California PATH
2003 Annual Report

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PATH

California PATH

2003
Annual Report

PATH

C A L I F O R N I A

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

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

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Director's Introduction

The California PATH Program, founded in 1986 through collaboration between Caltrans and the University of California, is a unique multidisciplinary research program. The mission of PATH is to harness the capabilities of advanced technologies to improve transportation efficiency, safety and accessibility. PATH's primary goals are to improve safety and reduce the congestion of California's transportation systems. By achieving these objectives, PATH researchers also work toward reducing travel stress, pollution, and energy consumption.

While PATH research focuses on California transportation issues, it also stands at the forefront of national transportation research. Since its conception, PATH has played an important role in the development of the national Intelligent Transportation System program and conducted research under a number of federally sponsored ITS research initiatives. Today, a significant fraction of PATH's research funding comes from the federal government and private industry.

In the 1990s under the leadership of my two predecessors, Professors Pravin Varaiya and Karl Hedrick, PATH achieved international reputation in the area of Advanced Vehicle Control and Safety Systems (AVCSS). In the early 90s, PATH made contributions to the National ITS Architecture. From 1994 to 1998, PATH was a key member of the National Automated Highway System Consortium. Since 1998, PATH has participated in the U.S. DOT's Intelligent Vehicle Initiative Programs. Throughout, PATH researchers made fundamental advances in the application of control and systems engineering methods to collision warning and avoidance for automobiles, buses and trucks.

PATH researchers have also contributed significantly to research in the areas of Advanced Traffic Management and Information Systems (ATMIS). The list of accomplishments in this area includes the development of state-of-the-art Traffic Surveillance technologies, algorithms for Traffic State estimation, improved Traffic Flow theories, intelligent On-ramp metering control schemes, new models for traveler route choice in the presence of Advanced Traffic Information Systems, and other state-of-the-art developments. PATH researchers in this area benefited from the close participation of Transportation faculty and researchers based at many California universities.

Based on this solid foundation of accomplishments, the new thrust at PATH has shifted to the validation of these research products through Field Operational Testing (FOT). This represents the logical next step in moving the results of the research toward deployment. Until recently, most of the validation of PATH research was performed through simulation or controlled experiments. While these are helpful, they cannot be a substitute for testing new technologies or strategies in the real-world.

To reflect this new thrust on FOT, PATH underwent a re-organization during the summer of 2003. The previous division of PATH between AVCSS and ATMIS research was not appropriate to the new research emphasis, where experts in sensing and communication technologies, transportation science, behavioral research, economics and policy, work collaboratively in the planning, design and implementation of innovative solutions to transportation problems. The new organizational structure of PATH emphasizes an application problem orientation, rather than a technology orientation.

The new PATH is organized along four programs:
- Traffic Operations Research
- Transit Operations Research
- Transportation Safety Research
- Policy and Behavioral Research.

As part of the re-organization, the California Center for Innovative Transportation (CCIT) was spun-off from PATH and established as an independent unit within the Institute of Transportation Studies at UC Berkeley. The scope of CCIT has changed to focus on the deployment and commercialization of research products developed at PATH and at other transportation research centers in the state of California.

In this annual report, we highlight many of the ongoing research projects at PATH in its four programs. Among the many exciting developments at PATH, one is especially worthy of mention: PeMS (Performance Measurement System) has been successfully field tested and is currently being deployed at Caltrans to provide traffic control centers and travelers with up-to-date information and predictions of travel times. This is an excellent example of how PATH research makes its way from research to testing and finally deployment.

Perhaps the most impressive aspect of PATH is the quality and enthusiasm of the researchers, faculty and students who participate in its research. I am thrilled to be part of PATH and to have the opportunity to help shape its future.

Samer Madanat California PATH Director

A Word from Caltrans

The Division of Research and Innovation, within the California Department of Transportation (Caltrans), strives to improve the safety and efficiency of California's transportation system through the development and deployment of transportation innovation. The goal of the Caltrans Division of Research and Innovation is to work with its partners to develop the best concepts and carry them through the prototype stage, the field operation stage, and finally, to deployment, in order to improve Caltrans' internal operations and ability to better manage the transportation system to benefit the travelers and the movement of goods.

Caltrans works with a number of university programs to achieve its mission of providing the best transportation solutions and options to Californians. The California Partners for Advanced Transit and Highways (PATH) research program is one of the key programs that support the Division of Research and Innovation in leading Caltrans to achieve this important mission. This past year PATH and Caltrans worked together to make major changes in many program areas to meet the changing needs of Californians and to cope with difficult budget shortcuts. In these difficult times, we must continue to work together to improve communications and collaboration between researchers and practitioners to help even more the state's transportation system by doing things better and more efficiently. I am pleased to see that many of the concepts that have been developed in collaboration with our partners at PATH over the past decade are now moving towards field operational testing and soon will lead to deployment. Over the next two years, we are looking forward to working with PATH and The California Center for Innovative Transportation (CCIT) to implement many of the ongoing projects such that our customers can benefit from them.

I am proud to be associated with colleagues at Caltrans, at PATH, at CCIT, and at many of the other university programs that are dedicated to the betterment of California's transportation system. I am confident that over the next few years, even during these difficult financial times, we will make more progress in improving the safety and efficiency of the transportation system, while at the same time provide more choices to California travelers and businesses.

Laurence H. Orcutt

Lawrence H. Orcutt
Division Chief
Division of Research and Innovation

California PATH Program

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 and conducting field operational tests, developing public/private/academic partnerships, and educating students as well as practitioners about ITS.

PATH's mission is to develop solutions to the problems of California's surface transportation systems through cutting edge research. PATH develops these solutions by harnessing the knowledge of transportation researchers, working in conjunctions with experts in the fields of information technology, electrical engineering, mechanical engineering, economics, transportation policy and behavioral studies. The PATH charter includes conducting leading research, planning and evaluating field operational tests, developing partnerships between academia, the public sector and private companies, and educating both students and practitioners. 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 thirty full-time staff members, including a core group of research staff members, plus program managers and administrators. A substantial body of research is done by the full-time research staff at PATH headquarters, but most PATH research work is done by faculty members employing graduate students on the campuses of the universities that form the PATH partnership. This work is supplemented by subcontracts to private companies as needed, and by cooperative research agreements with a variety of organizations, including private companies as well as public institutions, both domestic and international. The product-development-oriented work of private companies complements the more basic work of the academic researchers, so that each group can concentrate on what suits it best. Publication of PATH research work is coordinated at PATH headquarters.

PATH Activities in National ITS Programs

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

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

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

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

State-Funded Core Program of ITS Research

The core of the PATH program is its collection of research projects funded by Caltrans' Division of Research and Innovation. Currently there are about 80 such projects, selected on the basis of an annual Request for Proposals (RFP) and proposals submitted from throughout California. These involve the work of about 35 professors, representing 10 academic departments on 11 different university campuses, supervising the research of more than 90 graduate students and post-doctoral researchers. Projects are currently being conducted at: UC Berkeley, UC Davis, UC Irvine, UC Los Angeles, UC Riverside, California Polytechnic State University at San Luis Obispo, California State University San José, Ohio State University, San Diego State University, Stanford University, and the University of Southern California.

Other projects

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

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

Policy and Behavioral
Susan Shaheen, Program Leader

Carlink II

Smart Parking Sensor

Preparing to Place Sensor

UC Davis Transit

Other UC Davis Transit

The Policy and Behavioral Research program focuses on understanding the role, response, and impacts of advanced transportation technologies. It brings together a variety of theories, methodologies, and disciplines in answering applied policy, planning, and implementation questions related to transportation technology use, markets, and response. Disciplines and approaches include: engineering, planning, economics, systems and policy analysis, psychology, sociology, business, and marketing. Research in this area seeks to address transportation issues related to congestion, air quality, energy, and land use.

Projects involve faculty, staff, and students from across the State. These include: institutional approaches to interjurisdictional system management, assessment of Caltrans' communication needs and solutions, smart parking management, planning for Caltrans' Innovative Corridors Initiative, carsharing, and long-term innovative transportation and land-use planning for the Davis-Sacramento region.

Results from recently completed Task Order (TO) 4000 series projects include:

- CarLink II (TO 4104), a smart carsharing system, was deployed in Palo Alto from 2001 to 2002, resulting in increased transit ridership, reduced vehicle miles traveled, and cost savings among users.

- Smart parking sensors (TO 4305) were deployed at the Bay Area Rapid Transit (BART) District Rockridge station, which calculated the number of available parking spaces real time. Based on potential to increase ridership and parking efficiencies at the Rockridge station, a demonstration pilot project is planned at this location.

- Mode choice results from the Davis-Sacramento Smart Mobility Model (TO 4302) survey were consistent with those obtained from focus groups. The comprehensive network of bicycle paths and transit in the City of Davis to the UC Davis Campus has encouraged higher bicycle ownership, allowed for more households to exist without autos, and significantly increased the rate of bicycle and transit use and discouraged the rate of driving (relative to the regional average). In addition, relatively high cell phone and Internet phone service subscriptions in the community may facilitate use of advanced traveler information systems. At the close of the project, four innovative mobility options were recommended for the UC Davis campus and the greater Sacramento area, including: e-stores (advanced vending machines), carsharing, carfree housing, and advanced traveler information (transit stops).

CarLink II Pilot Deployment, TO 4104; Susan Shaheen, California PATH.

Scope and Evaluate Transportation, Land-Use, and Housing Plans for UC Davis and the City of Davis as Part of a Broader Innovative Mobility Services Model, TO 4128; Susan Shaheen, California PATH and Caroline Rodier, University of California Davis.

Assistance to Caltrans for Assessment of Communications Needs and Solutions, TO 4133; C. Arthur MacCarley, California Polytechnic University, San Luis Obispo and Ben Coifman, Ohio State University.

UC Davis Long-Range Development Plan: A Davis Smart Mobility Model, TO 4144; Susan Shaheen, California PATH and Caroline Rodier, University of California Davis.

Innovative Corridors Initiative/2005 ITS World Congress, TO 4151; Susan Shaheen, California PATH.

Institutional Approaches for Interjurisdictional System Management, TO 4155; Michael McNally, University of California, Irvine.

University of California, Davis Long-Range Development Plan: A Davis-Sacramento Smart Mobility Model Proposal, TO 4302; Susan Shaheen, California PATH and Caroline Rodier, University of California Davis.

Smart Parking Management Pilot Project Planning: A Bay Area Rapid Transit (BART) District Parking Demonstration, TO 4305; Susan Shaheen, California PATH.

Transportation Safety
Jim Misener, Program Leader

The PATH Safety Program is committed toward actively collaborating with our customers to produce research products that can be deployed. While our perspective is research, our aim is "near term deployment". Our technical and research skills are formidable, stemming from our heritage in vehicle-highway cooperative systems and human factors research gained through our "science of driving" investigations.

We cluster our projects into three areas: science of driving, active safety (cross-cutting, intersections and heavy vehicles) and general. We also highlight that this categorization is temporary, as our current emphasis on mid- to short-term field deployable products is a change from our prior longer term approach which emphasized automation. Thus, 2003 was a year of transition – from highway automation to more direct and explicit applied safety research.

Our mix of projects reflects this transition. While the projects clustered under "science of driving" remain the same, two of the three active safety clusters, cross-cutting and heavy vehicles, carry with them some longer term research elements. We emphasize, however, that these elements serve a valuable foundation; they continue the research legacy in vehicle-highway cooperation and allows PATH to transition key conceptual and engineering ideas into revolutionizing more conventional transportation safety pursuits with a necessary infusion of Intelligent Transportation Systems ideas and talent.

Below are the projects in the Task Order (TO) 4000 series or RTAs for 2003.

Science of Driving

Detection and Avoidance of Collisions: The ACT Model, TO 4220; George Andersen, University of California, Riverside.

The Naturalistic Driver Model: Development, Integration, and Verification of Lane Change Maneuver, Driver Emergency and Impairment Modules, TO 4238; Delphine Cody; California PATH.

Active Safety: Cross-cutting

Integrated Roadway/Adaptive Cruise Control System: Safety, Performance, Environmental and near Term Deployment Considerations, TO 4242; Petros Ioannou, University of Southern California.

The Use of Combined Physical and Situational Models for Data Fusion in ACC Systems, RTA 012169; J. Karl Hedrick, University of California, Berkeley.

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

PATH Laboratory, TO 4224; Raja Sengupta, University of California, Berkeley

Testing and Evaluation of Robust Fault Detection and Identification for a Fault Tolerant Automated Highway System, TO 4209; Jason Speyer, University of California, Los Angeles.

MOBIES (Model-Based Integration of Embedded Systems), Contract F33615-00-C-1698; J. Karl Hedrick, University of California, Berkeley.

Active Safety: Intersections

Intersection Decision Support: A System Approach to Achieve Nationally Interoperable Solution, TO 4403; James Misener, California PATH.

Improved Grade Crossing Safety with In-Pavement Warning Lights, TO 4138; Theodore Cohn, University of California, Berkeley.

Active Safety: Heavy Vehicles

Development of the Advanced Rotary Plow (ARP) for Snow Removal Operations (Advanced Highway Maintenance and Construction Technology), RTA 65A0068; Masayoshi Tomizuka, University of California, Berkeley.

Parameter Estimation of Heavy Vehicles for Regulation and Coordination Layer Control, TO 4235; Christian Gerdes, Stanford University.

Vehicle Lateral Control Under Fault in Front and/or Rear Sensors, TO 4204; Masayoshi Tomizuka, University of California, Berkeley.

The Aerodynamics of Heavy Trucks, TO 4214; Fred Browand, University of Southern California.

General Safety

Collision Recording and Documentation, RTA 65A0081; Ching-Yao Chan, California PATH.

Evaluation of Automated Work Zone Information Systems (AWIS); RTA 65A0155; Chao Chen, CCIT.

Preparing Taurus for Driver Modeling

PATH Instrumented Intersection

Advanced Rotary Plow

At Grade Rail Crossing

Aerodynamic Testing of Heavy Vehicles

Loop Detectors for Berkeley Highway Lab

Mobile TMC

Video Camera for Berkeley Highway Lab

Laser Photodiode Array Vehicle Detection

Sample of Roadway Showing Magnets

Traffic Operations
Alex Skabardonis, Program Leader

The PATH Traffic Operations Research Program focuses on advancing the state-of-the-art in traffic management and traveler information systems, and producing results that can be implemented in the field. The research is undertaken by statewide research team of nineteen faculty and more than 50 graduate students and staff working closely with the program customers. Examples of ongoing projects include research on surveillance technologies, algorithms for data processing, fusion and analysis, development and application of analytical and simulation techniques, and formulation and testing of advanced operational strategies.

Results from recently completed Task Order (TO) 4000 series and RTA projects include:

Ongoing work at the Berkeley Highway Laboratory (BHL), produced loop detector diagnostics and improved algorithms for vehicle tracking from the video data collection system, (TOs 4129 & 4307). Vehicle trajectory data from BHL are utilized in the large scale US DOT project Next Generation of Traffic Simulation Models (NGSIM).

A production version of the Freeway Performance Measurement System (PeMS) was developed for immediate deployment by California Department of Transportation (Caltrans). Enhancements to the PeMS include the calculation of congestion delay on state highways, calculation of travel time and travel time reliability measures, collection and processing of incident data, and improved algorithms for analysis and visualization of loop detector data (TOs 4127 & 4301).

Several enhancements to microscopic simulation models were developed and tested in real-world environments (TOs 4214, 4143 & 4304). These enhancements include Application Program Interfaces (APIs) to widely used microsimulation models such as PARAMICS to better model ramp metering, adaptive control and traveler information systems.

Improved on-line ramp metering algorithms have been developed and tested through simulation (TO 4136). A field test of the most promising strategies is planned for next year in Los Angeles. A prototype traveler information system via changeable message signs has been developed (TO 4306) and will be field tested in the San Francisco Bay Area.

Traffic Surveillance

Conventional Surveillance and Communications Technologies

Assistance to Caltrans for Assessment of Communications Needs and Solutions, TO 4133; C. Arthur MacCarley, Cal Poly San Luis Obispo.

Mobile TMC, TO 4156; Jeffrey Gerfen, Cal Poly San Luis Obispo.

Automated Diagnostics of Loop Detectors and the Data Collection System in the Berkeley Highway Laboratory, TO 4307; Adolf May, University of California, Berkeley, Ben Coifman, Ohio State University.

New Detector Technologies

Berkeley Highway Laboratory: Proposal for Continuous Operation of Video Data Collection System, TO 4129; Robert Tam, University of California, Berkeley.

Assessment of MEMS Sensors in an Urban Traffic Environment, TO 4153; Pravin Varaiya, University of California, Berkeley.

Anonymous Vehicle Tracking for Real-Time Freeway and Arterial Street Performance Measurements, TO 4159; Stephen Ritchie, University of California, Irvine.

Analyses of the Response of Pavements Containing Plugs for Vehicle Guidance, TO 4219; John Harvey, University of California, Davis, Carl Monismith, University of California, Berkeley.

Development and Field Testing of Laser Photodiode Array Based Vehicle Detection Systems, TO 4310; Harry Cheng, University of California, Davis.

Data Processing/Analysis/ Performance Measurement

Traffic Flow

Validation of Daganzo's Behavioral Theory of Multi-lane Traffic Flow, TO 4113; Michael Cassidy, University of California, Berkeley, James Banks, San Diego State University.

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

Estimating and Validating Models of Microscopic Driver Behavior from Video Data, TO 4154; Alexander Skabardonis, Jitendra Malik, University of California, Berkeley.

Performance Measurement

Considering Risk-Taking Behavior in Travel Time Reliability, TO 4110; Will Recker, University of California, Irvine.

Freeway Performance Measurement System, Version 3, Phase II, TO 4127; Pravin Varaiya, University of California, Berkeley.

A Tool for the Incorporation of Non-Recurrent Congestion Costs of Freeway Accidents in Performance Measurements, TO 4137; Tom Golob, University of California, Irvine.

Freeway Performance Measurement System: PeMS Version 4, TO 4301; Pravin Varaiya, University of California, Berkeley.

A Performance Measurement System for Arterial Streets (APeMS), RTA 20861; Pravin Varaiya, Alexander Skabardonis, University of California, Berkeley.

Modeling

Development of a Path Flow Estimator for Deriving Steady-State and Time-Dependent Origin-Destination Trip Tables, TO 4135; Will Recker, University of California, Irvine.

Developing a Freeway Analysis Manual, TO 4309; Adolf May, University of California, Berkeley.

Development and Application of Traffic Simulation Models

Bay Area Simulation and Ramp Metering Study, TO 4106; Yonnel Gardes, Adolf May, University of California, Berkeley.

Large Scale Traffic Simulation through Parallel Computing, TO 4142; Henry Liu, University of California, Irvine.

Real-time Traffic Information Estimation Through On-Line Simulation and Hybrid Data Fusion System for ATMS Applications, TO 4143; Lianyu Chu, University of California, Irvine.

Development of a Heavy-Duty Diesel Modal Emissions and Fuel Consumption Module for SmartAHS, TO 4215; Matthew Barth, University of California, Riverside.

PATH Paramics Development and Support, TO 4304; Henry Liu, Lianyu Chu, University of California, Irvine.

Traffic Control, Management and Traveler Information Systems

Design, Field Implementation and Evaluation of Adaptive Ramp Metering Algorithms, TO 4136; Roberto Horowitz, UC Berkeley, Michael Zhang, University of California Davis

Control of Heavy-Duty Vehicles: Environmental and Fuel Economy Considerations, TO 4203; Petros Ioannou, University of Southern California.

Feasibility Study and Pilot Program for Providing Real-Time User Travel Times on Freeway Changeable Message Signs, TO 4306; Alexander Skabardonis, Pravin Varaiya, University of California, Berkeley.

Congestion Costs of Freeway Accidents

Changeable Message Sign Studies

Ramp Meter Studies

Heavy-Duty Vehicle Emission Studies

Traffic Flow Studies

Automated Bus Rapid Transit

Driver Vehicle Interface

Precision Docking of Transit Vehicle

Precision Docking Provides Small Gap

Rapid Transit in Los Angeles

Transit Operations
Wei-Bin Zhang, Program Leader

The California PATH transit program is built upon a solid foundation of technical research gained through fundamental research and field operational tests. The program, working with many transit agencies, addresses real world problems by investigating advanced yet practical solutions. We emphasize new service concepts, methods and ITS technologies for innovating, enhancing and improving transit solutions with a goal that an enhanced public transit system will provide transportation choices that ultimately help to reduce traffic congestion.

In 2003 the PATH transit program embraced the following research areas in the Task Order (TO) 4000 series, RTA's or outside funding sources:

- We conducted significant research in the area of Bus Rapid Transit (BRT) investigating issues related to enabling technologies, evaluation and deployment planning to assist transit agencies for near term BRT planning. As an example, PATH has developed an Adaptive Bus Signal Priority System concept that enables buses to gain priority at the intersection while minimizing the disturbance to other traffic. PATH also conducted research on advanced BRT concepts. In August 2003, PATH demonstrated Automated Bus Rapid Transit System components on I-15 in San Diego.

- Demand Responsive Transit (DRT) and Paratransit provide critical links for transit dependent riders to gain mobility, but have been less cost effective for the transit agencies to operate. PATH studies address factors influencing productivity and operating cost of DRT and develop approaches for improving cost effectiveness.

- Transit IVI is an initiative by the US Department of Transportation to improve transit safety. Under the sponsorship of Federal Transit Administration, PATH is working with transit agencies, Caltrans and bus manufacturer and suppliers to develop requirement specifications for a frontal collision warning system.

Bus Rapid Transit

Assessment of BRT Opportunities in the San Francisco Bay Area, RTA 20829; Mark Miller, California PATH.

Use of Refined Toolset with California Bus Rapid Transit Concepts, TO 4400; Tunde Balvanyos, California PATH.

Field Evaluation of VTA Line 22 Bus Signal Priority System, TO 4406; Yafeng Yin, California PATH.

Development of an Adaptive Transit Signal Priority System, RTA 18364; Wei-Bin Zhang and Hongchao Liu, California PATH.

Deployment Planning for Bus Rapid Transit, RTA 18365; Mark Miller, California PATH.

Development of Precision Docking Technologies for Transit Operation, MOU 397: Wei-Bin Zhang, California PATH.

Development Needs and Requirements for Transit Lane Assist Systems, RTA 20866; Wei-Bin Zhang, California PATH.

Demonstration of Automated Bus Rapid Transit System

PATH Demo 2003, TO 4228; Ching-Yao Chan, California PATH.

Development of Demonstration Systems for Demo 2003, TO 4229; Ching-Yao Chan, California PATH.

Magnetometer/GPS/INS Demo 2003 Support and Mitigation of GPS Signal Blockage Research, TO 4232; Jay Farrell, University of California, Riverside.

Evaluation of Truck and Bus Automation Scenarios, TO 4236; Jan Botha, San José State University. Randolph Hall, University of Southern California, and H.-S. Tsao, San José State University.

Cooperative Vehicle Highway Automation Systems (CVHAS) Pooled Fund Study Case Study Analysis, TO 4401; Steven Shladover and Mark Miller, California PATH.

Coordination Layer Control Design for Automated Trucks and Buses, TO 4237; Xiao-yun Lu, California PATH.

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

On-Demand Responsive Transit

Personalized Demand Responsive Transit Service, TO 4102; Y.B Yim, California PATH.

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

Bench Marking Best Practice of Demand Responsive Transit System, TO 4108; Maged Dessouky, University of Southern California.

High Coverage Demand-Responsive Transit: A New Design Concept and Simulation Evaluation of Operational Schemes for Future Technological Deployment, TO 4111; R. Jayakrishnan, University of California, Irvine.

Evaluating the Impact of ITS on Personalized Public Transit, TO 4114; Maged Dessouky, University of Southern California.

Dynamic Transit Schedule Information via Wireless Handheld Devices, TO 4125; Raja Sengupta, University of California, Berkeley.

Assessment of Service Integration for Public Transportation, TO 4152; Mark Miller, California PATH.

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

Transit Intelligent Vehicle Initiative

Transit Bus Collision Warning Systems Integration Program, RTA 20855; Wei-Bin Zhang, California PATH.

Development of Performance Specifications for Frontal Collision Warning System (FWCS), TO 4231; Wei-Bin Zhang, California PATH.

Rapid Transit San Pablo Ave Corridor

Demand Responsive Transit Vehicle

Forward Collision Warning Bus

FCWS Sensors Evaluated

FCWS LED Warning Lights

2003

Smart Buses, Smart Intersection Shine at Washington IVI Meeting

Ching-Yao Chan, Jim Misener, Joanne Lins
California PATH

Driver Infrastructure Interface (DII) in its 3 stages

C alifornia PATH staff demonstrated the results of three current research projects at the National Intelligent Vehicle Initiative (IVI) Meeting held in Washington, DC from June 24-26, 2003. The technically successful demonstrations, held at the Turner-Fairbanks Federal Highway Administration (FHWA) Research Center, in McLean, Virginia, won high praise and contributed significantly to the IVI meeting. They illustrated the professionalism and technical capabilities of PATH teams, and promoted awareness of PATH among peers and transportation organizations around the world.

Intersection Decision Support

One demonstration introduced an intelligent intersection, the product of the Intersection Decision Support (IDS) project sponsored by the FHWA and Caltrans. PATH demonstrated a promising, near-term deployable IDS system that warns drivers when it is unsafe to make a permitted left turn in the face of an oncoming vehicle. Using multiple detection and sensing devices (including Lidar, radar, inductive loop detectors and in-vehicle GPS), the system can identify and track vehicles approaching the intersection in real time. A central processing unit (CPU) fuses the vehicle motion data from the sensors with the signal timing and phasing data sent from the intersection's traffic controller to run a decision making algorithm. When conditions for making a left turn are unsafe, the system triggers a large flashing "No Left Turn" road sign to warn drivers of a hazard. The circle/slash under the "No Left Turn" arrow not only flashes, but grows 50 percent in size and thickness. This apparent "looming" motion affects the fastest and most sensitive pathways in the visual nervous system and makes the sign especially visible. The sign is placed just above eye level at the opposite corner of the intersection. IEEE 802.11a wireless communication is also incorporated in the system, to allow direct communication between the CPU and approaching vehicles, which could provide information directly to in-vehicle devices.

Gap Between Bus and Platform
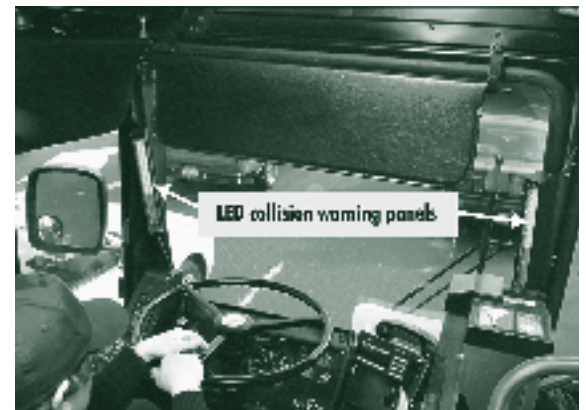
Frontal Collision Warning System

PATH'S second demonstration featured Frontal Collision Warning Systems on a San Mateo Transit bus, a project sponsored by the Federal Transit Administration (FTA). The demo showed how bus drivers can benefit from a warning system that uses radar, lidar, and computers to "watch" the operating environment and a driver-vehcle interface to warn the driver of a possible frontal collision. For several years, PATH has conducted research to understand the causes and consequences of transit frontal collisions. The knowledge gained has led to the development of a prototype collision warning system that provides the driver with an effective warning when the system determines that a potential collision may occur. Based on a well established data fusion model, a preliminary detection algorithm was developed that can track different obstacles within the sensor field of view and can decouple the bus motion from the sensor measurements. A warning algorithm was also developed to incorporate a warning threshold synthesized from the drivers' normal braking behavior. When the system determines that the distance to a vehicle or obstacle in front of the bus is closing too rapidly, it lights up two orange LED lightbars mounted on each side of the windshield. The LED elements are illuminated sequentially, giving

Driver Vehicle Interface for Forward Collision Warning System

the illusion of a moving bar of light. The more imminent the collision, the longer and faster the bar moves. This prototype has been put into regular transit service for field testing, to verify if the performance requirements developed under this project are within a reasonable and reachable range.

PATH human factors researchers worked closely with SamTrans drivers to understand their needs and expectations and their operational environment, and to define system boundaries. Drivers' inputs and their active involvement in brainstorming different design options greatly contributed to the design of the prototype Driver Vehicle Interface (DVI). Through extensive field tests and close interaction with bus drivers, the system is being improved, and is now being integrated with side collision warning system through a joint effort by a California and Pennsylvania partnership to provide an integrated solution for transit collisions.

Precision Docking

The third demo showcased precision docking, an essential element of Bus Rapid Transit (BRT) operations. The PATH system involves a variety of BRT technologies implemented on a 40-ft compressed natural gas (CNG) bus, made possible by a FTA lane-assist project and a Caltrans BRT development project.

In the precision docking demonstration, the bus steered itself along a demonstration course representing the path a bus would take to approach a curbside bus stop. The bus was completely computer-controlled, automatically following a series of magnets that defined the course, and using a smooth speed profile for its acceleration and braking.

A 90-meter-long path of magnetic markers was placed on the roadway surface, 1.2 meters apart, to form a reference trajectory. Using PATH's magnetic guidance system and highly sophisticated signal processing techniques, an onboard computer directs a steering input to an actuator on the steering column, which steers the bus precisely along a desired trajectory, with a tolerance of approximately one centimeter. The bus is also equipped with throttle and brake control systems that allow it to stop within ten centimeters of a designated location. With these capabilities, buses can be automated to dock precisely at bus stops, thus providing easy access and enhancing passenger safety. When combined with a boarding platform that is at the same level as the floor of the bus, precision docking eliminates the need for stepping up into the bus, which can be difficult for elderly or persons with mobility impairments. It also eliminates the need for wheelchair lifts or similar costly devices.

The PATH precision-docking bus provides highly reliable and accurate performance. Several LED lights on the dashboard inform the driver about the status

Precison Docking Bus and Course

Intelligent Intersection at FHWA Turner-Fairbanks Research Center

Magnetometer and Magnets for PATH's Magnetic Marker Reference System

and readiness of the bus and the docking systems. The driver can easily select between full and partial automation, and make the transition smoothly.

Because the guidance system eliminates driver variation and driver error in steering, a guided vehicle is capable of precise lane-keeping. The result can be a significant reduction in accidents involving side collisions to transit buses, collisions at bus stops, and passenger injuries during boarding, alighting, bus starting, bus stopping and bus turning. Guided pathways could also reduce scrapes at narrow toll booths and at the bus wash.

PATH's technical staff has considerable experience and expertise in vehicle guidance systems and safety applications. PATH was instrumental in developing and deploying technology for the National AHS Consortium 1997 Demonstration, and many other international technology demonstrations. In recent years, PATH technologies have been deployed on snow removal equipment (snowplow and snowblower) under the sponsorship of Caltrans.

PATH Demonstrates Automated Bus Rapid Transit Technologies

Steven E. Shladover

PATH researchers demonstrated some of the key technologies for automated bus rapid transit (A-BRT) services for invited visitors in San Diego on the weekend of August 23-24. This demonstration continued a distinguished PATH tradition of demonstrating the most advanced ITS capabilities under realistic conditions on full-scale vehicles, and true to that tradition it exceeded the expectations of the visitors.

PATH has equipped three transit buses with the sensing, actuation, communication and computation systems needed to enable them to operate under completely automatic control. At the same time, these buses were equipped with a specially-designed driver-vehicle interface (DVI) system to show how easy it is for the driver to interact with the automation systems, to transfer back and forth between normal manual driving and automation and to initiate automated maneuvers such as lane changing on the highway and precision docking at local bus stops. The emphasis of this demonstration was showing the realistic opportunities for implementation of the A-BRT technologies to improve transit service and economics. Since the demonstration buses were two standard-size (40 foot) buses powered by compressed natural gas (CNG) and one 60-foot articulated bus powered by a diesel engine, it was also possible to show how the automation technologies can harmonize the performance of these very different vehicles so that they can operate close together in an electronically-coupled "virtual train".

The transit service functions that were demonstrated included:

Precision Docking Demonstration

• **Precision docking** of a bus at two different platforms, one representing an in-line platform at a bus terminal and the other representing a curb-side platform requiring an approach with a lane change ahead of a line of parked cars. In both cases, the bus stopped with a gap of less than an inch between the bus floor and the platform, making it easy for one of visitors to roll on and off the bus in a wheelchair. Both the steering and the stopping of the bus were controlled automatically, although initial deployments of this service would probably only use the automated steering function, leaving the full attention of the driver for watching out for pedestrians and passengers.

• **Automatic lane-keeping** (or lane assist) of the buses operating in a line-haul mode on the I-15 HOV lanes. This demonstration showed the ability of the automatic steering system to keep the bus centered accurately over the lane, while providing a smooth ride for the passengers. This is an important capability to enable buses to operate in narrow lanes where right of way is costly or unavailable. The driver was able to switch back and forth between automatic and manual steering at will, showing how a driver could override the automatic system when necessary.

Lane Assist Demonstration

• **Automatic lane-changing** while operating on the highway, initiated by the driver pressing a button on the DVI. In order for buses to be able to enter or exit from an A-BRT bus-way, or from off-line stations, it is necessary for them to be able to change lanes automatically. This part of the demonstration showed the ability to execute this maneuver repeatedly, with a minimum of effort required by the driver.

• **Fully automated bus driving**. The buses were operated in both low speed (docking) and high speed (highway driving) conditions with fully automatic steering and speed control. Once the driver trans-

Driver Vehicle Interface (DVI)

ferred control to the automated system, he did not need to do anything else until reaching the other end of the HOV lanes, where he regained control. This capability indicated the potential for future operations without requiring a driver to be on every bus operating along a dedicated, protected bus-way. However, the technology is not yet sufficiently mature and fault-tolerant to make it possible for our drivers to leave the driver's seat (except in the limited case of the low-speed precision docking maneuver).

• **Automated "virtual train"** of buses. The diesel bus was electronically "coupled" behind one of the CNG buses for a run down the length of the I-15 HOV lanes (8 miles), making use of a "WiFi" wireless data link, combined with forward-looking lidar and radar sensors to detect the gap and speed difference between the buses. The buses ran at separations of 40 m and 15 m to each other and smoothly performed the automatic transitions between these two different target separations. The operations at the 15 m separation showed the potential for automated bus trains to carry very high passenger volumes in the highest- density corridors. With that size separation between the buses in the "virtual train", and with a long enough separation between consecutive bus trains to ensure that no failure would involve more than one bus train, a sequence of three-bus trains could provide 70,000 seats per hour in one lane, which is competitive with the highest-volume rail transit services.

The visitors who participated in this demonstration included members of the Board of Directors of ITS America and the Program Steering Committee of the Cooperative Vehicle-Highway Automation Systems (CVHAS) pooled-fund project, as well as the attendees of the TRB meeting on "Urban & Community Transit – The Role for Automated BRT". The reactions of the visitors were very enthusiastic. For example, Neil Schuster, the President and CEO of ITS America, said,

"The San Diego demo went very well and I know our members enjoyed it; this is the fourth time I've seen the technology in action, and each time I'm amazed - now I can tell friends I rode in a city bus, going down a real highway at speed, too close to a bus in front of us for a human driver to attempt. For me, the expression on someone's face the first time they comprehend they are in a moving vehicle without a driver is priceless!...what a great morning!"

The discussions in the TRB meeting that immediately followed the demonstration were strongly influenced by many comments indicating that the demonstration changed people's minds about what was possible and opened their eyes to new possibilities for using vehicle automation technology to improve transit operations. That, of course, is one of the strongest reasons for investing the effort to present such a demonstration.

The efforts were considerable and involved extensive time spent away from home by a team of fifteen PATH research and development engineers, working under the leadership of Dr. Ching-Yao Chan. Their work schedule was governed by the limited availability of the I-15 HOV facility for testing in preparation for the demonstration. All of the preparatory testing needed to be conducted during the four weekends prior to the demonstration (8 am to 8 pm each day) and during the weeknights in the two weeks immediately before the demonstration (8 pm to midnight). With outstanding cooperation and support from Caltrans District 11 and Division of Research and Innovation (DRI) colleagues, extremely rapid progress was made during that final month of preparations for the demonstration.

Close Following Bus Platoon Demonstration

Automated Rotary Plow Demonstration

Han-Shue Tan

The snow falls. It falls thickly, saturating the air, swirling on gusts of wind. At times, white, dull white striking your windshield is all you can see. You pass by Donner Summit, on I-80, tires skidding slightly on the freshly plowed road. The snow clears slightly, and you are greeted with the sight of a huge machine, a 20-ton snowblower, blowing snow out next to the guardrail. As you continue on, you take note of the perfect straight line of snow along the guardrail. Passing by, you are further surprised by the fact that the driver waved at you, smiling; you get the feeling that his hands are not on the wheel. The goal of PATH researchers is to make this scene real.

Background

A snowblower, a.k.a rotary snowplow, is a massive snow removal apparatus that blows snow high into the air and off the roadway. It is a key component of the snow removal strategy employed by the snow fighters, especially on mountainous highways. To achieve effective removal of the snow built up along the roadside created by either a single snowplow or a fleet of snowplows, the operator needs to drive the snowblower at the edge of the road and often with a very tight tolerance range in order to eliminate the left-over snow "bleeding" back into the highway. This tactic makes it a difficult task when the snowblower is operated along a guardrail.

An operator generally uses the rear steering joystick to position the snowblower to the appropriate "crab" angle before he reaches a section of guardrail. The operator then drives the huge vehicle body toward the guardrail until the front side of the blower head touches

it. He then "tries" to maintain a somewhat constant contact between the blower head and the guardrail using his hands (feeling the pressure), his ears (hearing the contact sounds), and his eyes (looking for the snow poles and obstacles) as he plows forward. Since the blower head can weigh up to 6 tons, it creates a natural oscillation when it hangs in front of the snowplow body. Consequently, the snowblower continuously "bounces" in and out of the guardrail. "Riding on the guardrail," as the operators commonly put it, creates damages such as tilting, ripping and tearing of the guardrail that can be easily identified by travelers. This damage leads to frequent repairs and replacements of guardrail in the treacherous mountain regions. While guardrails require rehabilitation throughout all the areas maintained by the Department of Transportation, the frequency of rehabilitation due to snowblower damage, typically once every two years, represents a significant cost, thus becoming an opportunity for excellent return through application of advanced technologies such as precision steering control. Application of precision steering control, if successful, will reduce, even eliminate contact of the snowblower with the guardrail, while also improving the repeatability and accuracy of the work performed. Furthermore, the application will increase operational safety by allowing the operator to concentrate on "plowing" and remove the exhausting "drive by feel" as well as reduce the operator's visual fatigue.

In 2000, the Advanced Highway Maintenance and Construction Technology Center (AHMCT) at University of California Davis, PATH and Caltrans started a pooled fund study, "Development of the Advanced Rotary Plow (ARP) for Snow Removal Operations," with Nevada and Alaska's DOT as partners. Caltrans manages the overall project and coordinates resources for field tests and evaluation. AHMCT conducts feasibility studies on the radar warning system, GPS application and rotary protection device. PATH is responsible for the design and development of the ARP automated control

system, ranging from the system architecture design, to hardware installation. PATH is also accountable for the development of sensor signal processing and control algorithms, as well as the human machine interface, operator training, and performance evaluation and field operational tests. The ultimate goal of this project is to develop a prototype automated snowblower that will be used by Caltrans operators and can perform real snow removal operations under harsh winter environments.

Demonstration

On October 15, 2003, Caltrans conducted an ARP ride-along Demonstration to more than 30 stakeholders from 3 states at Kingvale using a simulated guardrail under various operational scenarios for over 3 hours. All participants were impressed by the performance. We were especially surprised by the positive comments from those who had previous experience working with snow removal equipment. Comments like

"It works!" and *"Having the system keep the front in (on the guard rail) while the operator can use the rear steer for different snow accumulations and (road) turns is just what we need."* were timely encouragements to us in facing the next big challenges: blowing snow along I-80! New "realities", such as huge potholes on a tilted shoulder, "missed" or displaced magnets, hitting big ice packs, snow chains, and driver interferences, would show up and challenge the system when the snow hits the blower, and we hope we are ready to face and overcome them.

Deployment

Looking forward, we hope to conduct the first field-testing and evaluation along the I-80 guardrails before the end of this winter. Based on the data collected, human factor studies, and the operators' feedback, we will upgrade and redesign the prototype system

during the summer and fall of 2004. Full winter field operational tests are then anticipated during winter 2004/2005. However, when the questions like "where can be we buy it?" or "when can we get it?" kept coming out, we got a sense that we might be successful enough to have some people look over the performance feasibility question and start asking about the question of deployment feasibility – the eventual objective of Caltrans. The issues of maintainability, cost effectiveness, reliability, and commercialization feasibility will then have to come to the forefront. As for now, the $50 k price tag on the current prototype equipment installed on the snowblower seems to be a good start. Meanwhile, we have work to do before this winter ends.

Center for the Commercialization of ITS Technologies renamed to California Center for Innovative Transportation

During the summer of 2003, California PATH and CCIT were reorganized by the University of California in collaboration with the California Department of Transportation (Caltrans). CCIT was spun off from the PATH program and is now a stand alone center within UC Berkeley's Institute of Transportation Studies. A major motivation for the reorganization was to expand CCIT's mission to include deployment support to facilitate and accelerate implementation of transportation technologies that are developed by all the centers that are funded by Caltrans. Among the centers are PATH, Advanced Highway Maintenance and Construction Technology (AHMCT), Traffic Safety Center and the Advanced Pavement Research Center. In addition CCIT is charged with integrating the Berkeley Highway Lab (BHL) at UC Berkeley, and the testbeds at UC Irvine. At a recent meeting with Caltrans, CCIT was given the lead to work with Caltrans-funded centers and Caltrans Divisions to develop a process to improve Caltrans ability to take projects from research to deployment. As a result of the reorganization and its expanded mission, CCIT was renamed the California Center for Innovative Transportation.

CCIT Projects in 2003 (some projects are funded through PATH)

Corridor Management Plan

The goal of the Corridor Management Plan is to develop a standard corridor planning template for Caltrans that will allow for effective decision making in addressing transportation needs. This multi-modal project incorporates system monitoring, infrastructure maintenance, demand management, incident management, traffic control, and traveler information through intelligent transportation system (ITS) applications. The Corridor Management Plan project was launched in 2003.

Incident Detection Camera Network

CCIT is evaluating automated video incident detection systems from two vendors in a trial conducted by Metropolitan Transportation Commission (MTC) and Caltrans. The systems were installed at three Bay Area locations. An evaluation plan was drafted, data will be evaluated as it becomes available.

Innovative Corridors Initiative (ICI)

In fall 2003, the California Department of Transportation (Caltrans), the Metropolitan Transportation Commission (MTC), and the Los Angeles County Metropolitan Transportation Authority (LAMTA) formed a partnership, coordinated by the ICI project staff, to test a new way of doing business for the agencies and a new way of interacting with industry. The goals are to accelerate mainstreaming of Intelligent Transportation Systems (ITS), to test a new business model, and to gain better real-time information about the transportation system. In the fall the partners issued a Call for Submissions which invited industry to propose innovative ITS pilot projects. The purpose of the pilot projects is to test and illustrate traveler services that facilitate mobility, convenience, and safety to travelers. Proposers that are selected will have an opportunity to showcase their projects as part of the 2005 ITS World Congress in San Francisco. It is expected that project participants will receive considerable exposure from the World Congress, as well as unique public right-of-way access opportunities.

Berkeley Highway Lab

Evaluations of new digital video systems to replace the existing analog video data collection system were started. The new system will send video data from eight cameras in real time or near real time, have complete coverage of 1 km of I-80 in both directions, and have better image quality which will improve tracking performance. The new system should be operational by May 1, 2004.

Freeway Performance Measurement System (PeMS)

The Freeway Performance Measurement System or PeMS is an on-going research, development, and deployment project. PeMS is a web-based database system that collects and stores data from Caltrans

freeway loop detectors. In addition to offering real-time and historical data, PeMS has many built-in applications that process these data and covert them into useful information to help manage the transportation systems and other types of analysis. In 2003, the training materials for PeMS were completed and included the latest version of the PeMS software. A pilot training session was successfully conducted in Sacramento in 2003. The migration of the PeMS software to a Caltrans server has been started.

Smart Parking Management Pilot Project: A Bay Area Rapid Transit (BART) District Parking Demonstration Expansion and Year Two Research Evaluation

The two-year smart parking pilot project is a partnership among Innovative Mobility Research (IMR) at CCIT, the California Department of Transportation (Caltrans), the Bay Area Rapid Transit (BART) District, and ParkingCarma. This pilot will use communication technologies to better manage existing parking at and around a transit station to increase parking capacity and improve transit access. Research efforts accomplished to date include a comprehensive review of smart parking technologies as well as initial user evaluations that include observational analyses, focus groups, and surveys. After a review and testing of technology, the pilot will be launched at the Rockridge BART station in the East Bay of the San Francisco Bay Area in spring, 2004.

Improving Bay Area Rapid Transit (BART) District Connectivity and Access with the Segway Human Transporter and Other Low-Speed Mobility Devices

The low-speed modes project is a partnership among Innovative Mobility Research (IMR) at CCIT, the California Department of Transportation (Caltrans), Segway LLC, and the Bay Area Rapid Transit (BART) District. This two-year research program was launched to evaluate the use of low-speed modes to improve transit access in a suburban location. The research and feasibility analysis of the project was completed this fall. The result is a plan to test a pilot program that introduces shared Segway HTs, electric bicycles, and bicycles to the Pleasant Hill BART station in the East San Francisco Bay Area and surrounding employment centers. A presentation on the safety of low-speed modes was made at TRB this winter based on the results of this research.

ITS Benefit-Cost Website

ITS Benefit-Cost Website is a comprehensive web-based source of instruction and information on applying benefit-cost analysis to transportation investment decisions. It will contain instructional material on the use of benefit-cost analysis methodology for varying levels of expertise, methods and models for benefit-cost analysis, and instructions on how to obtain and use them. In 2003, the website was designed and constructed and content was accumulated.

Carsharing Education and Outreach

Innovative Mobility Research (IMR) manages a contract that supports carsharing through research and outreach. The Caltrans Division of Mass Transportation (DMT) has partnered with IMR on this initiative in response to the state's Interregional Transportation Improvement Program (ITIP) goals to "reduce congestion and promote livable communities." The project includes a research component that tracks insurance and other data on carsharing organizations nation-wide. Thus far, outreach efforts have included two presentations at TRB and the website design. In addition, planning is in process for a transportation fair, with a unique mobility theme, that will take place on June 2, 2004 in Sacramento. IMR is working with state and local government, local transportation providers, and planning agencies to promote mobility options for state workers and others employed in downtown Sacramento.

ITS Decision Support Website

The ITS Decision website is intended to be a gateway for objective information regarding the nature and performance of various Intelligent Transportation Systems or ITS services. The site provides objective information about ITS Services and Technologies and their performance, presented at varying levels of detail, from brief summaries to detailed reports to the online library of published Reports and Articles. In 2003, the work on this long running project continued and it involved keeping track of the site contents, regular material updating, scheduling new additions and updates; supervising creation of new content and editing; publicizing and monitoring the usage.

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

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

SCOPE AND COVERAGE

The Database contains references to all aspects of Intelligent Transportation Systems, ranging from historical materials dating back to the 1940s to topics of current and international research and applications. It reflects a wide coverage of information on ITS, including monographs, journal articles, conference papers, technical reports, theses, web sites, and selected media coverage. Currently there are over 28,000 records with abstracts contained in the Database. Full bibliographic information is provided, and URLs are included for documents that are available full-text in electronic format.

ACCESS AND AVAILABILITY

To access the California PATH Bibliographic Database, go to:

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

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

http://www.lib.berkeley.edu/ITSL/newpath.html

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

http://www.lib.berkeley.edu/ITSL

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

Seyem Petrites, Database Librarian at:
spetrite@library.berkeley.edu

Policy and Behavioral Research

U.S. Shared-use Vehicle Survey Findings: Opportunities and Obstacles for Carsharing and Station Car Growth
Susan A. Shaheen, Mollyanne Meyn, Kamill Wipyewski
The paper first presents an overview of market growth for shared-use vehicle programs since 1998, looking at topics such as organizational size, partnerships, pricing, costs, and technology. The authors discuss the emergence of more growth-oriented organizations, total membership, and vehicle trends. In the second section, the authors examine several challenges facing organizations and explore opportunities for overcoming them. The report concludes with a summary of key observations and conclusions.
UCB-ITS-PRR-2003-20
June 2003
19 pp., $5.00

Davis Smart Mobility Model Project: Initial Scoping and Planning Study
Susan A. Shaheen, Rachel S. Finson
This report presents the initial scoping and planning for the Davis Smart Mobility Project, a project designed to optimize individual mobility options through improved connectivity among modes, enhanced techniques to link land-use planning and transportation system design, advanced information technologies, and clean-fuel vehicles. The report is presented in three parts: Part One: Orientation to campus planning environment and campus long range development; Part Two: Develop and summarize mobility opportunities analysis; and, Part Three: Purchase video conferencing equipment for UC Davis Institute of Transportation Studies.
UCB-ITS-PRR-2003-21
June 2003
39 pp., $10.00

University of California, Davis Long-Range Development Plan: A Davis Smart Mobility Model
Susan Shaheen, Caroline J. Rodier, Rachel S. Finson
The goal of the Smart Mobility Model project was to optimize individual mobility options through improved connectivity among modes, enhanced techniques to link land use planning and transportation system design, advanced information technologies, and clean-fuel vehicles. The report includes the following sections: 1) the UC Davis campus-planning environment including a description of the campus long-range development plan; 2) a summary of innovative mobility options and their potential opportunities and barriers associated in the context of the campus-planning environment; 3) focus group results, reflecting response of UC Davis participants to a range of innovative mobility options; 4) a simulation analysis of innovative mobility options favored by focus group participants for estimating potential future reductions in auto travel and emissions as well as increases in net economic benefits;5) a summary of the results of the UC Davis Travel Survey to assess current travel patterns and needs; 6) a list of innovative mobility options reflecting the results of the focus groups, simulation study, and survey; and, 7) conclusions regarding the need for innovative mobility services in the community and near term prospects.
UCB-ITS-PRR-2003-28
October 2003
184 pp., $25.00

Transportation Safety Research

Evaluation of the Effects of Intelligent Cruise Control Vehicles in Mixed Traffic
Petros Ioannou
This report describes two research tasks. In the first task, the authors examine the mixed manual/adaptive cruise control (ACC) traffic characteristics on the microscopic level during disturbances that may arise due to high acceleration maneuvers and lane changes. The effect of the ACC vehicles on the environment is evaluated using an emissions model. Results show the beneficial effects of ACC vehicles. Sensitivity curves are developed showing the variation of the benefits with respect to the different variables. In the second task, the authors describe the macroscopic analysis of mixed manual/semi-automated traffic. Focus is on the fundamental traffic flow-density diagram and traffic flow disturbances such as shock waves. The authors also show using queuing theory the effect of semi-automated vehicles on the average delay and number of vehicles in a queue on the highway during the presence of shock waves that produce stop-and-go traffic. The report demonstrates that the presence of ACC vehicles will attenuate shock waves and pass them on to the vehicles upstream in a much faster way than in the case of manual vehicles due to the shorter reaction times that characterizes the ACC vehicle.
UCB-ITS-PRR-2003-2
January 2003
64 pp., $15.00

Evaluation of the ACC Vehicles in Mixed Traffic: Lane Change Effects and Sensitivity Analysis
Petros Ioannou, Margareta Stefanovic
This report examines the sensitivity of results obtained in earlier studies with respect to several variables such as level of disturbance, percent penetration of the adaptive cruise control (ACC) vehicles, etc. It also evaluates the effect on lane changes on traffic flow characteristics on the microscopic level and environment. The report demonstrates that during lane changes, the smoothness of the ACC vehicle response attenuates the disturbances introduced at the cut-in or exiting vehicle in a way that is beneficial to the environment when compared with similar situations where the ACC vehicle is absent.
UCB-ITS-PRR-2003-3
January 2003
32 pp., $10.00

Enhanced AHS Safety Through the Integration of Vehicle Control and Communication
J.K. Hedrick, R. Sengupta, Q. Xu, Y. Kang, C. Lee
In this report, the authors focus on incorporating the vehicle-vehicle/roadside-vehicle (V-V/R-V) communication design and the adaptive cruise control/cooperative adaptive cruise control (ACC/CACC) system design. They also study the influence of such design on the behavior of highway vehicles on both microscopic and macroscopic levels. The authors first describe the two specification communications concepts that were applied. The next describe the simulation scenarios and the system modelling for the simulation, as well as reporting the results of the simulation.
UCB-ITS-PRR-2003-4
January 2003
54 pp., $15.00

Safety Performance and Robustness of Heavy Vehicle AVCS
Paul Yih, Krishna Satyan, J. Christian Gerdes
This report describes the development of a multi-body dynamic model of a tractor semitrailer using a commercially available dynamic analysis software program. A survey of heavy truck literature was used to determine model parameters. The report discusses different types of component configurations as well as providing numerical ranges for important physical parameters. It proposes several safety performance measures along with associated maneuvers, designed to serve as a test for quantifying overall safety of the controlled vehicle.
UCB-ITS-PRR-2003-5
February 2003
99 pp., $15.00

Evaluation of Magnetic Markers as a Position Reference System for Ground Vehicle Guidance and Control
Ching-Yao Chan, Han-Shue Tan
This report evaluates sensing techniques and implementation issues of magnetic sensing as a position reference system. The field patterns of sample magnetic markers were measured to show the characteristics of the systems. Different sensing approaches were explained and compared regarding their functioning principles and sensitivity to measurement variations. Three algorithms were discussed with illustrations of respective mapping methods. A framework for dealing with technical limitations and objectives is presented. The constraints and preferences of sub-systems and the corresponding issues are indicated.
UCB-ITS-PRR-2003-8
March 2003
26 pp., $10.00

Lateral Control of Heavy Vehicles for Automated Systems: Final Report for MOU 313
Pushkar Hingwe, Jen-Yu Wang, Meihua Tai, Masayoshi Tomizuka
This report presents five lateral control methodologies for tractor-semitrailers. The methodologies address the following challenges which arise in controlling heavy vehicle lateral dynamics: 1) large inertia which causes slower response to steering; 2) inherent non-linearities in the vehicle model such as the longitudinal velocity and tire lateral force saturation; and, 3) unusually large uncertainties in vehicle parameters and environmental disturbances. The report presents an analysis and synthesis of control algorithms based on system identification and calibration results. Results from closed loop experiments are presented. The limits and performance of sensors, actuators and control schemes as inferred from data collected during the closed loop experiments are presented. In addition, baseline safety requirements based on closed loop data.
UCB-ITS-PRR-2003-10
March 2003
73 pp., $15.00

Experimental Verification of Discretely Variable Compression Braking Control for Heavy Duty Vehicles
Ardalan Vahidi, Anna G. Stefanopoulou, Phil Farias, Tsu Chin Tsao
This report proposes a recursive least square scheme with multiple forgetting factors for on-line estimation of road grade and vehicle mass. These estimations can be used to make automatic controllers in conventional or automated heavy-duty vehicles more robust. The report describes experiments with measured test data in which the pro-

posed scheme estimates mass within 5% of its actual value and tracks grade with good accuracy. It discusses the experimental setup, signals, their source and accuracy. Issues such as the lack of persistent excitations in certain parts of the run, or difficulties of parameter tracking during gear shift are explained, with suggestions offered to bypass the problems. The report explains steps taken to develop the compression brake map, transmission map, and tuning a controller for coordinated user of service and compression brake. The test data are used in simulation to show that the inclusion of the splitting torques scheme resulted in a service brake use decrease of 90%.
UCB-ITS-PRR-2003-12
March 2003
50 pp., $10.00

Parameter Estimation and Supervisory Techniques for Robust Longitudinal Control of Heavy Vehicles

Maria Druzhinina, Lasse Moklegaard, Anna G. Stefanopoulou
In this report, the authors address the integration of vehicle retarders for safe automation of commercial heavy vehicles. They describe the development and experimental validation of a coordination scheme between friction and discretely variable compression brakes for a Class 8 Freightliner truck used as a development platform in the California PATH program. The report describes the following: 1) experimental hardware and software set up; 2) open-loop experiments conducted to identify the models for the friction brake and the compression brake; 3) identification procedure of the friction brake and the compression brake characteristics and the identification results; 4) the development of the coordination scheme for the friction and compression brakes; and, 5) results of closed loop experiments validating the coordination scheme performance.
UCB-ITS-PRR-2003-15
April 2003
34 pp., $10.00

Parameter Estimation and Command Modification for Longitudinal Control of Heavy Vehicles

Hong S. Bae, J. Christian Gerdes
This report addresses the task of maintaining string stability in a platoon formation of heavy trucks. It proposes a new control scheme for putting on-line bounds, or artificial saturation, on command signals using parameter estimation such that all members in a platoon can follow the reference commands without saturating actuators and thus maintaining string stability. The report also describes two methods for obtaining an estimate of road grade using a Global Positioning System (GPS) on a ground vehicle. The resulting grade

measurements are used together with engine torque information to produce estimates of mass, rolling resistance and aerodynamic drag from a simple longitudinal force balance.
UCB-ITS-PRR-2003-16
April 2003
33 pp., $10.00

Definition and Evaluation of Bus and Truck Automation Operations Concepts: Final Report

H.-S. Jacob Taso, Jan L. Botha, Aleksandr A . Zabyshny and Jennifer E. Day
This report summarizes the major findings of a research report dealing with the definition and evaluation of bus and truck automation operations concepts. The report first describes and justifies the key elements of operating concepts for a bus-truck automated highway system (AHS), as well as their deployment sequences. It next discusses the needs of the long-haul trucking industry and discusses several major design options for inter-city truck automation. Two operating concepts are proposed and their deployment sequences are summarized. Possible deployment sites and key deployment issues are discussed. The report then provides the foundation for the comparative benefit-costs analyses. It also identifies and defines major benefit-cost elements for comparison between the proposed automated bus systems and their conventional counterparts.
UCB-ITS-PRR-2003-19
May 2003
104 pp., $20.00

Robust Lateral Control of Heavy Duty Vehicles: Final Report

Meihua Tai, Masayoshi Tomizuka
This report describes a project which focused on designing new controllers or redesigning existing controllers for the lateral control of heavy vehicles. It summarizes all types of nonlinear and adaptive controllers for the lateral control of heavy vehicles. Various nonlinear robust control techniques such as sliding mode control, adaptive robust control, and robust nonlinear control based on feedback linearization are examined. The controllers are implemented on a tractor-semitrailer combination and their experimental results are compared.
UCB-ITS-PRR-2003-24
July 2003
80 pp., $15.00

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

Guang Lu, Jihua Huang, Masayoshi Tomizuka
Reports findings on the design of controllers that use the output from only one set of magnetometers and the development of an autonomous lateral control scheme that uses no magnetometers. Experimental results are pre-

sented to validate the controller design. An autonomous vehicle following control scheme has been added as a backup system using a laser scanning radar (LIDAR). A backup lateral control system was developed using the LIDAR and rear magnetometers.
UCB-ITS-PRR-2003-26
August 2003
50 pp., $10.00

Enhanced AHS Safety Through the Integration of Vehicle Control and Communication

J.K. Hedrick, R. Sengupta, Q. Xu, Y. Kang, C. Lee
We comparatively assess the influence of adaptive cruise control (ACC) and cooperative adaptive cruise control (CACC) systems on highway traffic behaviors. The primary goal is to study the design and implementation of vehicle-vehicle/roadside-vehicle communication, which enhances an ACC system to a CACC one. In addition, the impact of market penetration of ACC/CACC vehicles and controller aggression are also evaluated. Two simulation works are presented. The microscopic work simulates a single ACC/CACC vehicle using MATLAB/SIMULINK. A cut-in scenario and a braking scenario are tested. Vehicle-vehicle communication saves control effort in the former scenario, while shows little effect in the latter. In the macroscopic work we simulate ACC/CACC controlled highway merging with SHIFT language. The results show beneficial effects of communication in terms of braking effort, average velocity, waiting-to-merge queue length, and main lane traffic shock wave caused by merging. The higher the market penetration of controlled vehicles the better the system performs. A vehicle-vehicle Location-Based Broadcast (LBB) communication protocol is designed to meet highway safety applications' communication requirements. An analysis is conducted in accordance to the communication condition in the newly-assigned 5.9 GHz Dedicated Short Range Communication (DSRC) spectrum.
UCB-ITS-PRR-2003-27
September 2003
106 pp., $20.00

Traffic Operations Research

The Automated Highway System/ Street Interface: Final Report

Randolph Hall, Chinan Chin, Nishad Gadgil
This report examines how highway design affects operational performance of automated highways with respect to accommodating entering and exiting traffic. It contains a summary of findings from prior work described in

PATH Working Paper 2000-26 and PATH Research Reports 2001-37 and 2002-7. In these reports, vehicle sorting processes for highway entrances were investigated, as well as placement and separation of entrances and exits. The report also provides analyses for vehicle sorting on highways, platoon formation on highways, and physical design of entrances and exits.
UCB-ITS-PRR-2003-6
February 2003
99 pp., $15.00

Bay Area Simulation and Ramp Metering Study – Year 2 Report

Yonnel Gardes, Amy Kim, Dolf May
This report describes the second phase of an ongoing project directed at developing and applying advanced simulation tools to investigate the effectiveness of traffic management strategies in improving transportation network performance. Focus is on modeling freeway operation with the Paramics microsimulation core model and its supporting modules such as an Application Programming Interface (API). The report first describes the process used in collecting the traffic data needed for calibrating and validating the model against current typical traffic conditions. It next describes initial tests with modelling high occupancy vehicle (HOV) lanes. HOV lane investigations on I-680 are described. With the addition of ramp metering, the process of implementing a particular ramp control strategy (ALINEA) through the use of APIs is next described. The report concludes with results presented for the scenario combining an added HOV lane and ramp control.
UCB-ITS-PRR-2003-9
March 2003
108 pp., $20.00

Development of Integrated Meso/ Microscale Traffic Simulation Software for Testing Fault Detection and Handling Algorithms in AHS: Final Report

Roberto Horowitz
This report describers a project which focused on bridging the simulation gap between the Automated Highway Systems (AHS) microsimulation software SmartAHS and the AHS mesosimulation software SmartCAP. This was done by implementing an integrated AHS micro-meso simulation environment for simulating a large scale AHS network, where both SmartCAP and SmartAHS run simultaneously and interact with each other. The report documents the theoretical design and software implementation of the integrated micro-meso simulator. In addition, it provides a brief tutorial on its use, including a sample AHS simulation example.
UCB-ITS-PRR-2003-13
March 2003
34 pp., $10.00

Validation of Daganzo's Behavioral Theory of Multi-Lane Traffic Flow: Final Report
James H. Banks, Mohammad R. Amin, Michael Cassidy, Koohong Chung
This report describes a study to validate a new macroscopic traffic flow theory by Daganzo, with the objective of providing a better understanding of freeway traffic flow and improving the basis for modeling and managing freeway traffic. Daganzo's theory focuses on the concept of motivation, the conditions under which it is gained or lost, and the consequences of transitions from motivated to unmotivated states. It essentially constitutes a new theory of how transitions from uncongested to congested flow take place. Validating the theory involved a literature review and a series of case studies of merge bottlenecks and flow recovery following the removal of incidents. Specific predictions derived from the theory were tested by determining the time and magnitude of changes in traffic characteristics such as flow, speed, occupancy, average time gaps, and the relative flows and speeds in different lanes. Results of the study suggest that some of the phenomena predicted by Daganzo's theory do occur. However, they do not occur at all locations, and the underlying behavioral assumptions are oversimplified.
UCB-ITS-PRR-2003-14
April 2003
93 pp., $15.00

Loop Detector Data Collection and Travel Time Measurement in the Berkeley Highway Laboratory
Adolf D. May, Randall Cayford, Ben Coifman, Greg Merritt
This document constitutes the final report on the Berkeley Highway Laboratory (BHL) Project which focused on maintaining, improving, and conducting research on the BHL detector system. The first part of the report describes efforts directed at ensuring that the BHL detector system was maintained, and data was stored and distributed to researchers. The second part of the report describes efforts which resulted in an improved BHL detector system. This included detector diagnostics, system monitoring diagnostics, and improved communications.
UCB-ITS-PRR-2003-17
April 2003
93 pp., $15.00

Freeway Performance Measurement System (PeMS)
Chao Chen
This dissertation describes the Freeway Performance Measurement System (PeMS). It first describes PeMS web-based applications, defining PeMS performance measures and explaining their roles in transportation management. PeMS applications, as well as an advanced traveler information system (ATIS) application and loop diagnostics applications are described. The study then demonstrates the potential of PeMS for academic research by describing three statistical studies on capacity analysis of bottlenecks, travel time variation in Los Angeles, and the impact of incidents on overall delay. The components that comprise PeMS, including data collection, sensor technology, database structure, and system architecture of PeMS applications are described. The study concludes with a description of several PeMS algorithms that correct data errors, calculate speed from single loops, predict travel times, and find shortest routes.
UCB-ITS-PRR-2003-22
July 2003
216 pp., $30.00

TRACER: In-vehicle, GPS-based, Wireless Technology for Traffic Surveillance and Management
M.G. McNally, J.E. Marca, C.R. Rindt, A.M. Koos
This report summarizes research on GPS-based in-vehicle data collection for both traffic operations and travel behavior. It first provides an overview of the research literature associated with Global Positioning Systems (GPS) applications in transportation. This is followed by an overview of an in-vehicle data collection system known as TRACER. The report next documents some of the initial field experience using the extensible data collection unit (EDCU) and provides a summary of initial tests of system functionality. Evaluation results for probe vehicle and route choice studies are presented. The report next describes the technical design parameters for the EDCU. An overview is then given of the TRAC-ERMap geographic information system (GIS) developed for analyzing the data from the EDCU. The report concludes with a discussion of future research directions.
UCB-ITS-PRR-2003-23
July 2003
80 pp., $15.00

The State of Cellular Probes
Youngbin Yim
This report investigates the current state of cellular probe technologies. It begins whit background information on the technology and how it has evolved in particular from 2000 to 2003. The report reviews recently conducted field tests of cellular probe projects, focusing on test results of the System for TRaffic Information and Positioning (STRIP) project in Lyon, France. Research on cellular probes conducted at the California PATH program is described. Privacy issues of wireless services are also discussed. The report concludes with a summary and recommendations for further study.

UCB-ITS-PRR-2003-25
July 2003
40 pp., $10.00

Relationships Among Urban Freeway Accidents, Traffic Flow, Weather, and Lighting Conditions
Thomas F. Golob, Wilfred W. Recker
In this paper, the authors apply linear and nonlinear multivariate statistical analyses to determine how the types of accidents that occur on heavily used freeways in Southern California are related both to the flow of traffic and to weather and ambient light conditions. Traffic flow is measured according to a time series of 30-second observations from inductive loop detectors near the accident location. Results show that the type of collision is strongly related to median traffic speed and to temporal variations in speed in the left and interior lanes. Hit-object collisions and collisions involving multiple vehicles that are associated with lane-changing maneuvers are more likely to occur on wet roads, while rear-end collisions are more likely to occur on dry roads during daylight. Evidence also shows that controlling for weather and lighting conditions, accident severity is influenced more by volume than by speed.
UCB-ITS-PWP-2003-1
January 2003
25 pp., $5.00

Evaluation of Potential ITS Strategies Under Non-Recurrent Congestion Using Microscopic Simulation
Lianyu Chu, Henry X. Liu, Will Recker, Steve Hague
This report presents a micro-simulation method for evaluating potential Intelligent Transportation Systems (ITS) applications. A capability-enhanced PARAMICS micro-simulation model is used to model and quantitatively evaluate potential ITS strategies such as incident management, local adaptive ramp metering, coordinated ramp metering, and traveler information systems. An evaluation study is conducted on the effectiveness of potential ITS strategies under the incident scenarios over a corridor network located in Irvine, California. The scenarios are implemented and evaluated, based on the calibrated simulation model. Results from the evaluation show that all ITS strategies have positive effects on the network performance. Real-time traveler information systems were shown to have the greatest benefits among all single ITS components. A combination of several ITS is considered to generate better benefits.
UCB-ITS-PWP-2003-2
January 2003
52 pp., $15.00

Multi-Sensor Traffic Data Fusion
ZuWhan Kim, A. Skabardonis
In this report, the authors describe a unique surveillance system that was installed on a section of the I-80 freeway in Emeryville, California. Known as the Berkeley Highway Laboratory (BHL), the system consists of eight dual loop detector stations along the freeway section, and at twelve video cameras. In order to process the video data to generate vehicle trajectories, advanced machine vision algorithms were developed. The authors discuss current effort to fuse the loop and video detector data to obtain detailed and accurate information on traffic operating conditions.
UCB-ITS-PWP-2003-3
February 2003
17 pp., $5.00

Investigation of Traveler Information and Related Travel Behavior in the San Francisco Bay Area
Asad J. Khattak, Felipe Targa, Youngbin Yim
In this paper, the authors present the results of traveler response to Advanced Traveler Information Systems (ATIS) using several surveys conducted for the TravInfo evaluation study. A conceptual structure of the traveler information system, based on earlier work, is first presented. The authors discuss traveler behavior and information, factors affecting traveler response to ATIS, and evaluation issues. The goals and objectives of the TravInfo project are then described, as well as the structure of the project evaluation as a field operational test. Conclusions are reported, based on the results of the traveler response surveys and empirical findings documented in earlier studies.
UCB-ITS-PWP-2003-6
March 2003
30 pp., $10.00

Institutional, Organizational and Market Aspects of Successful ITS Deployment: A Case Study Analysis
Patrick Conroy
In this research, the author follows on a previous study to explore key aspects of successful Intelligent Transportation Systems (ITS) deployment within existing institutional, organizational and market environments. Three additional case studies of successful ITS deployment in the U.S. and Europe were developed by the author, while one case from the previous work was revisited. The author presents results from literature searches, survey analyses, and findings on institutional, organizational and market factors.
UCB-ITS-PWP-2003-7
April 2003
31 pp., $10.00

Implementing a Kalman Filtering Dynamic O-D Algorithm within Paramics–Analysing Quadstone Won Efforts for the Dynamic O-D Estimation Problem
Reinaldo C. Garcia
This paper describes research in which a Kalman filtering (KF) algorithm was implemented for the dynamics and prediction of network origin destination (OD) matrices with only the traffic simulator Paramics. The paper describes the four advanced programming interfaces (APIs) that were developed in order to implement the KF algorithm within Paramics. The paper also discusses the proposed Quadstone (developer of Paramics) approach for developing a dynamic origin destination (O-D) estimation procedure.
UCB-ITS-PWP-2003-8
May 2003
19 pp., $5.00

A Tool to Evaluate the Safety Effects of Changes in Freeway Traffic Flow
Thomas F. Golob, Wilfred W. Recker, Veronica M. Alvarez
This study describes a tool developed for assessing the changes in traffic safety tendencies resulting from changes in traffic flow. The tool uses data from single inductive loop detectors, converting 30-second observations of volume and occupancy for multiple freeway lanes into traffic flow regimes. Each regime has a specific pattern of crash types determined through nonlinear multivariate analyses of over 1,000 crashes on freeways in Southern California. The analyses showed ways in which differences in variances in speeds and volumes across lanes, as well as central tendencies of speeds and volumes, combine in complex ways to explain crash taxonomy.
UCB-ITS-PWP-2003-9
June 2003
25 pp., $5.00

On the Numerical Treatment of Moving Bottlenecks
Carlos Daganzo, Jorge A. Laval
This report describes how moving obstructions can be modeled numerically with kinematic wave theory. It shows that if a moving obstruction is replaced by a sequence of fixed obstructions at nearby locations with the same capacity, the error then in vehicle number converges uniformly to zero as the maximum separation between the moving and fixed bottlenecks is reduced. This result suggests that average flows, densities, accumulations and delays can be predicted as accurately as desired with this method. An example is given, showing that any convergent finite difference scheme can be used to model moving bottlenecks.
UCB-ITS-PWP-2003-10
July 2003
29 pp., $10.00

Estimation of Truck Traffic Volume from Single Loop Detectors Using Lane-to-Lane Speed Correlation
Jaimyoung Kwon, Pravin Varaiya, Alexander Skabardonis
This paper proposes an algorithm that uses data from single loop detectors for real time estimation of truck traffic in multi-lane freeways. The algorithm can be used in those freeway locations that have a truck-free lane and exhibit high lane-to-lane speed correlation. Real time estimates of truck traffic volumes at the location are produced by the algorithm. It also can be used for producing alternative estimates of the mean effective vehicle length which can improve speed estimates from single loop detector data. Tests with real freeway data reveal that the algorithm produces estimates for truck traffic volumes with only 5.7% error, as well as capturing the daily patterns of truck traffic and mean effective vehicle length.
UCB-ITS-PWP-2003-11
July 2003
29 pp., $10.00

A Method for Relating Type of Crash to Traffic Flow Characteristics on Urban Freeways
Thomas F. Golob, Wilfred W. Recker
A method is developed to determine how crash characteristics are related to traffic flow conditions at the time of occurrence. Crashes are described in terms of the type and location of the collision, the number of vehicles involved, movements of these vehicles prior to collision, and severity. Traffic flow is characterized by central tendencies and variations of traffic flow and flow/occupancy for three different lanes at the time and place of the crash. The method involves nonlinear canonical correlation applied together with cluster analyses to identify traffic flow regimes with distinctly different crash taxonomies. A case study using data for more than 1,000 crashes in Southern California identified twenty-one traffic flow regimes for three different ambient conditions: dry roads during daylight (eight regimes), dry roads at night (six regimes), and wet conditions (seven regimes). Each of these regimes has a unique profile in terms of the type of crashes that are most likely to occur, and a matching of traffic flow parameters and crash characteristics reveals ways in which congestion affects highway safety.
UCB-ITS-PWP-2003-12
August 2003
36 pp., $10.00

Safety Aspects of Freeway Weaving Sections
Thomas F. Golob, Wilfred W. Recker, Veronica M. Alvarez
One source of vehicle conflict is the freeway weaving section, where a merge and diverge in close proximity require vehicles either entering or exiting the freeway to execute one or more lane changes. Using accident data for a portion of Southern California, we examined accidents that occurred on three types of weaving sections defined in traffic engineering: Type A, where every merging or diverging vehicle must execute one lane change, Type B, where either merging or diverging can be done without changing lanes, and Type C, where one maneuver requires at least two lane changes. We found no difference among these three types in terms of overall accident rates for 55 weaving sections over one year (1998). However, there were significant differences in terms of the types of accidents that occur within these types in terms of severity, and location of the primary collision, the factors causing the accident, and the time period in which the accident is most likely to occur. These differences in aspects of safety lead to implications for traffic engineering improvements.
UCB-ITS-PWP-2003-13
August 2003
24 pp., $5.00

An Enhancement to Speed Estimation with Single Loops
Wei-Hua Lin, Joy Dahlgren, Hong Huo
In this paper, the authors investigate the discrepancy between the speed estimated with single loops and speed measured directly from double loops. They describe how speeds are estimated using single loop detectors and the key factors affecting the accuracy in estimation. Empirical evidence showing the behavior of the variance of pace and how it might affect the accuracy in estimating the prevailing vehicle speeds of a traffic stream are then provided. The authors next describe a proposed method for speed estimation and its properties. Field data are used to compare the performance of the proposed method with the performance of the conventional method based on the commonly used performance measures, the mean squared error and the mean relative error. The proposed method is summarized, and directions for future research are identified.
UCB-ITS-PWP-2003-14
November 2003
21 pp., $5.00

Advanced Simulation Tools for Freeway Corridor Management
Yonnel Gardes, Eric Tang, Jingtao Ma, Adolf D. May
As part of the California PATH program, the Paramics microscopic traffic simulation model was applied to the I-580 freeway-arterial corridor. The main purposes of the project were two-fold: 1) Develop the expertise and transfer the knowledge required in calibrating a largescale freeway corridor with Param-
ics; 2)Prepare a calibrated model for the I-580 corridor that could be used to address operational questions, evaluate potential improvement alternatives and provide input to the decision-making process.
UCB-ITS-PWP-2003-15
December 2003
85 pp., $15.00

Transit Operations Research

Benchmarking Best Practices of Demand Responsive Transit Systems
Maged Dessouky, Kurt Palmer, Tamer Abdelmaguid
This report presents the results of a nationwide study on Demand Responsive Transit (DRT) involving 62 large transit agencies and 12 small transit agencies. It evaluates the impact of implemented technologies and practices upon productivity and operating costs. The analyses involve technologies and practices such as a paratransit computer aided dispatching (CAD) system, agency service delivery, advanced communications technology, financial incentives, and the use of revenue mile in regard to service output.
UCB-ITS-PRR-2003-1
January 2003
64 pp., $15.00

SmartBRT: A Set of Planning, Analysis and Evaluation Tools for Bus Rapid Transit: Final Report Year 1 of 2
Tunde Balvanyos, Wes Bethel, Yonnel Gardes, Natalia Kourjanskaia, Hongchao Liu, Jim Misener, Joao Sousa, Joel VanderWerf, Wenbin Wei
This report presents the first year-results from a two-year project to develop a computer simulation, evaluation, and visualization toolbox, SmartBRT. The function of SmartBRT is to describe and evaluate operational aspects of bus rapid transit (BRT) concept in order to aid in the decision-making process. The report first introduces the relevant aspects of BRT operation, system elements, operation variables, and performance measures. It next discusses SmartBRT, looking at its simulation, evaluation, and visualization components. The report then discusses the application of SmartBRT to the Metro Rapid Transit system in Los Angeles. A discussion on the future work necessary to develop a fully functional SmartBRT is presented, followed by a summary discussion and a look at future plans.
UCB-ITS-PRR-2003-7
February 2003
91 pp., $15.00

Develop Precision Docking Function for Bus Operation
Han-Shue Tan
This report describes a project dealing with the implementation of a bus precision docking system and the demonstration of its accurate docking abilities. It presents an analysis and the experimental results of the development of an integrated lateral control system based on magnetic markers for both precision docking and lane-assist functions. It describes the design of a single steering controller that achieves all performance objectives. Data collected during demonstrations of precision docking and lane-assist control using a test vehicle are also presented.
UCB-ITS-PRR-2003-11
March 2003
32 pp., $10.00

Institutional Aspects of Multi-Agency Transit Operations
Mark A. Miller, Amy Lam
This report presents the findings from an examination of regional transit coordination activities in the U.S., with focus on California. Focus was on identifying and investigating institutional aspects of multi-organization transit operations, understanding the role that Intelligent Transportation Systems (ITS) can play in regional coordination, and recommending methods in which a model or set of models for California could be developed. Two primary methods for inter-agency coordination were employed: formal and informal, followed by a hybrid integrated approach. The report then describes demonstrations of regional transit coordination activities in both California and outside the state.
UCB-ITS-PRR-2003-18
April 2003
78 pp., $15.00

Development of Requirement Specifications for Transit Frontal Collision Warning System
Xiqin Wang, Joanne Lins, Ching-Yao Chan, Scott Johnston, Kun Zhou, Aaron Steinfeld, Matt Hanson, Wei-Bin Zhang
SamTrans operates a fleet of 316 buses in the counties of San Mateo, Santa Clara, and San Francisco that covers one of the most congested areas in the United States. Crash statistics tracked by SamTrans in recent years indicate frontal collisions can result in significant property damage and liability. In addition to frontal collisions, passenger falls resulting from emergency braking also contribute to an increased potential for passenger injuries and liability. This finding is further supported by the crash data collected by a number of transit agencies in the Bay Area (members of FCWS Bay Area Transit Advisory Committee). The crash data analysis suggests that a FCWS using advanced sensing and computer technologies can potentially reduce frontal collision rates, which will minimize losses and reduce operational interruptions. The collision warning system may also help the driver to adequately respond to the hazard with smoother maneuvers. Furthermore, information collected through sensors can be recorded for the purpose of crash analysis and for avoiding false claims. The purpose of the transit Frontal Collision Warning System (FCWS) under the context of this project are to (a) address imminent crashes, (b) provide warnings for smoother maneuvering, and (c) provide warnings when a bus is too close to a forward vehicle.
UCB-ITS-PRR-2003-29
November 2003
84 pp., $15.00

Integrated Smart Feeder/Shuttle Bus Service
Avishai Ceder, Youngbin Yim
This report describes an integrated smart feeder/shuttle system, designed to provide easy access to main haul transit services, meet the needs and desires of end users, utilize intelligent transportation technologies, and increase the operational efficiency. It examines ten different routing strategies, including combinations of fixed/flexible routes, fixed/flexible schedules, one or bi-directional approaches, and short-cut (shortest path) and /or short-turn (turn around) concepts. A simulation model is developed for examining: 1) various operating strategies from the user and the operator perspectives; 2) different routing models and scenarios; and, 3) different real-time communication possibilities between the user, operator, and a control center. A case study of Castro Valley, California, is used as the simulation model. The feeder/shuttle service is coordinated with the Bay Area Rapid Transit (BART) service and the ten routing strategies are compared while using four fleet-sized scenarios.
UCB-ITS-PWP-2003-4
March 2003
54 pp., $15.00

Traveler Response to Innovative Personalized Demand-Responsive Transit in the San Francisco Bay Area
Asad J. Khattak, Youngbin Yim
In this paper, the authors explore the demand for a consumer-oriented Personalized Demand Responsive Transit (PDRT) service in the San Francisco Bay Area. It presents results from six focus group meetings and a computer-assisted telephone survey of commuters and non-commuters. The results indicate that approximately 60% of the survey population were willing to consider PDRT as an option, while 12% indicated that they were very likely to use PDRT. A willingness to pay for the service was indicated, and the flexibility in scheduling the service was highly valued. Spatial analysis of the survey responses suggests locations where a PDRT would be suitable for field testing.
UCB-ITS-PWP-2003-5
March 2003
36 pp., $10.00