capacity

Carlos Daganzo, UC Berkeley  
TO 4115

We are developing a theory of access control for systems where route choice effects can be ignored, but including internal queues on freeways and the resulting storage benefits. Our goal is to extend previous PATH work by developing traffic management models that recognize explicitly the ability of freeways to store vehicles, and to do this by only using the simplest ideas that have passed empirical tests.  
UCB-ITS-PRR-2002-3

### Pooled Fund Study - Continuation of MORIP

Joy Dahlgren, Robert Tam, PATH  
TO 4124

This is a pooled fund project to study 1) transportation performance measurements, 2) data sharing with the private industry and 3)

ITS hardware maintenance management. A four state (CA, MN, TX, WA) working group has been established to share ideas and experiences in the field of intelligent transportation systems. This project will develop white papers to identify best practices and investigate new practices to implement.

UCB-ITS-PRR-2001-16

UCB-ITS-PRR-2001-23

UCB-ITS-PRR-2001-24

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

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

In this project we are designing, validating and implementing a new coordinated, traffic-responsive ramp metering strategy. The two main objectives of our approach are to (1) maintain traffic flow at freeflow speeds and (2) determine ramp metering policies that are perceived as fair by all users.

### Study of Traffic Dynamics and Management Strategies Using Berkeley Highway Lab Data

Joy Dahlgren, PATH  
TO 4141

A wide array of technologies is now available to manage traffic. However, the intelligence to manage the traffic is lagging behind. This is largely because of the dearth of empirical data with which to develop and test traffic theory and management strategies. The Berkeley Highway Lab is now providing such data. The area for which data are available includes a bridge approach, parallel frontage roads, HOV lanes, and four sets of onramps and offramps. We are using these data to study basic traffic dynamics, to develop and test the effects of traffic management strategies, and to evaluate traffic simulation models.



## Advanced Transportation Information

### Freeway Performance Measurement System Versions 3 and 4

Pravin Varaiya, UC Berkeley  
TO 4123, TO 4127, TO 4301

PeMS is a freeway performance measurement system for all of California that extracts information from real-time and historical data. It processes 2 GB/day of 30-second loop detector data in real time to produce useful information. Managers at any time can have a uniform, and comprehensive assessment of freeway performance. Traffic engineers can base their operational decisions on knowledge of the current state of the freeway network. Planners can determine whether congestion bottlenecks can be alleviated by improving operations or by minor capital improvements. Travelers can obtain the current shortest route and travel time estimates. Researchers can validate their theory and calibrate simulation models.

UCB-ITS-PWP-2001-1  
UCB-ITS-PWP-2001-17  
UCB-ITS-PWP-2001-41

## ITS Traffic Data Collection

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

Pravin Varaiya, UC Berkeley; Ben Coifman, Ohio State University  
TO 4107

The goals of this project include:

- maintain the high resolution loop detector surveillance and communication of the Berkeley Highway Lab,
- make the vehicle reidentification system compatible with the Caltrans open architecture ATMS software and bring the data into the Caltrans District 4 system,

- evaluate the costs and benefits of vehicle reidentification from an operational perspective, and
- develop a path to large scale deployment.

### Development and Testing of Field Deployable Real-Time Laser-Based Non-Intrusive Detection System for Measuring of True Travel Time on the Highway

Harry Cheng, UC Davis  
TO 4116

We have developed and tested a complete field deployable laser-based detection system that is capable of non-intrusively detecting high-resolution, site-independent delineations of vehicles for measurement of true travel time on the highway in real time. The detection system is reliable, easy to maintain and low-cost.

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

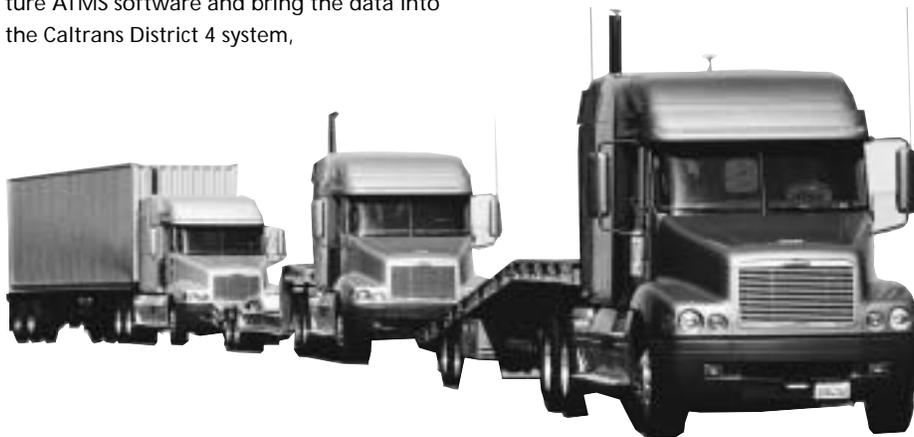
Michael McNally, UC Irvine  
TO 4120

The research seeks to gain better understanding of route choice behavior as part of individual travel patterns. The project is a full study of travel time patterns, which are collected using a travel survey, augmented with GPS data.

### Field Investigation of Advanced Vehicle Reidentification Techniques and Detector Technologies - Phase 2

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

Uses the latest technologies available for traffic detection to collect more accurate traffic



characteristics and traffic data necessary for ITS applications. The project consists of three components. The first is a field investigation of several emerging and advanced freeway detector technologies developed by PATH, including a laser, video, and a new loop detector. The second involves the utilization of the reidentification system at a major signalized intersection for real-time level of service estimation. The third component involves an investigation of the fusion of the data derived from the various advanced detection systems that have been developed by PATH for the purpose of vehicle reidentification.

### **Berkeley Highway Lab**

**Robert Tam, PATH**

**TO 4129**

This project established an array of cameras and associated video recording and communication systems on the roof of the Pacific Park Plaza building in Emeryville adjacent to I-80. The system has been accumulating a library of video tapes of I-80 traffic to be used in developing a machine vision system for tracking vehicle trajectories, enabling incident detection, travel time measurement, and volume measurement. The video also provides a means for systematic study of car following, queueing behavior, HOV lane operations, and many other aspects of traffic dynamics. It can also provide ground truth for testing various types of traffic data collection methods on I-80.

### **Loop Detector Data Collection and Travel Time Measurement in the Berkeley Highway Laboratory**

**Adolf May, UC Berkeley; Ben Coifman, Ohio State University**

**TO 4134**

The Berkeley Highway Laboratory covers 2.7 miles of Interstate 80 immediately east of the San Francisco-Oakland Bay Bridge. The facility includes five lanes in each direction, 14 surveillance cameras and 16 dual loop detector stations dedicated to assist researchers in advancing the state of the art for traffic surveillance, traffic management, and traffic flow theory. This unique resource provides high-resolution data that are not available anywhere else. This project seeks to maintain and improve the loop detector surveillance system and provide a valuable resource for the entire PATH program.

### **Technologies for Vehicle as Probes**

**Y. B. Youngbin Yim, PATH**

**TO 4139**

Travel time estimates are based largely on road sensors embedded in the pavement, but the data from sensors are not always reliable. This study investigated qualitative methods of estimating travel times using cellular and GPS technologies. The study shows that GPS and cellular positioning techniques can be used for obtaining relatively accurate travel time estimates.

### **Traffic Simulation**

#### **Enhancements of ATMIS Using Artificial Intelligence**

**Henry Liu, ATMS Testbed, UC Irvine**

**TO 4100**

Traffic management decisions frequently depend on qualitative assessments of network conditions. These high-level state variables can be used to determine what general strategies are most appropriate for improving the current system status. Accurate traffic condition assessment is vital to our understanding of how to provide information and control that leads to real-time, system-wide, traffic management. This project addresses methods of predicting flow patterns in real time, and adapting ramp metering and signal control strategies to meet these flows.

UCB-ITS-PWP-2001-16



## Bay Area Simulation and Ramp Metering Study

Joy W. Dahlgren, Yonnel Gardes, PATH TO 4106

The goal is to develop a simulation capability to be used in:

- analyzing the effects of new traffic management strategies,
- analyzing the effects of applying existing strategies in specific situations,
- developing and testing traffic theory.

The project focuses on the investigation of a portion of the southbound morning peak I-680 freeway facility, between I-580 in Pleasanton and SR 237 in San Jose. The project provides an opportunity for testing the Paramics model capabilities to replicate freeway traffic conditions, and assess to what extent the existing model can simulate various operational strategies such as HOV lanes and ramp metering.

UCB-ITS-PWP-2002-6

## Implementations to The Demand Estimation and Subsection Analysis of the Microscopic Traffic Simulator - Paramics

Reinaldo Garcia, ATMS Testbed, UC Irvine TO 4121

Paramics is an excellent "shell" or "framework" for a comprehensive and extensive transportation simulation laboratory. Paramics offers important features, such as high performance and scalability, to handle realistic real world traffic networks under ITS. Nevertheless, Paramics has its own limitations, particularly relating to the model's ability to interface with dynamic routing protocols, dynamic O-D estimation. This work addresses the continuing effort to expand the Paramics capabilities, making it a more complete tool to evaluate the expected net benefits of ATMS applications.

UCB-ITS-PWP-2002-4

## Dynamic OD Demand Estimation and Subsection Analysis of the Microscopic Traffic Simulator - Paramics

Reinaldo Garcia, ATMS Testbed, UC Irvine TO 4130

This project expands Paramics' capabilities, making it a more complete tool to evaluate the expected net benefits of ATMS (Advanced Traffic Management Systems) applications. A

set of improvements to Paramics' protocols has been identified that will enhance its Advanced Traffic Management and Information Systems applications. This work contributes to the improvements of the Paramics microscopic simulator, mainly to its demand estimation tool.

## Large Scale Traffic Simulation Through Parallel Computing

Henry Liu, ATMS Testbed, UC Irvine TO 4142

Develops a software system, using CORBA middleware, to allow Paramics users to distribute computation load demanded by large-scale microscopic traffic simulation over a number of homogeneous processors. The parallel environment for Paramics could be either a multi-processor machine, with shared memory or networked workstations connected by Ethernet.

## Real-time Traffic Information Estimation Through On-line Simulation and Hybrid Data Fusion System for ATMS Applications

Lianyu Chu, ATMS Testbed, UC Irvine TO 4143

This study focused on using simulation models, i.e. Paramics, as a real-time traffic information source. The method enables Paramics to simulate real-time traffic directly, using real-time loop data, instead of using dynamic OD estimation and prediction through the use of a loop-data actuated dynamic vehicle releasing API to replace the OD matrix. Also, this project will focus on the data fusion of link travel time data.

## Advanced Traffic Theory

### Identifying Density-Flow Relations on Arterial Streets

Mike Cassidy, UC Berkeley TO 4109

This research will extract and analyze empirical data to determine the precise shapes of density-flow relations for describing traffic along signalized arterial surface streets; possible forms for these range from piece-wise linear to non-linear, parabolic-like curves. Determining the correct forms is vital for modeling traffic signal control strategies.



### Considering Risk-Taking Behavior In Travel Time Reliability

Will Recker, UC Irvine

TO 4110

This research incorporates risk-taking, route choice behavior when estimating travel time reliability of a road network. This approach will allow the evaluation of network performance under uncertainty. It is particularly useful for the traffic information systems in which travel time is provided to the users for decision-making.

### Validation of Daganzo's Behavioral Theory Of Multi-Lane Traffic Flow

James Banks, San Diego State University

TO 4113

The research will validate Daganzo's behavioral theory by testing a set of predictions based on it. The major contribution will be a better understanding of freeway traffic flow and providing the basis for a very simple macroscopic model of freeway flow to design metering and other control measures.

UCB-ITS-PWP-2002-1

### Development of Tools to Assess the Effects on Traffic Safety of Changes in Traffic Flows under ATMS Operations

Tom Golob, UC Irvine

TO 4117

Our goals are to quantify the relationships between the characteristics of freeway traffic flow and the likelihood of crashes per vehicle mile. We also use these relationships to

assess safety benefits that are likely to be realized under specific ATMS implementations.

### Development of a Path Flow Estimator for Deriving Steady-State and Time-Dependent Origin-Destination Trip Tables

Will Recker, UC Irvine

TO 4135

The path flow estimator software tool (PFE) is a one-stage network observer that estimates path flows (hence O-D flows) and path travel times from traffic counts in transportation networks. The PFE can be implemented for both off-line transportation planning applications and on-line traffic management applications. The goal is to adapt the PFE that best meets Caltrans' needs and to further develop it to improve the reliability and efficiency of the O-D estimates.

## ITS Transit Applications

### Carlink II Pilot Deployment

Susan Shaheen, PATH

TO 4104

PATH and Caltrans funded the initial twelve-vehicle field test at Lawrence Livermore National Laboratory (LLNL) and the Bay Area Rapid Transit (BART) District (known as CarLink I). This new project deploys an expanded pilot program at a new commercial employment center. It also provides user and benefit assessments (e.g., willingness to pay) of the expanded CarLink system and new carsharing centers. It focuses on demonstrating economic viability, and explores the relative roles of public agencies and private enterprises in the deployment of carsharing systems.

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

Maged Dessouky, University of Southern California

TO 4114

A study of the obstacles and impediments to implementing ITS technologies for personalized public transit and demand-responsive system such as shared ride taxi service and paratransit. A review of past experiences of service providers will help in the evaluation of the costs and effectiveness of adapting existing ITS technologies to personalized pub-



lic transit systems. The intent is to identify cost-effective strategies.

## **Improved Grade Crossing Safety with In-Pavement Warning Lights**

Theodore Cohn, UC Berkeley  
TO 4138

Too many rail crossing collisions occur when drivers cross in front of oncoming trains, despite the activation of flashing signals. The project explores presently available in-pavement lights (IPL) that are intended for use at ungated rail crossings. The idea is that such lights, arranged to lie across the road at the crossing, can act as a visual barrier encouraging drivers to stop and not cross over the rails. Project aims are twofold: first, we plan to study commercial off-the-shelf versions to see if warning signal technologies that we have been working on have the ability to improve IPL visibility and the speed with which they are seen. Second, we plan to deploy these at a test crossing in California in order to see if they measurably improve driver behavior.

## **Personalized Demand-Responsive Transit Service**

Y. B. Youngbin Yim, PATH  
TO 4102

Our goal is to deploy a DRT system based on consumer needs and desires. In most cases, the existing DRT service is designed from the operator's perspective without a full understanding of what types of services would attract consumers. This study continues the personalized DRT system beyond the broad assessment of the DRT needs. We conducted a joint study to attain a deeper understanding of consumer attitudes toward DRT and trade-offs that consumers are willing to make between DRT and solo driving.

## **Benchmarking Best Practices of Demand-Responsive Transit**

Maged Dessouky, University of Southern California  
TO 4108

The objective of this research is to build on prior work and conduct a comprehensive international and national study to quantify the impact of APTS technologies and management practices upon the operating cost, productivity, and effectiveness of on-demand paratransit systems.

## **High Coverage Demand-Responsive Transit: A New Design Concept and Simulation-Evaluation of Operational Schemes for Future Technological Deployment**

R. Jayakrishnan, UC Irvine  
TO 4111

This research is developing and evaluating a new concept for implementable high-coverage demand-responsive transit systems, which relies on real-time communication and computing technologies, and advanced routing algorithms for efficient operation. The research relies on the premise that the failure of earlier demand-responsive transit systems stemmed from low passenger demands caused by excessive waiting time for patrons, poor coverage of the networks by demand-responsive vehicles, and poor computational algorithms and routing capabilities.

## **System Integration**

### **Commercialization of Intelligent Transportation Systems Technologies**

Hamed Benouar, PATH, CCIT  
TO 4126

Founded in 2001 by the University of California and the California Department of Transportation, CCIT's goal is to facilitate the commercial deployment of advanced transportation products and services to improve traveler safety, comfort and convenience. CCIT is structured to optimize private sector participation in the future of California's vast transportation network. It specializes in traveler information, transportation management, and vehicle information and control. CCIT provides support to the following projects: the Berkeley Highway Lab, Border Crossing ITS Technology Demonstration, CarLink II and the Freeway Performance Measurement System (PeMS), and CommerceNET's next generation Internet (NGI).

### **Scope and Evaluate Transportation, Land Use, and Housing Plans for UC Davis and the City of Davis as part of a Broader Innovative Davis Model for New Mobility Services Project**

Susan Shaheen, PATH  
TO 4128

The City of Davis, surrounding communities, and the UC Davis campus are struggling with

many of the same transportation problems that plague larger urban centers. These include increasing traffic, limited parking, and challenges to effective operation of the public transit system. The campus is expecting to grow by 6,000 students in the next ten years (plus approximately 3,000 faculty and staff) and is developing a Long Range Development Plan (LRDP) that will serve to guide this growth. This plan will include housing, traffic control, parking, alternative transportation modes, and interactions with the broader community.

UCB-ITS-PWP-2001-18

#### **Assistance to Caltrans for Assessment of Communication Needs and Solutions**

**C. Arthur MacCarley, California Polytechnic University, San Luis Obispo**

TO 4133

This project focuses on researching data communications needs and potential solutions, especially those associated with surveillance technologies for Caltrans operations. Needs focus on increasing bandwidth and number of connections between traffic management facilities and field elements, including vehicle detectors, changeable message signs, and video surveillance units. Improving data communications between districts is another goal.

#### **Benefit/Cost Evaluation**

##### **ITS Decision Website**

**Joy Dahlgren, PATH**

TO 4101

This project maintains the ITS Decision website, continually updating the website with new projects and publications. New ITS user services have been added, which are identified in the ITS architecture. The benefit/cost framework was added to the website, with links to other benefit/cost websites.

<http://www.path.berkeley.edu/itsdecision>

##### **Evaluation Methods For Measuring the Value of ITS Services and Benefits from Implementation**

**David Gillen, UC Berkeley**

TO 4119

This project examines the expected benefits and costs of different ITS applications that focus on traffic operations. The purpose is to provide Caltrans with a measure of the expected net benefits with the application ITS projects to the California highway system.

UCB-ITS-PRR-2002-16, 17, 18, 19

##### **Assessing the Value of TMCs and Methods to Evaluate the Long Term Effects of ITS Implementation**

**David Gillen, UC Berkeley**

TO 4132

This project assesses the gains from synergies across the joint application of ITS projects, and examines the effects of ITS investments on the broad economy through their impact on changing systems, markets and networks. First, we examine three to four cases in which ITS deployment has been undertaken, with an eye to identifying the positive and negative pressures that determine success. Second, we examine the integrative aspects of ITS in the form of TMCs, which represent an integration of a number of ITS applications including ramp meters, variable message signs, traffic information systems, traffic signal coordination and highway helper programs (Freeway Service Patrols). Third, we estimate models with empirical data of TMC installations in California and the length of time the TMC has been operational.



**A Tool for the Incorporation of Non-Recurrent Congestion Costs of Freeway Accidents in Performance Measurements**

Tom Golob, UC Irvine  
TO 4137

What is the total non-recurrent congestion (both directions) resulting from a (certain type of) accident on (a certain type of) freeway link at (a certain time of day) on a (certain day of the week)? We address this question by augmenting the existing fused accident and traffic flow database with loop detector data for periods long enough following each accident to calculate the non-recurrent delay due to it.

**ITS Decision Enhancements: Developing Case-Based Reasoning and Expert Systems and Incorporating New Material**

Joy W. Dahlgren, PATH  
TO 4140

This project keeps the ITS Decision website current, as new information becomes available. We will also add two new tools to facilitate the deployment of Intelligent Transportation Systems (ITS): a rule-based expert system and a case-based reasoning tool to enhance the experiences of users of the site. The tools essentially customize information about ITS technologies and their impacts (generally and in specific cases) to the needs of technology implementers and suppliers. They facilitate the consideration and evaluation of ITS technologies, and therefore serve as a catalyst for the commercialization of ITS technologies.

**Institutional and Societal Issues**

**Institutional Aspects Of Multi-Agency Transit Operations**

Mark A. Miller, PATH  
TO 4105

In this project, the goals are to identify and investigate the institutional aspects of multi-organizational transit operations in the US, develop a generic model or set of models for California, and understand the role that intelligent transportation systems can play in this environment.

UCB-ITS-PWP-2002-3

**Commercial Vehicle Operations**

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

Amelia Regan, UC Irvine  
TO 4112

This research addresses the following questions: (1) What is the state of the art in ATIS aimed at Commercial Vehicle Operators? (2)What is the perceived usefulness of these services? (3)Who is providing these services? The research plan involves information gathering, interviews, surveys, and analysis.

**ATIS for Ground to Air Connectivity**

Randolph Hall, University of Southern California  
TO 4118

A collaborative effort with UPS and Caltrans to evaluate information services targeted at assisting overnight carriers in routing their trucks, scheduling their shipments and optimizing their departure times.

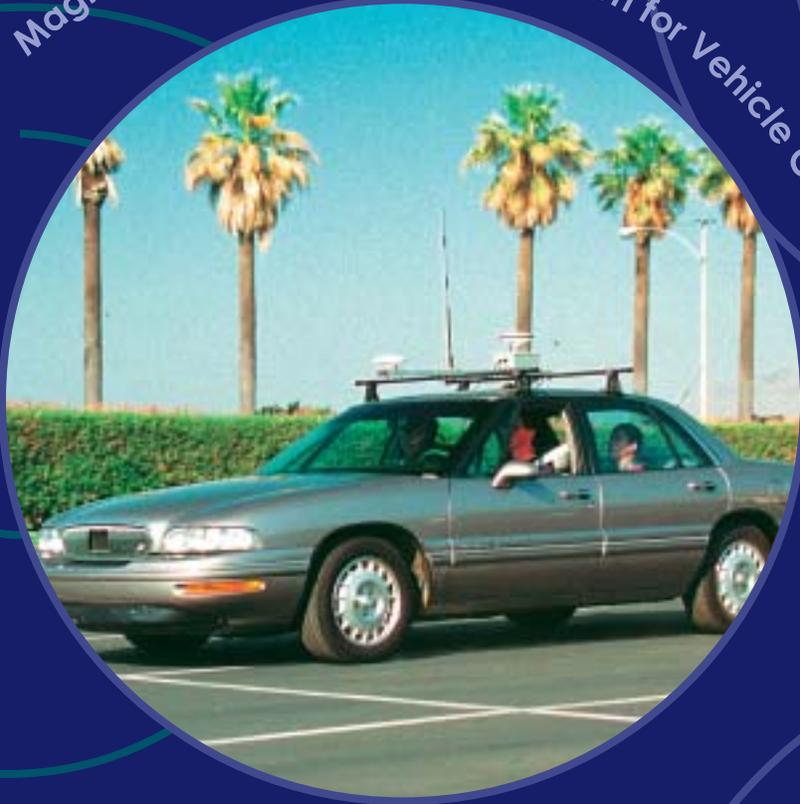
**Border Crossing ITS Technology Demonstration**

Hamed Benouar, Tony Brennan, CCIT, PATH  
TO 4300

This project's objective is to deploy and evaluate the application of proven ITS technologies to efficient movement of trade through the international border, specifically the commercial vehicle border crossing at Otay Mesa, California. The Technology Demonstration 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.



Magnetic and GPS-Aided  
Inertial Navigation for Vehicle Guidance



# Advanced Vehicle Control and Safety Systems

## Automation Concept Development and Evaluation

### The AHS/Street Interface Effects of Capacity Concentrations on System Performance

Randolph Hall, University of Southern  
California

TO 4216

The objective is to determine how the interface between an AHS and the arterial street network could be designed to accommodate the high volume of AHS traffic, and evaluate ways to maximize the benefits that accrue from added capacity. The focus is on how to accommodate concentrations of capacity within narrow corridors or a limited number of interchanges, and its implications on the surrounding street system. Strategic modeling will be used to create and compare models for generic scenarios, and evaluate system performance under a range of strategies. Operational modeling will be used to develop policies for controlling flows through, and queues at, interchanges and entry/exit points. Deployment modeling will focus on a few sites, with detailed analysis of requirements for accommodating both exiting and entering traffic.

UCB-ITS-PWP-2000-26

### Development of Integrated Meso/microscale Traffic Simulation Software for Testing Fault Detection and Handling in AHS

Roberto Horowitz, UC Berkeley

TO 4208

This project concludes our research on the analysis and simulation of AHS feasibility by making available a platform for performing exhaustive simulations of a large-scale AHS. This platform provides information for the different degrees of precision (at the micro and macro levels) that are required. It inte-

grates the PATH micro-simulation SmartAHS and 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, as well as the impact of a fault on the overall AHS response and how a fault can be handled at the macro level.

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

H.-S. Jacob Tsao and Jan Botha, San José  
State University

TO 4218

Develops and evaluates operating concepts for a fully automated bus-truck AHS as well as intermediate steps facilitating its deployment. This project builds on information from many years of PATH research as well as from information on truck and bus automation



around the world (e.g. the CHAUFFEUR project). This project also identifies some benefit-cost elements for more detailed benefit-cost comparisons between urban bus-AHS and its conventional public-transit alternatives, and between inter-city truck-AHS and its conventional freight-transportation alternatives.

#### **Evaluation of Truck and Bus Automation Scenarios**

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

Benefit-cost comparisons between urban bus-AHS and its conventional public-transit alternatives, and between intercity truck-AHS and its conventional freight-transportation alternatives, are needed for Demo 2003. The conventional public-transit alternatives include light-rail systems and busway systems. The project compares some aspects of the implementation of a bus-AHS to their counterparts of an existing light-rail system in California. A bus-AHS will also be compared to a conventional busway with respect to similar aspects. The conventional freight-transportation alternatives include addition of a conventional lane, addition of a truck lane and addition of an exclusive AHS truck lane and intermodal rail. Focus is on major cost and benefit elements that differ significantly among the alternatives.

#### **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 yet been developed primarily due to lack of appropriate second-by-second emissions data. So, under a current project sponsored by the US EPA, an emission trailer is being developed at UC Riverside CE-CERT that can be attached to a number of heavy-duty rigs to measure instantaneous emissions (including particulates) in situ. Using the emissions data, a heavy-duty diesel modal emissions/energy model will be developed and verified. The model will be integrated with PATH's SmartAHS to evaluate numerous automation scenarios that involve passenger cars, buses, and heavy-duty trucks. The model will be combined with control simulation tools to evaluate ITS scenarios such as adaptive cruise control.

#### **Collision Warning and Avoidance Systems**

##### **Automotive Collision Avoidance System (ACAS) Threat Assessment Simulator**

**Jim Misener, Steven Shladover, PATH**  
Sponsor: NHTSA/General Motors

PATH has developed a threat-assessment simulation system to be used by researchers at General Motors and Delphi Automotive to support their development of the ACAS warning algorithms. This software is built on the foundation of existing SHIFT and SmartAHS simulation software, but includes implementation of a variety of new modules to represent alternative sensor characteristics and hazard environments, together with graphical animation and integration of sensor data with video imagery of the driving scene.

##### **Transit Bus Forward Collision Warning System: Requirements Definition**

**Wei-Bin Zhang, Xiqin Wang, 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.

## **Transit Bus Rear Collision Warning System**

T. Cohn, UC Berkeley

**Sponsor: Federal Transit Administration**

Professor Theodore Cohn is supporting the development of a rear collision warning system for transit buses under the IVI program by testing the effectiveness of alternative configurations of warning lights intended to be mounted to the back of a bus belonging to the Ann Arbor Transit Authority.

## **Railroad Grade Crossing Safety**

T. Cohn, UC Berkeley, Jim Misener, PATH

**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.

## **Vehicle Control System Design and Development**

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

Jason Speyer, UCLA

TO 4209

The purpose of the project is to perform experimental implementation and verification of the fault detection and identification (FDI) algorithms, and data fusion approaches (fault detection filter and residual processing) developed under previous PATH projects. A robust fault monitoring system is

implemented to monitor failures in any actuator or sensor for a single vehicle in both longitudinal and lateral modes. Residual processes are evaluated to determine the probabilities of false and missed alarms for the fault monitoring system. The fault monitoring system is simulated, tested and fine-tuned in the presence of sensor noise and process noise such as road slopes and wind gusts. The monitoring system is evaluated using empirical vehicle data recorded at PATH's Crow's Landing facility.

## **Use of Combined Physical and Situational Models for Data Fusion in ACC Systems**

Karl Hedrick, UC Berkeley

**Sponsor: BMW**

Adaptive Cruise Control (ACC) systems need to be able to adjust their performance to address a wide variety of traffic conditions, especially if they are to be usable in stop-and-go traffic. In this project we explore how to use the data already available from the forward-looking radar of the ACC system, combined with vehicle inertial sensors, GPS and a map database, to characterize the driving environment, as well as to diagnose sensor faults. Following analysis and simulation stages, the proposed data fusion approach is to be tested on an ACC vehicle provided by the sponsor.

## **Vehicle Control Experimental Research and Support**

Dan Empey, PATH

TO 4227

AVCSS work at PATH requires experimental vehicles to support the research, development, testing and validation of the control systems. The Vehicle Control Experimental Group consists of specialists in control systems, communications, electronics, software development and implementation, as well as hardware development, integration and maintenance. This project covers support of heavy truck projects, fault-tolerant controls for buses and trucks, compression braking control, truck emissions and fuel consumption, integration of vehicle control and communication, integration of GPS/INS and magnets for vehicle control, adaptive cruise control experiments, communication systems, testing of fault detection algorithms, fault diagnosis

for vehicle control, and evaluation of longitudinal range and range rate sensors.

#### Mobile Offshore Base (MOB)

Karl Hedrick, William Webster, UC Berkeley

Sponsor: Office of Naval Research

Using cooperative vehicle control technology, integrating communications and hybrid control, develop, test and demonstrate a control system for "dynamic positioning" of semi-submersible vehicles. This project for the Office of Naval Research has led to a scale-model test, in the towing tank at UC Berkeley/RFS, of the MOB vehicles, showing that they can be "platooned" accurately enough to produce a virtual runway at sea for the landing of large transport aircraft.



#### Development of the Advanced Rotary Plow for Snow Removal Operations

Han-Shue Tan, PATH

Sponsor: AHMCT Program

A large rotary snow blower is being equipped with the PATH magnetic guidance sensing system and a steering actuator so that it can be steered automatically for low-speed operation on California highways, where it is used to clear heavy snow accumulations close to the guard rails. The automatic steering



system is intended to avoid the damage that is currently incurred by guard rails when drivers use them for mechanical guidance in poor visibility conditions.

#### Vehicle Lateral Control Under Fault In Front And/Or Rear Sensors

Masayoshi Tomizuka, UC Berkeley

TO 4204

The project evaluates the performance and robustness, both analytically and experimentally, of the magnetometer-based lateral control system when either the front or rear set of magnetometers fails. The autonomous lateral control (ALC) system, based on measuring the lateral error and yaw error relative to the vehicle in front, is studied and combined with the magnetometer-based lateral control system to enhance safety and reliability.

UCB-ITS-PRR-2000-25

#### Control of Heavy Duty Vehicles

##### Development of Vehicle Automation Systems for Demo 2003

Dan Empey, Ching-Yao Chan, PATH

TO 4228, TO 4229

Caltrans and PATH plan to conduct a large-scale demonstration in August 2003 to showcase innovative Bus Rapid Transit (BRT) and automated freight transport services supported by AHS technologies. The demonstration, an important milestone in the development of vehicle-highway automation technologies, will include two 40-ft and one 60-ft articulated transit buses and three Class 8 trucks, operating in full and semi-automatic modes.

This project involves several development steps: 1) system planning and design, 2) vehicle development, 3) control system development, 4) communication system development, 5) human-machine interface development, 6) software development, 7) maintenance and support, and 8) system integration.

### Fault Tolerant Lateral Control For Transit Buses And Trucks

Masayoshi Tomizuka, UC Berkeley  
TO 4205

Magnetometer fault tolerance can be achieved by modifying existing lateral control lane-keeping algorithms, but the results work well only at lower speeds. In this project, fault-tolerant controllers that guarantee safe vehicle operations at high speeds are developed, simulated and experimentally tested. A control strategy is developed that incorporates considerations of safety, performance and cost, geared towards implementation on transit buses. New lateral controllers are integrated with existing higher-level fault detection and identification algorithms. Yaw-rate sensors, gyroscopes and accelerometers are included to provide fault tolerant capabilities.

### Automated Fault Tolerant Longitudinal Control of Transit Buses

Karl Hedrick, UC Berkeley  
TO 4206

This research, in support of Demo 2003, is focused on three main objectives: vehicle modeling, automated longitudinal control, and fault diagnosis and management. The first objective is the development of a realistic mathematical model of transit buses to provide the first step in understanding the capabilities, limitations and overall performance of transit buses. The second objective is to design an automated longitudinal controller for a platoon of transit buses. The third objective is 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. The combined system will be tested in simulation and experiment.

### Fault Tolerant Autonomous Following Lateral Control for Heavy Vehicles

Masayoshi Tomizuka, UC Berkeley  
TO 4233

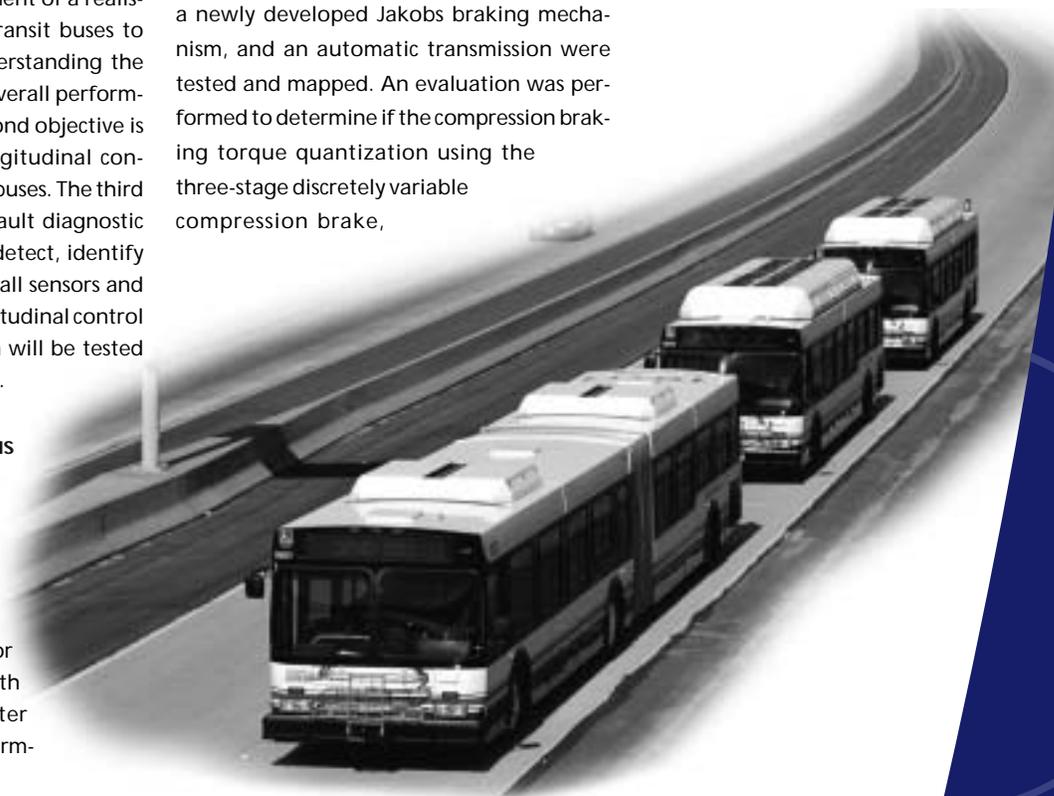
An optical sensing method for lateral control is integrated with PATH's existing magnetometer scheme to improve the perform-

ance, robustness and fault tolerance of current lateral control algorithms. This research covers analysis, simulation, and experimental verification of lateral control algorithms in a platoon of heavy vehicles. Specific objectives are (1) include intervehicle communication, to reduce the propagation of lateral tracking errors, (2) develop controllers to take advantage of the communicated information, (3) investigate fault tolerant control techniques for lateral control with optical sensor and communication faults, (4) integrate an optical system with the existing magnetometer system, to improve tracking performance, and (5) conduct experimental verification of the algorithms.

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

Tsu-Chin Tsao, UCLA; Anna G. Stefanopoulou, University of Michigan  
TO 4234

Addresses experimental verification of the compression braking control schemes developed under MOUs 372 and 393 on existing heavy-duty vehicle hardware. The braking capabilities of PATH's 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 three-stage discretely variable compression brake,



combined with multiple gear ratios, is sufficient for a vehicle following scenario. A rigorous study of heavy-duty vehicle parameter estimation, and its effect on HDV safety, efficiency and driving ability was conducted. It is anticipated that reliable on-line HDV parameter estimation will have an impact on emissions reduction, fuel efficiency and safety enhancement.

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

**Christian Gerdes, Stanford**

TO 4235

This project has two main objectives:

The design and implementation of a robust real-time estimation scheme. This scheme will estimate critical parameters that affect the performance of heavy-duty vehicles (HDVs). The scheme will enable estimation of mass, measurement of grade, estimation of rolling resistance and estimation of aerodynamic drag force.

The second objective is control algorithm development. This will involve the development of integrated regulation and coordination controllers which will be 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.

#### **Coordination Layer Control Design for Automated Trucks and Buses**

**Xiao-Yun Lu, PATH**

TO 4237

Develops higher-level coordination and link layer control strategies needed to govern the maneuvering interactions among vehicles and between vehicles and the roadway infrastructure. Until now, these interactions have been defined in rather general terms in simulations, but have not been implemented experimentally. For example, the automated merge that PATH has demonstrated recently is currently implemented entirely at the regulation layer, but a real implementation would need to involve coordination layer interactions as well. The results will be implemented for buses in a Bus Rapid Transit (BRT) system and automated trucks.

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

**Petros Ioannou, University of Southern California**

TO 4203

Evaluates the environmental performance of existing and developed heavy-duty vehicle-following control systems, and develops modifications or new designs where necessary for environmentally efficient controllers, using an emissions and fuel consumption model for heavy-duty vehicles being developed at UC Riverside with support from PATH and the US EPA. The controllers will not only guarantee good fuel efficiency, but also stability in close vehicle following. Theoretical findings are validated by experiments using actual vehicles. Trade-offs among environmental efficiency, traffic flow stability, capacity, and vehicle stability are identified and quantified.

#### **Traffic Safety**

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

**Karl Hedrick, UC Berkeley**

TO 4210

Performs three tasks to develop three related concepts that exploit the cooperative nature of AHS (vehicles communicating and coordinating with each other and the roadway) to yield safety and capacity gains. The first task uses communication systems to



implement dynamic position tracking of vehicles on an AHS and fully coordinated platoon maneuvers. The second develops and experimentally tests an algorithm that exploits position tracking and communication abilities to estimate the friction characteristics of the road and construct a map of the roadway's friction characteristics as a function of location. The third task merges the results of the first two with PATH work on emergency maneuvers to produce a detailed simulation of emergency stopping of a platoon on slippery roads.

### **Safety Assessment of Advanced Vehicle Control And Safety Systems (AVCSS): a Case Study**

Wei-Bin Zhang, Ching-Yao Chan, PATH  
TO 4225

PATH and INRETS, the French National Research Institute for Transportation Systems and Safety (Institut National de Recherche sur les Transports et leur Sécurité) collaborate in this project to do safety analysis and evaluation of AVCSS on a transit bus. The research also considers sensor reliability and diagnosis, and develops a system architecture to include fault tolerance and fault detection.

### **Collision Recording and Documentation**

Ching-Yao Chan, PATH

**Sponsor: California Office of Traffic Safety**

This project is exploring how ITS technology can be used to expedite the process of collision documentation and analysis to reduce the working hazards (for Highway Patrol officers) and the lane closure times (for the public) associated with post-crash reporting. Efforts are concentrating on development of hardware and software to facilitate surveying and documenting the collision scene.

### **Enabling Technologies for AVCSS**

#### **Magnetometer/GPS/INS Integration and Mitigation of GPS Signal Blockage**

Jay Farrell, UC Riverside

TO 4232

This project involves the development of an integrated magnetometer/GPS/INS system for reliable cm-level accuracy vehicle control. Specifically, closed loop advanced maneuvers (e.g. passing, merging) could be performed

at arbitrary locations along a trajectory, driver assistance technologies such as lane departure warning could be demonstrated, and vehicle positions and arrival times could be communicated back to the loading area. This project is also designing, developing and evaluating algorithms to address the issue of GPS signal loss following temporary signal blockages (e.g. inside a tunnel). Algorithms to decrease the time required for a GPS receiver to re-acquire phase lock and estimate integer ambiguities following a temporary loss of GPS signal will be designed.

### **Analyses of The Response of Pavements Containing Plugs For Vehicle Guidance**

Carl Monismith, John Harvey, UC Berkeley  
TO 4219

Examines the influence of magnets 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 magnet sizes and locations are developed for the pavement simulations. A range of temperature conditions is examined, and the effects of rate of loading (truck speed) are evaluated. The simulations are validated by a series of loading tests conducted with the Heavy Vehicle Simulator at the Richmond Field Station.

### **PATH Laboratory**

Raja Sengupta, Chin-Woo Tan, PATH  
TO 4224

Continues research on wireless communications and inertial navigation. Extends PATH's research on the design of AHS communication architecture and protocols by integrating it with emerging mobile data access products and standards. A mobile data access architecture and protocols are designed to facilitate the deployment of vehicle-vehicle and vehicle-roadside cooperative systems. Research on inertial navigation continues to design and deliver an improved testing and laboratory environment. The ultimate objective is to develop a gyro-free inertial navigation system with GPS-based error correction algorithms.

### **A Robust Communication Link and Architecture Design for the AHS**

**Andrea Goldsmith, Stanford**  
TO 4212

Investigates different communication requirements and quality of service (such as messages of varying lengths and priorities) for data access in automated highway system (AHS) communications. Robust communication link and data access protocols are designed, considering the problem that the overall communication architecture for an AHS is complicated by 1) the propagation environment of the signals, 2) the existence of multiple interference signals, and 3) the mobility and dynamic character of platoons. Existing and emerging commercial technologies are evaluated to determine if they can fulfill the communication requirements of an AHS. Focuses on the design of a hierarchical communication system architecture that supports all different layers (application, transport, network, data link, physical) and fulfills the communication requirements.

### **Aerodynamics of Heavy Trucks**

**Fred Browand, University of Southern California**  
TO 4214

Continues research on two important aerodynamic components for heavy-duty vehicles. The first task is to carry out wind tunnel



measurements of drag and potential fuel savings for two scale-model tractor-trailers in tandem at short headway. The second task is to derive sufficient vehicle roll stability margin for safe handling of Class 8 trucks at high speeds and under strong crosswind and abnormal road conditions (such as a wet highway). Measurements are made on static tractor-trailer configurations to yield estimates of the quasi-steady limit forces.

### **Distributed Autonomous Agent Networks**

**Raja Sengupta, UC Berkeley/PATH**  
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.

### **Model-Based Integration of Embedded Software (MoBIES)**

**Pravin Varaiya, Karl Hedrick, UC Berkeley**  
Sponsor: DARPA

With funding from the Defense Advanced Research Projects Agency (DARPA), PATH is supporting this program to facilitate the transition of real-time control system designs from the current state of practice of multiple analysis, simulation, coding and test environments to the target of model-based end-to-end real time implementations with minimum effort and maximum accuracy. PATH vehicles are being equipped to serve as the test beds for the automotive sample problems in vehicle-vehicle communication, focusing on "cooperative" adaptive cruise control with some forward collision avoidance functionality as well.

### **Driver Behavior**

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

Continues and extends the effort on human driver modeling development. The goal is to

provide other researchers with a tool for analyzing the effects of ITS systems on conventional driving performance in terms of throughput by reproducing the information processing string developed by the driver. The project will extend and refine the capabilities of the human driver model by developing more processing mechanisms that assess the effectiveness of other driving assistance systems. It will also increase the number of driving parameters that the model should incorporate, and begin to validate the model using data collected during real driving.

### **Development of a Vehicle Data Acquisition System for Naturalistic Driving Data Collection**

**Scott Johnston, PATH**  
TO 4223

A vehicle data acquisition system (DAS) has been developed to collect data about how human drivers actually drive. The data will be used to help calibrate and validate the human driver model that is being developed under TO 4222. The DAS is unobtrusive to the driver of the test vehicle and drivers of other vehicles, and can record many driving parameters, such as throttle position, acceleration, range and range rate relative to other vehicles, lane position, and presence of adjacent vehicles. Data collection and analysis software is developed and refined, and all are integrated on a late model passenger car on loan from Caltrans.

### **Automated-Manual Transitions: Human Capabilities and Adaptive Cruise Control**

**Theodore Cohn, UC Berkeley**  
TO 4221

Deals with automated-to-manual transition (A-MT) of an adaptive cruise control (ACC) vehicle when the vehicle in front suddenly applies maximum braking. It develops experiments, using a driving simulator, to investigate the ability of a human operator (HO) to detect the closing intervehicle spacing, the time to collision, and the conditions required for a safe and smooth A-MT in this scenario. The study focuses on those visual capabilities required by the HO 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 HO action. The research will sup-

ply a model for how to study A-MT in other settings, for example, longitudinal control of a platoon of vehicles.

### **Detection and Avoidance of Collisions: the ACT Model**

**George Andersen, UC Riverside**  
TO 4220

This project investigates the visual information (e.g. angle of collision) used by human drivers to detect and avoid collisions. Involves experiments with 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 evaluate the viability of the model to detect collisions in the car following and lane changing scenarios. Validation of the simulation-based results will be performed by comparing driving performance from simulation studies with data from extant studies on real-world driving behavior.

### **A Rural Field Test of the RoadView System**

**Han-Shue Tan, Dan Empey, PATH**  
AHMCT Program

The lane guidance assistance system developed for the Advanced Snowplow Project is being tested in winter operations in both California and Arizona. These tests will collect data regarding its use by drivers and how it helps them drive better in poor visibility conditions.

### **Development of an Inertial Measurement Unit and a Human-Machine Interface for Motorcycle Navigation Systems**

**Karl Hedrick, UC Berkeley**  
Sponsor: BMW

This project designs, develops and evaluates an integrated Inertial Measurement Unit (IMU) and Human-Machine Interface (HMI) prototype system for motorcycle navigation. The IMU will provide uninterrupted motorcycle state information. The HMI is aimed at providing navigation information to the driver so that the perceptual and cognitive demands are safe and convenient for motorcycle riding.

## NEW RESEARCH INITIATIVE:

# Bus Rapid Transit

### Bus Rapid Transit System Research Program

Wei-Bin Zhang, PATH

Bus Rapid Transit (BRT) is a new type of transit system that uses integrated land use and planning, advanced design concepts, ITS and advanced bus technologies to achieve significantly faster operating speeds, greater service reliability, and increased convenience. PATH's BRT research program brings together ATMIS and AVCSS researchers, supported by Caltrans, the Federal Transit Administration (FTA) and several transit agencies to address a wide range of planning, technology, and implementation issues. The program includes the following research areas:

#### Adaptive Bus Signal Priority System

Hongchao Liu, Chinwoo Tan, Mark Miller, PATH; Alex Skabardonis, UC Berkeley  
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.

#### Bus Precision Docking and Electronic Guidance System

Wei-bin Zhang, Han-shue Tan, PATH; Masayoshi Tomizuka, UC Berkeley  
64A0028



This system seeks to achieve, with the help of automation technologies, a high docking accuracy that allows fast loading and unloading of passengers with special needs. The utilization of precision docking at bus stations could improve bus movement efficiency, drivers' productivity, work-life quality and reduce the needs of bus driver training.

#### Evaluation of Advanced Concepts for an Integrated Bus Stop Design

Joy Dahlgren, PATH

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.

#### BRT Evaluation Tools

Jim Misener, 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 Smart BRT is a microsimulation, complete with appropriate bus and infrastructure geometric libraries and high-fidelity photo-realistic 3D graphics. This will allow computation and visualization of the incremental effect of adding 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, PATH

64A0027

This project involves work with transit properties, bus manufacturers, researchers, planners, decision makers and other transportation officials to further define BRT. The overall goal is to have a regionally integrated system where transit supports para-transit, cars, buses, rail, biking and walking.

## PATH PUBLICATIONS:

# Transportation Management and Information Systems

### Advanced Traffic Management

#### Documentation of the Irvine Integrated Corridor Freeway Ramp Metering and Arterial Adaptive Control Field Operational Test

M. G. McNally, James E. Moore, II, C. Arthur MacCarley, et al.

Due to the failure of any of the planned technologies to be successfully implemented in the field, and to the eventual failure of the Field Operational Test, this report does not constitute a formal evaluation. Rather, it summarizes the project development, institutional barriers, and technical failures.

UCB-ITS-PRR-2001-2

January 2001, 159 pages, \$25

#### Completing the Circle: Using Archived Operations Data to Better Link Decisions to Performance

Joy Dahlgren, Reinaldo C. Garcia, Shawn Turner

An overview of a traffic performance measures system and its components, with a summary of the major findings for each system component. A joint research team from PATH and the Texas Transportation Institute (TTI) investigated data archiving and performance monitoring activities in selected locations, with a primary focus on the use of performance measures in improving operations.

UCB-ITS-PRR-2001-23

September 2001, 39 pages, \$10

#### Incident Management: Process Analysis and Improvement

Randolph W. Hall

This study highlights the importance of the following principles:

- Response units should be adequate in number to handle anticipated demand.
- Response units should be strategically located to minimize maximum response times.
- Especially during busy periods, response

units should not be dispatched over long distances. It is better to wait for a closer unit to become available.

- Because response units are frequently busy responding to other incidents, it would be very beneficial for dispatchers to have access to location data.

UCB-ITS-PRR-2001-41

December 2001, 45 pages, \$10

#### Evaluation of Onramp Control Algorithms

Michael Zhang, Taewan Kim, Xiaojian Nie, Wenlong Jin, Lianyu Chu, Will Recker

This research had three objectives: 1) review existing ramp metering algorithms and choose a few attractive ones for further evaluation, 2) develop a ramp metering evaluation framework using microscopic simulation, and 3) compare the performance of the selected algorithms and make recommendations about future developments and field tests of ramp metering systems.

UCB-ITS-PRR-2001-36

December 2001, 122 pages, \$20

#### Data Sharing of Traveler Information With the Public and Private Sectors: State of the Practice

Mark A. Miller, Kevin Balke

A review of the literature was performed, followed by an analysis of responses to a survey instrument that was designed and administered to practitioners in the field. These are primarily representatives from public sector agencies that collect traveler information data. Survey results address the subjects of what data is shared, with whom it is shared, why it is shared, how it is institutionally arranged and managed, how effective the sharing enterprise has been, and how the enterprise can be improved.

UCB-ITS-PRR-2001-16

August 2001, 40 pages, \$10

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[www.path.berkeley.edu/PATH/Publications](http://www.path.berkeley.edu/PATH/Publications)*

### **ITS Hardware Maintenance Management Systems: White Paper for MORIP Pooled Fund Study**

**Beverly T. Kuhn, Brooke R. Durkop**

One of the challenges associated with intelligent transportation systems and transportation management centers is tracking the maintenance history of the various system hardware components to determine the actual long-term cost of maintaining them. This cost information can then be used for a variety of purposes, including determining the reliability and cost-effectiveness of individual hardware components, estimating the benefit-cost ratios of these systems and components, and justifying the request of maintenance funds and the use of those funds for ITS systems.

UCB-ITS-PRR-2001-24

September 2001, 17 pages, \$5

### **Evaluation of Onramp Control Algorithms**

**Wenlong Jin, Michael Zhang**

The fundamental philosophy of ramp metering is that the corridor can maintain its optimal operation by regulating the freeway demand to be under its capacity.

Our evaluation study finds that:

- Ramp metering reduces the total vehicle travel time up to 7 percent compared with no metering.
- No significant performance differences exist among ALINEA, modified Bottleneck, modified SWARM with 1 time-step-ahead prediction, and Zone algorithms.
- Coordinated ramp metering algorithms do not necessarily perform better than local control algorithms.
- Ramp metering performance and parameter values are non-linearly related.

UCB-ITS-PWP-2001-14

April 2001, 21 pages, \$5

### **Advanced Transportation Information**

#### **Event-based ATIS: Practical Implementation and Evaluation of Optimized Strategies**

**R. Jayakrishnan, Wei K. Tsai, Jun-Seok Oh, Jeffrey Adler**

Develops a framework to generate optimal routing schemes for advanced traveler infor-

mation systems (ATIS). The framework is based on network optimization, heuristics and driver-behavior-based detailed simulation for both evaluation and information design. Algorithms are developed for finding routing messages for variable message signs. To find an optimal routing scheme, static network optimization and dynamic simulation approaches are used.

UCB-ITS-PRR-2001-1

January 2001, 104 pages, \$20

### **Revenue Models for Advanced Traveler Information Systems**

**Y. B. Youngbin Yim**

In the past, public agencies have been reluctant to share traffic management responsibilities with the private sector. However, this study found that the current trend is toward a public-private partnership in the form of a franchised or revenue sharing program. In Japan, several types of in-vehicle devices are already commercially available to the consumer. In the United States and Europe, entrepreneurs are assessing the viability of ATIS services, but because consumer purchase behavior for traveler information is largely unknown, the market potential is yet to be determined.

UCB-ITS-PRR-2001-3

February 2001, 46 pages, \$10

### **ATIS-Alternative Revenue Approaches**

**Y. B. Youngbin Yim**

The fifteen largest metropolitan regions in the US were investigated through a literature review and in-person and telephone interviews. The study goals were to investigate alternative revenue approaches to achieve a self sustaining publicly supported ATIS, identify institutional barriers to achieving self-sustainability, and develop a framework of assumptions.

UCB-ITS-PRR-2001-4

February 2001, 70 pages, \$15

### **TravInfo Evaluation: Traveler Response Element Broad Area Study: Phase 2 Results Analysis of Wave-2 Survey**

**Y. B. Youngbin Yim**

Objectives of the survey were threefold:

- compare the post-TravInfo survey results to the pre-TravInfo survey results;
- assess changes in travel behavior before and

after the TravInfo field test; and,

- identify any travel behavior changes due to TravInfo being on-line.

UCB-ITS-PWP-2001-4

January 2001, 58 pages, \$15

**TravInfo Evaluation: Traveler Response Element Willingness to Pay for Traveler Information: Analysis of Wave 2 Broad Area Survey**

Louis Wolinetz, Asad J. Khattak, Y. B. Youngbin Yim

Results indicate that travelers are willing to pay for specific information content: constant updates, alternate route information, in-car computer information, expected delay and comparison of route times. Future commercialization efforts may focus on experimenting with various types of information content and conducting demonstration projects that charge for information.

UCB-ITS-PWP-2001-5

January 2001, 26 pages, \$10

**TravInfo Evaluation: Traveler Response Element; TravInfo 817-1717 Caller Study; Phase 2 Results**

Ronald Koo, Y. B. Youngbin Yim

The general public can obtain current traveler information through TravInfo's Traveler Advisory Telephone System (TATS) and privately offered information services including traffic Web sites. As part of the TravInfo FOT Evaluation, two waves of TATS callers were surveyed. This paper presents the findings of the second survey of TravInfo 817-1717 callers. Offering easy access to traveler information via a single telephone number was one of the highly desirable features of TravInfo TATS.

UCB-ITS-PWP-2001-7

February 2001, 43 pages, \$10

**ITS Traffic Data Collection**

**Use of Los Angeles Freeway Service Patrol Vehicles as Probe Vehicles**

James E. Moore, II, Seongkil Cho, Arup Basu, Daniel B. Mezger

The LA FSP program is the largest in the nation, operating 144 service vehicles covering 393 freeway miles. It is possible to determine FSP truck speeds automatically because field units are polled frequently and each is equipped with a GPS that can identify its loca-

tion to within 100 feet. If the information FSP trucks provide in LA is of sufficient quality and quantity to measure level of service, then similar vehicles would also be useful for measuring level of service in other Caltrans Districts, especially those with fewer loop detectors.

UCB-ITS-PRR-2001-5

February 2001, 93 pages, \$15

**Development and Testing of 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, Xudong Hu, Bin Lin, Jonathan E. Larson, Kirk Van Katwyk

Tests done with the field prototype system verify that the principle of our detection system is technically sound and that the algorithm implemented in the software works in most cases.

UCB-ITS-PRR-2001-6

March 2001, 62 pages, \$15

**New Hardware and Software Design of a 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, Bin Lin, Xudong Hu, Bo Chen, Jason Parks

Test results show that this new system can obtain the accuracy of measurement necessary to distinguish moving vehicles on the highway. The new system quantitatively proved that the principle of measurement is feasible, instead of qualitatively, as did the last version system.

UCB-ITS-PRR-2001-15

June 2001, 65 pages, \$15

**Section-Related Measures of Traffic System Performance: Prototype Field Implementation**

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

Field implementation of previous research, in which a vehicle reidentification algorithm based on loop signature analysis was developed using freeway traffic data. This algorithm was extended to non-freeway cases using a section of 2-lane major arterial and a

major specially instrumented signalized intersection in Irvine, California.

UCB-ITS-PRR-2001-32

October 2001, 80 pages, \$15

#### **Traffic Data Measurement and Validation**

**Benjamin Coifman**

Caltrans collects traffic data for many monitoring and control applications and the ultimate goal of the traffic surveillance system is to provide accurate data to these high level applications. The surveillance system includes data measurement, averaging and verification algorithms. This report presents improvements to many elements of the surveillance system.

UCB-ITS-PRR-2001-40

December 2001, 91 pages, \$15

#### **Investigation of Vehicles as Probes Using Global Positioning System and Cellular Phone Tracking: Field Operational Test**

**Y. B. Youngbin Yim, Randall Cayford**

A custom software package was developed as part of this project. The software, the Travel Information Probe System (TIPS) maps positions of probes of arbitrary accuracy to an embedded Geographical Information System (GIS) in order to determine the path the probe took. Once the path has been determined, the software calculates the travel time for each road segment traversed. Preliminary analysis of two Bay Area counties showed that accurate location technologies are capable of producing travel time information for nearly all roads.

UCB-ITS-PWP-2001-9

February 2001, 60 pages, \$15

#### **Video-Based Vehicle Signature Analysis and Tracking System Phase 2: Algorithm Development and Preliminary Testing**

**C. Arthur MacCarley**

The V2SAT System uses computer vision methods to make simple optical measurements of digitized real-time images of each vehicle on the freeway. For each passing vehicle, a numeric Video Signature Vector (VSV) is generated and transmitted to a central correlation computer via a low-power wireless network. The computer attempts to match VSV's to reidentify vehicles at each detectorized site

and determine the progress of each vehicle through the freeway network.

UCB-ITS-PWP-2001-10

February 2001, 67 pages, + 3 CD's \$40

#### **Using Vehicles Equipped with Toll Tags as Probes for Providing Travel Times**

**John Wright, Joy Dahlgren**

The introduction of electronic toll collection on the eight bridges crossing San Francisco Bay offers the means for a simple, low cost system for measuring travel times. FasTrak toll tags can be read by readers at various locations on congested roads, so that the time difference between when a vehicle passes one reader and passes the next can be computed. Such a system is already operating in Houston, where it is the primary source of travel-time data. Bay Area bridges and their maze of approaches are excellent candidates for such a system.

UCB-ITS-PWP-2001-13

April 2001, 49 pages, \$10

#### **Traffic Simulation**

##### **Integrating a Comprehensive Modal Emissions Model into ATMIS Transportation Modeling Frameworks** **Matthew Barth, Carrie Malcolm, George Scora**

The UC Riverside, College of Engineering-Center for Environmental Research and Technology (CE-CERT) has developed a comprehensive modal emissions and energy consumption (CME/EC) model that can be directly used for ITS evaluation. Much of this project's work focused on integrating the CME/EC model with PARAMICS, and two case studies were carried out using this PARAMICS/CME-EC tool. One examined the emissions impact of HOT lanes along the SR-91 corridor in Southern California, the other examined the emissions impact associated with redesignating uphill lanes on SR-60 near Riverside, California.

UCB-ITS-PRR-2001-19

August 2001, 54 pages, \$15

##### **Paramics API Development Document for Actuated Signal, Signal Coordination and Ramp Control**

**Henry X. Liu, Lianyu Chu, Will Recker**

Paramics is a suite of high performance soft-

ware tools used to model the movement and behavior of individual vehicles on urban and highway road networks. Access is provided through a Functional Interface or Application Programming Interface (API). The capability to access and modify the underlying simulation model through API is essential for research. Three developed APIs are documented in this report; namely, full-actuated signal control, actuated signal coordination, and actuated ramp metering control.

UCB-ITS-PWP-2001-11

February 2001, 40 pages, \$10

## **Advanced Traffic Theory**

### **How the Reconstruction of I-880 Affected Travel Behavior**

**Joy Dahlgren**

The reconstruction of I-880 in Oakland, California ten years after it was destroyed by an earthquake in 1989 provided a rare opportunity to study the effects of a highway capacity increase that was not motivated by increased development, so that the effects of the increased capacity were not confounded by the expectation of increased development.

UCB-ITS-PWP-2001-15

December 2001, 23 pages, \$5

### **Relationships Among Urban Freeway Accidents, Traffic Flow, Weather and Lighting Conditions**

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

Linear and nonlinear multivariate statistical analyses are applied to determine how the types of accidents that occur on heavily used freeways in Southern California are related to both the flow of traffic and weather and ambient lighting conditions. Results indicate that hit-object collisions and collisions involving multiple vehicles that are associated with lane-change maneuvers are more likely to occur on wet roads, while rear-end collisions are more likely to occur on dry roads during daylight. Controlling for weather and lighting conditions, there is evidence that accident severity is influenced more by volume than by speed.

UCB-ITS-PWP-2001-19

December 2001, 26 pages, \$10

## **ITS Transit Applications**

### **Assessing Opportunities for Intelligent Transportation Systems in California's Passenger Intermodal Operations and Services**

**Mark A. Miller, Dimitri Loukakos**

Institutional aspects were captured by means of a survey administered to transit service providers sharing a BART station and a Caltrain station in the San Francisco Bay area, and the Santa Fe Depot in San Diego where buses, commuter rail lines, and the San Diego Trolley come together. User views were captured by means of a survey administered to users of the BART station. From the literature, numerous barriers associated with the successful implementation of passenger intermodal operations and services were identified along with strategies to overcome these barriers.

UCB-ITS-PRR-2001-34

November 2001, 97 pages, \$15

### **Carlink II: Research Approach and Early Findings**

**Susan A. Shaheen, John Wright**

Launched in Summer 2001, CarLink II continues the investigation of commuter-based car-sharing that was originally explored in the 1998 CarLink longitudinal survey and the 1999 CarLink I field test. Lessons learned during the CarLink I field test helped guide the project team's design of the CarLink II project,



resulting in several differences and improvements.

UCB-ITS-PRR-2001-39  
December 2001, 33 pages, \$10

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

**Maged M. Dessouky, Randolph W. Hall, Rutvij Shah, Majid Aldaihani**

Studies alternative system architectures and ITS technologies that can improve the efficiency of personalized public transit and demand responsive systems such as paratransit. Reviews available and emerging ITS technologies that have been deployed or are being considered for this industry. We also conducted a survey of commercially available computer aided dispatching software. Also, included is a statistical analysis of travel patterns of a paratransit provider in Los Angeles County.

UCB-ITS-PWP-2001-12  
March 2001, 45 pages, \$10

### **Benefit/Cost Evaluation**

#### **Prospects for High Occupancy/Toll (HOT) Lanes: Where Should They be Implemented?**

**Joy Dahlgren**

Interest grows in converting high occupancy vehicle (HOV) lanes with unused capacity to either mixed flow or high occupancy/toll (HOT) lanes. Also, regions considering highway expansion see HOT lanes as a means of generating revenue. Santa Cruz County is studying the feasibility of constructing a HOT

lane on Highway 1 near Capitola. HOT lanes have also been proposed on I-680 between Pleasanton and San Jose and US 101 between Petaluma and Novato.

UCB-ITS-PRR-2001-22  
September 2001, 36 pages, \$10

#### **Freeway Performance Measurement System: Final Report**

**Pravin Varaiya**

Describes PeMS, a freeway performance measurement system that extract information from real time and historical data. It summarizes the communication and software architecture, describes PeMS applications, and presents observations. It also contains an empirical study of congestion, capacity, and ramp metering using PeMS

UCB-ITS-PWP-2001-1  
January 2001, 55 pages, \$15

#### **Freeway Performance Measurement System, PeMS v3, Phase 1: Final Report**

**Pravin Varaiya**

PeMS is a freeway performance measurement system that extracts information from real time and historical data. It processes 2 GB/day of 30-second loop detector data in real time to produce useful information, and presents information in various forms to assist managers, traffic engineers, planners, freeway users, researchers, and value added resellers or VARs (VARs are businesses that package travel time information with other location-dependent services.)

UCB-ITS-PWP-2001-17  
October 2001, 18 pages, \$5



**Evaluation Methods for Measuring the Value of ITS Services and Benefits from Implementation: Part X Freeway Service Patrols**

**David Levinson, Pavithra Kandadai Parthasarathi**

Investigates factors that influence why people choose to rely on highway assistance services rather than private assistance services. The first part reviews the literature regarding the value and methods for calculating the economic value of a good. The second and third parts examine the Revealed Preference analysis and Stated Preference analysis. Concludes with an estimate of a cost model for the freeway service patrol.

UCB-ITS-PWP-2001-3

January 2001, 53 pages, \$15

**PATH ITS Research Digests**

**Melanie Curry, Clark Scheffy, Ted Chirachivala**

Topics include Benefits, Detection, ITS, Signals, System Performance, Traveler Information, and Video

UCB-ITS-PWP-2001-20

December 2001, 214 pages, \$30

**Institutional and Societal Issues**

**Institutional Aspects of Bus Rapid Transit Operation**

**Mark A. Miller, Stephen M. Buckley**

Presents findings through a macroscopic examination, a survey of members of the US Bus Rapid Transit Consortium and several Canadian transit properties, and an examination of three California BRT systems. These issues were deemed the most important and most difficult to resolve:

- Local and business community opposition to the removal of/restrictions on parking spaces for BRT use
- Availability and acquisition of right-of-way or physical space
- Integration of multiple priorities, objectives, and agendas
- Concerns over long term funding commitments to BRT

- Impacts of BRT on roadway operations
- Finding political champions to support BRT
- Gaining community support for transit-oriented development
- Educating the public on BRT, and
- Managing perceptions and expectations.

UCB-ITS-PRR-2001-9

April 2001, 68 pages, \$15

**Evaluation of UC Davis Long-Range Transportation, Land Use, and Housing Plans: Examining the Potential for Innovative Mobility Pilot Projects**

**Rachel S. Finson, Susan A. Shaheen**

The City of Davis, surrounding communities, and the UC Davis campus are struggling with many transportation problems that plague larger urban centers, including increasing traffic, limited parking, and challenges to effective operation of the public transit system. The campus Long Range Development Plan (LRDP) will serve to guide this growth. It will include housing, traffic control, parking, alternative transportation modes, and interactions with the broader community.

UCB-ITS-PWP-2001-18

December 2001, 16 pages, \$5

**Commercial Vehicle Operations**

**Truck Scheduling for Ground to Air Connectivity**

**Randolph W. Hall**

On-time arrival of trucks at airport terminals is critical to the overnight package business. Late trucks delay the sorting and transfer process, which can delay aircraft departures from the local terminal, as well as aircraft departures from hub terminals that depend on timely aircraft arrivals. This paper models the airport terminal as a queueing process with random bulk arrivals. Predictions are provided for expectation, and standard deviation, of arrived work. The methods are being implemented as a web-based scheduling tool.

UCB-ITS-PWP-2001-8

February 2001, 35 pages, \$10

## PATH PUBLICATIONS:

Advanced Vehicle Control  
and Safety Systems

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[www.path.berkeley.edu/PATH/Publications](http://www.path.berkeley.edu/PATH/Publications)

**Vehicle Control****Compression Braking for Longitudinal Control of Commercial Heavy Vehicles**

Lasse Moklegaard, Maria Druzhinina, Anna G. Stefanopoulou

We develop a detailed crank angle based diesel engine model and a low order engine torque model for a Class-8 commercial heavy vehicle (CHV) as well as longitudinal control algorithms that coordinate the variable compression brake mechanism with service brakes and gear ratios. This work bridges the gap between the detailed crank angle based models developed in the engine design community, and the low order representation of engine torque response used in the vehicle dynamics community. Simulation results show that the variable compression brake allows smooth and fast speed regulation and rejection of torque disturbances due to changes in the road grade.

UCB-ITS-PRR-2001-11

April 2001, 104 pages, \$20

**Emergency Vehicle Maneuvers and Control Laws for Automated Highway Systems**

Charmaine Toy, Kevin Leung, Luis Alvarez, Roberto Horowitz

The work presented is specifically designed for use with the PATH hierarchical control architecture. The types of control laws that are needed for the different hierarchical layers are examined, and specific maneuvers for the coordination and link layers are presented. Simulations using SmartCAP (a mesoscopic traffic simulator) and SmartAHS (a microscopic traffic simulator) demonstrate the maneuvers' functionality.

UCB-ITS-PRR-2001-17

August 2001, 143 pages, \$20

**Brake System Modeling and Control**

J. K. Hedrick, M. Uchanski

Provides solutions to two common brake control problems: variable brake torque gain and

brake rotor-induced brake torque oscillations. The adaptive control solution for the variable brake torque gain problem is shown to work experimentally, and the algorithm to eliminate brake torque oscillations is demonstrated in simulation. In addition, documentation is provided for differential braking hardware, wheel speed measurement hardware, and a strain-based brake torque sensor, all of which were constructed to test these algorithms.

UCB-ITS-PRR-2001-25

September 2001, 82 pages, \$15

**Robust Lateral Control of Heavy Duty Vehicles**

Meihua Tai, Jeng-Yu Wang, Ryan White, Masayoshi Tomizuka

Earlier PATH research in this field emphasized theoretical aspects such as model development and controller designs. Our research focused on designing enhanced robust controllers and verifying them experimentally, and also studying autonomous vehicle following control.

UCB-ITS-PRR-2001-35

December 2001, 70 pages, \$15

**Integration of GPS/INS and Magnetic Markers for Advanced Vehicle Control**

Jay Farrell, Matthew Barth

The main objective of our project was to develop and demonstrate a triple redundancy navigation system incorporating magnetometer, inertial, and carrier phase differential Global Positioning System (GPS) measurements. This triplicate redundancy navigation system reliably demonstrated vehicle control in these situations: GPS and magnetometer-aided INS, GPS aided INS, magnetometer aided INS, and switching between GPS and magnetometer aiding of the INS at random times.

UCB-ITS-PRR-2001-38

December 2001, 62 pages, \$15

## Vehicle Lateral Warning, Guidance and Control Based on Magnetic Markers: PATH Report of AHSRA Smart Cruise 21 Proving Tests

Han-Shue Tan, Bénédicte Bougler

Details the PATH proving test results on the test track of the Public Works Research Institute (PWRI) of the Ministry of Construction in Tsukuba City, Japan. Discussions are based on preliminary observations from test results during the short proving test period. UCB-ITS-PWP-2001-6

January 2001, 71 pages, \$15

## Safety

### Fault Detection and Handling for Longitudinal Control

Jingang Yi, Adam Howell, Roberto

Horowitz, Karl Hedrick, Luis Alvarez

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 control system of automated vehicles. The fault diagnostic module effectively monitors all of the sensors and actuators required for longitudinal control, while the fault handling module corrects for any detected faults via controller reconfiguration and degraded modes of operation. UCB-ITS-PRR-2001-21

September 2001, 117 pages, \$20

### System Fault Detection in Human-Augmented Automated Driving

Theodore Cohn

Implementation of AHS will require a thoughtful deployment in which the human operator has been integrated into the system. How can the human operator (HO) best be integrated into the automated highway system? How can we incorporate human guidance into the lateral control system? We concentrate here on fault detection under several types of combined human/controller guidance. For each, system performance is quantified in a simulated lateral guidance task using both human cognition models derived from signal detection theory and measured performance incorporating human observers.

UCB-ITS-PRR-2001-26

September 2001, 15 pages, \$5

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

J. K. Hedrick, M. Uchanski, Q. Xu

Two novel applications of vehicle-to-vehicle networks are developed and simulated:

- Cooperative Adaptive Cruise Control uses communicated information to improve on ordinary cruise control systems.
- The idea behind our Cooperative Estimation algorithm is that each vehicle on the road is potentially a driving condition sensor. By combining data communicated from many vehicles on the roadway, the algorithm is able to produce estimates of driving time and road condition significantly better than those a single vehicle could produce. An exciting new type of slip-based road condition estimator is developed and experimentally shown to be able to distinguish between wet and dry roads using no dedicated road condition sensors.

UCB-ITS-PRR-2001-28

October 2001, 142 pages, \$20

### Safety Assessment of Advanced Vehicle Control and Safety Systems (AVCSS): A Case Study

Ching-Yao Chan, Wei-Bin Zhang, El Miloudi

El Koursi, Etienne Lemaire

To ensure the safety of a system, an assessment or evaluation methodology must be developed and implemented prior to implementation of new technologies such that errors in the processes of specification, design, development, and integration can be revealed in order to prevent hazardous consequences. Since some AVCSS technologies (e.g., adaptive cruise control) will begin to be implemented widely in the next few years, timely development of a sound safety assessment/evaluation method for AVCSS is crucial.

UCB-ITS-PRR-2001-30

October 2001, 63 pages, \$15

### Assessing Benefits of Coordination on Safety in Automated Highway Systems

Woosuk Choi, Darbha Swaroop

We present a methodology for assessing the benefits of different vehicle coordination strategies on the safety of a platoon during emergency braking. One can say that a coordinated braking strategy B is more beneficial than a strategy A, if strategy B leads to a larger reduction in the probability of a collision, the expected number of collisions, and the

expected relative velocity at impact as compared to strategy A.  
UCB-ITS-PRR-2001-33  
October 2001, 42 pages, \$10

## Enabling Technologies

### Human Driver Model for SmartAHS

**Delphine Delorme, Bongsob Song**

SmartAHS is a micro-simulation tool designed for the simulation of automated vehicles. To apply SmartAHS to the design of partially automated systems, it is necessary to develop a human driver component for this simulation tool. This component needs to allow the comparison of human driving characteristics versus automated vehicles in the long term, but first, it has to permit the production, for simulation purposes, of a realistic human driving behavior.

UCB-ITS-PRR-2001-12  
April 2001, 50 pages, \$10

### Aerodynamic Forces on Truck Models, Including Two Trucks in Tandem

**Mustapha Hammache, Mark Michaelian, Fred Browand**

Describes a wind tunnel experiment in which 6-component force and moment data are measured for both the cab and the trailer of a simplified model truck. Forces and moments are presented in coefficient form. The test matrix includes variation of the cab-trailer gap, and the yaw angle between the model plane of symmetry and the axis of the wind tunnel. The yaw angle is meant to account for the presence of an over-the-road side-wind.

UCB-ITS-PRR-2001-27  
October 2001, 24 pages, \$5

### Sensor-Friendly Freeways: Investigation of Progressive Roadway Changes to Facilitate Deployment of AHS

**James A. Misener, Paul Griffiths, Lee Johnson, Andy Segal**

Intelligent driver assistance systems using in-vehicle, forward-looking sensors can be supplemented by vehicle-vehicle and vehicle-highway cooperative elements to comprise a sensor-friendly highway environment that would enhance the operational efficiency, and ultimately, the safety benefits of these systems. We identify the current limitations of autonomous sensing systems and propose relatively inexpensive vehicle-highway cooperative systems to allow those limitations to

be mitigated. Emphasis is on 77 GHz (millimeter wave) automotive radar sensors.  
UCB-ITS-PRR-2001-31  
October 2001, 112 pages, \$20

## Communications

### A Token-Ring Medium-Access-Control Protocol with Quality of Service Guarantees for Wireless Ad-hoc Networks

**Roberto Attias, Duke Lee, Anuj Puri, Stavros Tripakis, Raja Sengupta, Pravin Varaiya**

Describes the design and implementation of a wireless token bus protocol for local area networks that permits wireless radios to dynamically join and leave the network while still maintaining the quality of service for those remaining in the network. This version relaxes an earlier version of the protocol, which worked only when each wireless radio in the network was within range of every other radio in the network at all times.

UCB-ITS-PRR-2001-7  
March 2001, 58 pages, \$15

### Geographical Routing Using Partial Information for Wireless Ad Hoc Networks

**Rahul Jain, Anuj Puri, Raja Sengupta**

Presents an algorithm for routing in wireless and ad hoc networks using information regarding the geographic location of the nodes. The algorithm, which is a new type of distributed, adaptive and asynchronous algorithm, is known as a geographical routing algorithm (GRA). It is discussed in relation to other routing algorithms in the literature. A system model and problem statement are presented.

UCB-ITS-PRR-2001-8  
March 2001, 15 pages, \$5

### Wireless Token Ring Protocol

**Duke Lee**

WTRP is a medium access control protocol for wireless networks in Intelligent Transportation Systems that supports quality of service in terms of bounded latency and reserved bandwidth. WTRP reduces the number of retransmissions due to collisions. It supports many topologies since not all stations need to be connected to each other or to a central station. WTRP is robust against single node failure, and is designed to recover gracefully from multiple simultaneous faults. It has appli-

cations to inter-access point coordination in ITS DSRC, and safety-critical vehicle-to-vehicle networking.

UCB-ITS-PRR-2001-10

April 2001, 97 pages, \$15

## **Coordinating Automated Vehicles via Communication**

**Soheila Vahdati Bana**

Discusses issues in the design and implementation of a controller for automated vehicles that coordinates the interaction among vehicles. We propose a communication structure of local and wide area networks, LANs and WANs, that allows automated vehicles to exchange information about their relative positions and planned actions. We also explain communication address resolution in the context of AHS. Finally, we present a vehicle positioning system by using spread spectrum magnetic signals, which are used in space-time division multiple access (STDMA) communication and coordination control.

UCB-ITS-PRR-2001-20

September 2001, 145 pages, \$20

## **Optimized Vehicle Control/Communication Interaction in an Automated Highway System**

**J. K. Hedrick, Y. Chen, Sonia Mahal**

The concept of platooning in an Automated Highway System (AHS) allows a group of vehicles to share information across a wireless local area network (LAN). Unfortunately, perfect wireless communication does not exist. We analyze the effects of various communication delays on string stability. We also develop handshaking protocols that allow platoon LANs to reconfigure themselves in response to any physical changes to the composition of the platoon. These protocols are designed to be robust towards packet losses, as well as satisfying certain safety and liveness conditions.

UCB-ITS-PRR-2001-29

October 2001, 132 pages, \$20

## **Automation Concept Development and Evaluation**

### **Development and Performance Evaluation of AVCSS Deployment Sequences to Advance from Today's Driving Environment to Full Automation**

**Steven Shladover, Joel VanderWerf, Mark A. Miller, Natalia Kourjanskaia, Hariharan Krishnan**

What steps need be taken to get from manually-controlled to fully automated vehicles? We identify targets of opportunity for accelerating progress toward highway automation, taking account of operational constraints. After reviewing existing literature, a set of principles is suggested to govern the design of deployment strategies. Deployment sequences for automated highway systems are proposed, beginning with adaptive cruise control, then adding elements of vehicle cooperation and lane protection to build toward automated highway systems capabilities within constraints of technological, human factors and economic feasibility.

UCB-ITS-PRR-2001-18

August 2001, 82 pages, \$15

### **The AHS/Street Interface: Effects of Capacity Concentration on System Performance: Phase 1 Final Report**

**Randolph Hall**

Discusses strategic issues in Automated Highway Interface design, including creation of interface components and design alternatives, with emphasis on interchange separation and highway orientation. The report also discusses land use issues associated with interchange construction. Additional results from this project can be found in UCB-ITS-PWP-2000-26.

UCB-ITS-PRR-2001-37

December 2001, 50 pages, \$10

# PATH Bibliographic Database

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

The Database, created in 1989, is sponsored by Caltrans and the 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 25,000 records with abstracts contained in the Database. Full bibliographic information is provided, and URLs are included for documents that are available in electronic format. The majority of the indexed items are held at the Harmer E. Davis Transportation Library.

## Access and Availability

To access the California PATH Bibliographic Database, go to:  
<http://www4.nationalacademies.org/trb/tris.nsf/web/path>

To access the Harmer E. Davis Library Web site, go to:  
<http://lib.berkeley.edu/ITSL/newbooks.html>

The "New Acquisitions in Intelligent Transportation at the Harmer E. Davis Transportation Library" list is a compilation of records that have been added to the Database in the previous month. To access the New Acquisitions list, go to:  
<http://www.lib.berkeley.edu/ITSL/newbooks.html>

For information regarding the availability of documents held at other University of California at Berkeley libraries, go to:  
<http://www.lib.berkeley.edu/ILS/nonuc.html>

Loans and photocopies of materials are available to persons affiliated with the University of California and California PATH sponsors. For others, information on interlibrary loans or photocopies may be obtained at the HEDTL Web site. Questions regarding the Database may be directed to:

Seyem Petrites, PATH Database Manager at: [spetrite@library.berkeley.edu](mailto:spetrite@library.berkeley.edu)

Michael Kleiber, PATH Database Librarian at: [mkleiber@library.berkeley.edu](mailto:mkleiber@library.berkeley.edu)



