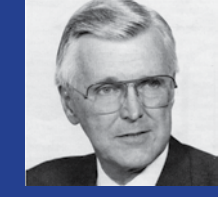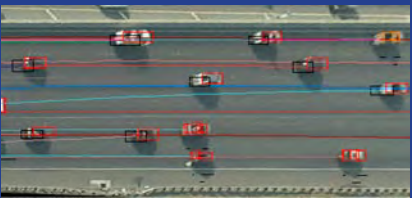# California PATH Annual Report 2006

CALIFORNIA PATH

20th Anniversary

California PATH

2006
Annual Report

The California Partners for Advanced Transit and Highways (California PATH) is a collaboration between the University of California and the California Department of Transportation (Caltrans), together with the U.S. Department of Transportation, other public agencies and organizations and private industry.

PATH's mission is to develop innovative Intelligent Transportation Systems (ITS) strategies and technologies to improve the safety, flexibility, mobility, stewardship and delivery of transportation systems in California, the United States and the world.

I n this year's annual report, we highlight many of the ongoing projects and new research thrusts. Some developments in 2006 include:

- PATH researchers developed methodologies based on surveillance data for performance measurement, bottleneck identification and estimation of the congestion causes and impacts. Improved ramp metering strategies were developed and field tested. Improved car-following and lane-changing algorithms for oversaturated traffic flow were developed and validated with field data as part of the Federal Highway Administration's NGSIM (Next Generation SIMulation) project. PATH researchers are working on new modeling approaches for traffic corridors as part of the Integrated Corridor Management (ICM), a major ITS federal initiative. In addition, PATH leads the research effort on two major traffic corridors: I-880 in San Francisco Bay Area and I-15 in San Diego, as part of the ICM initiative. Ongoing work focuses on the analysis of existing operating conditions and the development of multimodal ITS strategies on both the freeway and the adjacent surface street networks.

- We continue to devote significant research efforts in the area of Bus Rapid Transit (BRT) focusing on large impact solutions such as vehicle assist and automation technologies. We are investigating deployment aspects of lane assist technologies and field testing of guided busses in real-world environments. PATH researchers also developed and successfully demonstrated an integrated collision warning system for transit vehicles. Research on transit operations includes field testing and evaluation of an adaptive signal priority system that allow busses to gain priority at signalized intersections while minimizing the disturbance to other traffic, and new approaches for demand responsive transit systems.

- PATH researchers are leading the research efforts in several vehicle-infrastructure integration (VII) related projects. They developed, tested and installed VII California, the first of its kind roadside deployment of VII. This testbed will serve as part of the national VII testing program by USDOT. The Cooperative Intersection Avoidance Systems–signalized left turn assist (CICAS STLA) project has begun to develop concepts and driver based prototype systems for active left-turn countermeasures at signalized intersections. PATH researchers also developed an innovative onboard safety monitoring system for commercial truck fleet and drivers under FMSA and Caltrans sponsorship.

- The Field Operational Test (FOT) of PATH's Smart Parking research project was successfully completed. Follow up smart parking pilot projects are underway in the Bay Area and San Diego. The EasyConnect project, low speed travel modes linked to transit, began at the Contra Costa Transit Village and other businesses around the Pleasant Hill Bay Area Rapid Transit (BART) District station in May 2006.

The year 2006 marked the 20th anniversary of the launch of the PATH program. In October of 2006, we hosted the "PATH at 20" symposium and gala event, generously sponsored by several organizations. Symposium presentations and demonstrations highlighted past PATH accomplishments, ongoing projects and future research directions. "PATH at 20" was also celebrated at the ITS America and ITSC IEEE Annual Meetings.

PATH's accomplishments are due to the work of an impressive group of researchers, faculty and students of the highest quality, dedication and enthusiasm. I am privileged to work closely with them in developing and testing new concepts and technologies and leading the way on the national ITS research efforts.

Alexander Skabardonis
Director, California PATH

The Division of Research and Innovation (DRI) and its research partners have enjoyed a truly exciting year in research, development and deployment. Through our involvement in key national research initiatives, including the Vehicle-Infrastructure Integration (VII) and the Cooperative Intersection Collision Avoidance Systems (CICAS) Programs, new research has been launched to address some of our biggest transportation challenges.

The VII Program builds on the successful results of its predecessor, the Intelligent Vehicle Initiative, to improve traffic safety and mobility by employing a wireless vehicle-to-vehicle and vehicle-to-infrastructure communications technology called Dedicated Short Range Communications (DSRC). In partnership with the Metropolitan Transportation Commission, DRI and PATH are building a VII test bed in the Palo Alto area, in close proximity to the four automotive industry laboratories located there. We are providing the roadside infrastructure, and the auto labs are providing the VII-equipped vehicles, so that VII safety and mobility applications can be tested and evaluated. The U. S. Department of Transportation recently recognized our VII test bed as one of only two in the nation (the other being the Detroit, Michigan test bed) that will be used for Proof of Concept testing of VII applications.

In addition, we are working closely with the Michigan Department of Transportation to jointly develop a Research Roadmap for VII that will guide our program as it moves closer to deployment. Communication of the research results to the transportation practitioners is critical to the success of implementing research. The Research Roadmaps and Strategic Research Plan will improve our ability to communicate and market transportation innovations to our customers and partners.

Closely related to VII, the CICAS Program will address the challenge of improving intersection safety. About 25% of all roadway deaths nationwide, roughly 9,000 per year, are the result of vehicle crashes that occur at or near intersections. As part of the CICAS Program, DRI and PATH are working in partnership with the U.S. Department of Transportation, automotive manufacturers, and State and local departments of transportation to pursue a combination of transportation technologies that are intended to reduce the number and severity of crashes, and their associated injuries and deaths, that occur at intersections. To test the feasibility of CICAS, DRI and PATH recently instrumented the intersection at 5th Avenue and El Camino Real (State Route 82) in the city of Atherton with the CICAS roadside equipment needed to warn drivers of impending collisions and to give them an opportunity to take corrective action to avoid the crash. This installation is the first of its kind in the entire nation, and clearly shows yet again that DRI and PATH are leaders in the field of transportation research.

As the CICAS Program moves through the research phase and gets closer to Field Operational Testing (FOT), this leadership will put California in a strong position to compete for the limited number of CICAS FOT sites that will be chosen by the U. S. Department of Transportation, and other transportation grant programs.

These Programs are but two examples of what can be accomplished through our continued affiliation with PATH and other university programs. I am confident that together we will continue to provide leadership that will enhance the safety and productivity of our state highway system - one that sets the standard nationwide for seamless, safe movement of people and goods.

Lawrence 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 a national and California leader in ITS (Intelligent Transportation Systems) research since PATH's founding in 1986. PATH's focus is on improving traffic operations, and in particular mobility and safety, with advanced ideas, technologies and a deployment focus. Collateral benefits include traveler information, regardless of the mode or modes taken, reduced energy consumption and lesser environmental impact and better land-use management, improving transportation equity amongst all users, and ultimately, in strengthening of California's economy. Because PATH's goals and objectives coincide with national interest in solving transportation problems using advanced technologies, PATH played an important role in initiating ITS in the United States and the creation of the Intelligent Transportation Society of America.

The California Department of Transportation (Caltrans) provides the seed funding for PATH's core research, based on its goal of promoting the development of new knowledge and innovative technology that can improve the safety, flexibility, mobility, stewardship, delivery, and environmental impacts of California's surface transportation systems. As a California statewide ITS research program, PATH's mission is to develop solutions to the problems of California's surface transportation systems through cutting edge, applications-oriented research. PATH also conducts research outside of California—both nationally and internationally. PATH develops these solutions by harnessing the knowledge of transportation researchers, working in conjunction with experts in a host of fields including information technology, electrical engineering, economics, mechanical engineering, planning, systems and policy analysis, psychology, sociology, and business/marketing. Research and development done under PATH auspices include:

- identification of problems and needs
- basic research on enabling technologies
- system conceptualization
- applied technology and research and development
- system-level design and evaluation
- analytical and simulation work in design and evaluation
- experimental verification of design predictions
- evaluations of existing technologies or equipment
- evaluations of costs and benefits
- technology assessments
- investigation of users' behavioral responses
- predictions of the impacts of technology use
- real-world field demonstrations and pilot project testing
- field operational tests
- policy assessment and recommendations
- evaluations of legal and institutional issues.

PATH's charter includes conducting leading-edge research, evaluating and conducting controlled field demonstrations, pilot operational tests and field operational tests, while developing public/private/academic partnerships, and educating students as well as practitioners about operational benefits resulting from research in ITS.

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 forty full-time staff members, including a core group of research staff members, plus program leaders and administrators. The full-time research staff at PATH headquarters conducts a substantial body of research, but much PATH research work is done by

faculty members and graduate students from various UC campuses and California universities that form the PATH partnership. This work is supplemented by subcontracts to private companies as needed, or by cooperative research agreements with a variety of public and private organizations, 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.

Research Groups at PATH

Parsons Arterial Traffic and Transit Laboratory

PATH and Caltrans have established an arterial traffic and transit laboratory at PATH Headquarters. The initial goal of this lab is to collect traffic and probe vehicle data from arterial streets in order to meet the needs of a number of PATH research projects including "Development of Adaptive Transit Signal Priority (ATSP) System," "Red Light Running Avoidance," "Relieve Congestion and Conflicts between Railroad and Light Rail Grade-Crossing Intersections," "Development of Hardware-in-the-Loop (HiL) Simulation and Paramics/VS-PLUS Integration," and "Development of an Integrated Simulation and Optimization Tool".

The lab has become a permanent data collection system, which collects real-time or quasi real-time data from several signalized arterials. Data include sensor data, signal status data from field controllers, and automatic vehicle location (AVL) or tag data from busses or probe vehicles. Currently, PATH researchers are developing a set of tools to assist in data processing, analysis and dissemination. The data and software tools in the lab can be used to support academic research on ITS, hardware in the loop simulation, field testing and evaluation of signal control algorithms, and student workshops and training.

Innovative Mobility Research (IMR) Group

Since 2002, PATH headquarters has housed the Innovative Mobility Research (IMR) group. IMR is a group of researchers, staff, and students focused on exploring innovative mobility technologies and services that could improve transportation options, while reducing negative societal and environmental impacts.

In 2006, IMR received research grants from Caltrans, the San Francisco Bay Area Metropolitan Transportation Commission (MTC), the Mineta Transportation Institute, the University of California Transportation Center, the Transit Cooperative Research Program, and several automakers (DaimlerChrysler, Nissan, and Toyota). IMR's current research areas include: carsharing, ridesharing, smart truck parking, smart parking for transit, older mobility, uncertainty in travel and land-use models, exploration of hydrogen fuel cell vehicles and infrastructure, low-speed modes linked to transit, transit villages, demographic analysis of diverse traveling populations in California, older mobility, automated enforcement (ASE), virtual weigh-in-motion (VWS), and the Innovative Corridors Initiative (ICI).

Vehicle Infrastructure Technology, Analysis and Science (VITAS) Center

Since its inception, PATH has been in the forefront of vehicle-infrastructure and vehicle-vehicle communication, initially for mobility with potential safety benefits. The advent of the national "Vehicle Infrastructure Integration" (VII) program and the subsequent first-of-its-kind Caltrans roadside deployment and experimentation of VII, implemented with Dedicated Short Range Communication (DSRC), brings to focus the historical and ongoing PATH leadership in using communications—and information—to facility mobility and safety concepts.

These projects are manifold, with current projects addressing VII, and in particular VII California, Cooperative Adaptive Cruise Control, car-to-car communications for vehicle safety, and building radio testbeds for DSRC. These projects are now organized in the cross-cutting VITAS Center within PATH. The VITAS Center now gives to PATH and its research sponsors:

- Focus on vehicle-infrastructure research at PATH
- Cross-fertilization of research ideas and researchers
- Housing of VITAS Center research assets in a common laboratory

The VITAS Center has been created to give energy and focus to long-standing PATH research and leadership in vehicle-infrastructure cooperative systems.

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 over 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 45 professors, representing 14 academic departments on 14 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 Riverside, UC Santa Barbara, UC Los Angeles, California Polytechnic State University at San Luis Obispo, California Polytechnic State University Pomona, San José State University, Ohio State University, San Diego State University, Texas Tech, Utah State University, and the University of Southern California.

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:

- Understanding How Individuals Make Travel and Location Decisions: Implications for Public Transportation
- Older Mobility Research Focused on Minimizing Transit Barriers
- CICAS Signalized Left Turn Assistance (SLTA) System (FHWA)
- Onboard Monitoring for Commercial Vehicle Safety (FMCSA)
- Next Generation Simulation (NGSIM) Program: Improved Algorithms for Oversaturated Freeway Flow (FHWA)
- Integrated Corridor Management (ICM): Analysis, Modeling and Simulation (FHWA)
- Integrated Corridor Management (ICM): San Diego I-15 Demonstration (FHWA)
- Integrated Corridor Management (ICM): Alameda County I-880 Demonstration (FHWA)
- Development of performance specifications and interface requirements for Transit Lane Assist Systems (FTA)
- Integrated Transit Collision Warning Systems (FTA)
- Development of TSP Control Strategies and Modeling Tools (FTA)

Other Projects

PATH attracted research support from a variety of other sources during the past year. Some of these projects include:

- Development and evaluation of a variety of technologies and methodologies for Bus Rapid Transit
- Assessment of Bus Rapid Transit Opportunities in the San Francisco Bay Area
- EasyConnect: Improving BART Connectivity with Low-Speed Modes

- Smart Parking for Transit Field Test
- Understanding How Individuals Make Travel and Location Decisions: Implications for Public Transportation
- Older Mobility Household Research
- Hydrogen Fuel Cell Vehicle and Infrastructure Research
- San Francisco Bay Area Regional Ridesharing Evaluation
- Applying Safety Improvements to Fleet Vehicles
- San Joaquin Rail Corridor Crossing Survey
- Bicycle Detection and Operational Concept at Signalized Intersections
- Methods for Preventing Vehicle Backing Accidents
- Methods for Reducing Headlight Glare
- Quantifying Performance of Countermeasures for Collision Concentrations Related to Ramp / Freeway Mainline Junctions
- Safety of HOV Ingress / Egress along Limited Access Buffer-separated Facilities
- Evaluation of Wet Weather Accident Causation Criteria
- Animal Warning System Effectiveness
- Data Collection, Analysis and Evaluation Support in the Development of the Strategic Highway Safety Plan
- Cooperative Vehicle Safety
- VII California

Highlights

- October 26-27, 2006, PATH hosted its 20th anniversary symposium and gala event. Sponsors included: Toyota Information Technology Center USA, Toyota Motor Engineering and Manufacturing North America, Inc., DaimlerChrysler Research and Technology North America, Inc., American Honda, Delcan, IMRA America, Inc., Econolite Control Products, Inc., Eberle Design Inc., Quixote Transportation Technologies, Inc., and Iteris, Inc.
- PATH's 20th anniversary was celebrated at the ITS America Annual Meeting in Philadelphia, May 2006, and the 9th ITSC IEEE Conference in Toronto, Canada, September 2006. Presentations highlighted past PATH accomplishments and ongoing research at special "PATH at 20" conference sessions.
- Toyota InfoTechnology Center presented PATH with gift grant to support research in driver behavior and safety
- Parsons Arterial and Traffic Laboratory established
- PATH conducts landmark "Human Factors and Safety Workshop" to public sector stakeholders
- PATH hosts numerous national and international visitors on a variety of safety and VII topics
- Nissan Motor Corporation presented PATH with gift grant to support research in older mobility.
- PATH continues our research relationship with automobile manufacturers on cooperative safety systems, hydrogen fuel cell vehicle and infrastructure work.
- EasyConnect: Low-Speed Modes Linked to Transit Project launches at Contra Costa Transit Village and other businesses around the Pleasant Hill Bay Area Rapid Transit (BART) District station in May 2006.
- PATH embarks on partnership with UC Davis Energy Efficiency Center.
- PATH hosts carsharing briefing with Shanghai delegation and major carsharing operators in June 2006.
- PATH co-sponsored the 1st International Symposium on Freeway and Tollway Operations organized by the Transportation Research Board and hosted by the Atikes Diadromes SA in Athens, Greece, June 2006. PATH researchers presented ongoing research on freeway operations and management.

Policy and Behavioral Research
Susan Shaheen, Program Leader

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: innovative strategies to enhance transit services and increase ridership, such as carsharing (short-term vehicle access) and low-speed modes (such as Segway Human Transporters and electric bikes); smart parking linked to transit; hydrogen transportation applications for the State and Caltrans; smart cards for transit; wireless Internet access on trains; ITS solutions to goods movement (such as smart truck parking and virtual weigh stations); and understanding travel behavior of diverse population groups.

Results from recently completed Task Orders (TO) 5000 series projects include:

Smart Parking Management: Phase I Field Test Research (TO 5101). Park-and-ride lots are often used by transit agencies as an amenity to encourage ridership, especially among commuters, who value quick and convenient parking. The increasing popularity of park-and-ride lots may, however, limit peak period capacity in some areas. In addition, environmental, institutional and financial factors may preclude an agency from building new parking spaces to meet demand, particularly in urban areas where land availability can be scarce. In response to this unique problem, researchers conducted a field test at the Rockridge Bay Area Rapid Transit (BART) District station, located in Oakland, to evaluate the effectiveness of a concept called "smart parking." Smart parking, as applied in this project, integrated several innovative technologies to provide motorists with real-time parking information during morning commute hours, when demand for parking is very high. Changeable message signs (CMSs) broadcasted the number of park-and-ride lot spaces available on roadways near the transit station; users had the option to reserve spaces through an interactive voice response (IVR) system, accessible via mobile phone, or by an Internet web site. The goal of the project was to evaluate the effectiveness of smart parking at increasing parking efficiency at the Rockridge BART station. Tested between December 2004 and April 2006, smart parking involved a partnership between the California Department of Transportation (Caltrans), California PATH, the BART District, ParkingCarmaTM, and Quixote Corporation. Researchers conducted a literature review on the travel effects of systems similar to the smart parking concept and evaluated the field test results through user analyses, including focus groups and surveys. Initial results demonstrate that the project attracted new (14 percent) and infrequent BART commuters (25 percent). Also, total travel reductions among users

are estimated to average 18 miles; thus, the project appears to remove cars from the road during peak periods and encourage drivers to take transit. Capital and operating costs of the project, including equipment acquisition and installation costs, were also estimated for transportation planners.

Strategies for Successful Implementation of Virtual Weigh and Compliance Systems in California (TO 5105).

Freight transportation, particularly by trucks, plays a crucial role in the state and national economies. Trucking accounts for three-fourths the value and two-thirds the weight of freight traffic in the U.S. Domestic freight is projected to increase by 87 percent between 1998 and 2020. Increasing trucking traffic poses numerous challenges for the agencies that plan, construct, operate and maintain the transportation system, including traffic congestion, safety hazards, deterioration of the transportation infrastructure, environmental effects, and impacts on economic development. As a leading state in the deployment of advanced technologies for commercial vehicle operations, California has adopted and is operating modern weigh-in-motion (WIM) systems that allow legal trucks to bypass weigh stations without stopping. The objective of this project is to document recent efforts and technologies associated with the automated monitoring and enforcement of commercial vehicles and to document current practices for addressing overweight vehicle enforcement using advanced WIM technologies. Researchers investigated the historical background and current state of commercial vehicle enforcement practices and emerging new technologies and methods applicable to upgrading existing commercial vehicle weight enforcement methods, including WIM systems, automated vehicle identification systems, and truck bypass programs. Also examined were virtual weigh and compliance systems (VWCS) considered by Caltrans and key considerations when implementing VWCS, including the physical and institutional requirements of development and deployment. Furthermore, strategies for successful implementation of the VWCS were recommended, drawing on the experiences of other VWCS systems. Finally, researchers developed a prototype simulation model for the I-710 Corridor, which is the main access corridor to the Long Beach and Los Angeles Ports Complex. This model can be used to examine the benefits of locating a VWCS at some point in this corridor.

California Trains Connected (TO 5106).

Wireless Internet services have become more common in both public and commercial spaces, especially as the world moves toward a faster information-based economy. Extending Internet accessibility to trains would allow passengers access to the web for business and personal reasons and to train operators for ticketing, public safety and security purposes, and other applications. This project investigated wireless Internet access on State Intercity Rail Services to provide information to the Capital Corridor Joint Power Authority (CCIPA) and Caltrans. Researchers investigated current international wireless technologies, including wireless fidelity (WiFi) and Worldwide Interoperability for Microwave Access (WiMAX), surveyed WiFi service and use at the San Francisco

International Airport, surveyed existing Internet access applications on trains, and considered ridership data from Intercity Rail Service routes in making recommendations for wireless Internet access services and features. Numerous aspects of the wireless technologies were considered, including technology trends, existing options, emerging technologies and security features. Researchers reported the benefits and disadvantages of two recommended business and technology model options: 1) a conservative model option, with low capital investment, but low revenue potential and a higher running cost; and 2) a maximized market model option, with a high revenue potential and lower running cost, but higher capital investment. Researchers also found that satellite communication may be used as a backup option or in an emergency scenario.

Clean Hydrogen for Transportation Applications (TO 5107).
Much attention has been given to transport-related hydrogen technologies as a means to reduce greenhouse gas emissions and dependence on foreign oil, including the infrastructure necessary to support a shift in the fuel economy. Researchers conducted a study to investigate what hydrogen station would best fit the needs of Caltrans, depending on a variety of factors, and how Caltrans may use rest stops to increase the hydrogen infrastructure in support of the recent Hydrogen Highway Network initiative. As part of this initiative, Caltrans is planning a hydrogen fueling station in Sylmar, a district in the San Fernando Valley. Using a station cost model, researchers considered the costs associated with capital, financing, fixed operations, and feedstock. Based on the results from this model, three types of fueling stations were recommended: 1) a mobile refueler, the simplest type of station; 2) an electrolyzer, which can use grid or renewable electricity; and 3) an electrolysis-based energy station, which produces hydrogen fuel, electricity, and heating and cooling. Researchers concluded that the energy station option should be considered if the main factor is high public visibility for demonstration purposes, since it encompasses renewable energy ability, advanced technologies, and the ability to provide back-up facility power. If cost is the key consideration, however, the mobile refueler option should be considered for a demand of two to three vehicles per day or the photovoltaic electrolyzer for six to eight vehicles per day. Another aspect of the research was to investigate and identify the future ability of Caltrans to use rest stops as hydrogen fueling stations. Researchers found that they are best used for inter-regional trips (e.g., San Francisco to the Los Angeles area), because they reside on interstates. Using modeling abilities, researchers estimated that a statewide line of hydrogen stations would result in an average "between" distance of 54 miles, with the shortest distance at 31 miles and the longest at 73 miles.

Smart Cards: Investigating A Statewide System Architecture for An Interoperable and Intermodal System (TO 5108).
Smart cards have many potential benefits for transit agencies, including increased passenger convenience, enhanced intermodal accessibility, better security and fare evasion prevention, faster boarding times, and easier access to ridership data. Smart cards may also help increase overall transit ridership. Current smart card systems have fallen into one of two categories: 1) stand-alone systems that are inoperable with other systems and 2) interoperable systems that are a part of a regional, multi-agency system. Interoperable systems may be more economically viable for agencies, allowing competitive bidding and achievable economies of scale, though they require both technical specifications and institutional agreements. Researchers interviewed stakeholders from transit agencies and smart card systems, in addition to conducting an extensive literature review to investigate how technical and institutional barriers to interoperability are currently being addressed.

Researchers found that technical specifications are easier to address and resolve than institutional differences. Institutional differences often arise because transit agencies frequently act independently. Decentralized transportation systems make decisions difficult, and there is a lack of understanding about the true costs and benefits of an interoperable smart card system. Also, researchers found that there is limited literature on overreaching solutions for such issues. Researchers also used an online survey of national transit agencies to document interest in smart card systems, investigate current system adoption, and examine traits that are common among early adopters of the technology. Researchers found that adoption depends on a variety of factors, including funding resources and the presence of multi-agency partnerships. In addition, system planning and implementation play a key role in how managers perceive the benefits, costs, and risks of these technologies.

A GIS-Based Tool for Forecasting the Travel Demands of Demographic Groups within California (TO 5110).

Past transportation investments have most often considered the economic costs and benefits of a particular project, while not fully taking into consideration social efficiency viewpoints. One key element hindering this consideration is the lack of methodology to measure the effect of a proposed investment on residents in a specific area. The aim of this project was to develop a methodology that best allocates statewide transportation resources. Social welfare was considered by accounting for resident accessibility; efficiency was measured using stochastic frontier regression analysis. Researchers developed a methodology, using U.S. Census data and Santa Barbara as a test case, which comprised two analytical levels: 1) statewide geographic (zonal level) mapping and 2) an individual resident level, which considers travel behavior. The zonal level analysis enabled researchers to identify transportation projects that have maximized public benefits.

Understanding Travel Behavior for Diverse Population Groups (TO 5111).

California is experiencing, and will continue to experience, a shifting demographic pool, particularly increases in populations of foreign-born, minority groups, and the elderly (65 years of age and older). Their unique transportation needs necessitate special consideration by transportation planners, particularly as the population in California becomes increasingly diverse. This project aimed to investigate the travel behavior and needs of immigrants, racial and ethnic groups, American Indians, and the elderly and youth populations in California through an extensive literature review. Key elements investigated include whether their mobility needs are satisfied by the current system; how they cope, especially with reduced vehicle access; the social and financial costs associated with these groups using cars; and policies that may be beneficial for enhancing their mobility options. Researchers found that all populations showed a trend towards increasing automobile dependence. This raises equity issues, since the youth and elderly may be limited in their ability to drive, and the cost of affording a vehicle may be too high for minority groups. Transit services are thus important for these groups; this was demonstrated in the research, since they comprised a significant share of overall transit ridership.

EasyConnect Phase I Planning Study (TO 5113).

California's population is expected to grow nearly 20 percent in the coming decade, and one smart growth strategy often proposed to address this increase are transit villages. Transit villages are usually characterized by easy access to transit, mixed-land uses, and a low-speed infrastructure that supports walking and bicy-

cling. Bridging the last mile from a transit station with innovative technologies may enhance the ability of transit to compete with the automobile. The goal of EasyConnect is to create seamless transportation for participants. Situated at the Pleasant Hill Bay Area Rapid Transit (BART) District station, this project phase employs electric bicycles, traditional bicycles, and Segway Human Transporters to connect participants to their workplace and BART. The units are stored in electronic lockers ("eLockers") at the station and also at partner workplaces. The goal of the EasyConnect project is to investigate whether such alternative transportation modes can increase transit use (and reduce auto travel); how effectively the new modal infrastructure can link new alternative modes to traditional transit services; and the viability of such a service. The project represents a public-private partnership among small technology businesses, private developers, transportation agencies, city and county governments, and academia. Businesses using the service are located within three miles of the BART station, and target participants are commuters. Research during the planned field operational test phase will be collected through on-site modal and parking observational analyses, focus groups, in-person interviews, questionnaires, and travel diaries.

Smart Parking Management Pilot Project: A Bay Area Rapid Transit (BART) District Parking Demonstration Expansion and Year Two Research Evaluation, TO 5101; Susan Shaheen, California PATH. UCB-ITS-PWP-2006-10

California's Chassis Network, TO 5104; Amelia Regan, University of California, Irvine.

ITS Solutions to I-710 Corridor Challenges, TO 5105; Amelia Regan, University of California, Irvine. UCB-ITS-PWP-2005-5, UCB-ITS-PRR-2005-33, UCB-ITS-PRR-2006-19

California Trains Connected, TO 5106; Hamed Benouar, California Center for Innovative Transportation (CCIT). UCB-ITS-PRR-2006-4

Clean Hydrogen for Transportation Applications, TO 5107; Dan Sperling, University of California Davis. UCB-ITS-PWP-2006-5

Establish and Develop a Statewide System Architecture for Interoperable, Intermodal SmartCard System and Determine the Cost Benefits to Public Transit, TO 5108; Brian Taylor, University of California Los Angeles. UCB-ITS-PWP-2006-2, UCB-ITS-PRR-2006-12

Effectiveness of Mobility Pass Program in San Diego, TO 5109; Louis Rea, San Diego State University.

A GIS-based Tool for Forecasting the Travel Demands of Demographic Groups within California – an Optimal Resource Allocation Tool, TO 5110; Kostas Goulias, University of California Santa Barbara, Michael McNally and Tom Golub, University of California Irvine.

Understanding Travel Behavior for Diverse Population Groups in California, TO 5111; Susan Handy, University of California Davis.

Low-Speed and Electric Modes to BART: Project Deployment & Evaluation, TO 5113; Susan Shaheen, California PATH UCB-ITS-PWP-2006-7.

Strategies for Linking Trucking and Smart Parking Technologies, TO 6101; Susan Shaheen, California PATH,.

Removing Barriers for Seniors at Transit Stops and Stations and the Potential for Transit Ridership Growth, TO 6102; David Ragland, University of California Berkeley.

Feasibility Study for the Use of Biodiesel in the Caltrans Fleet, TO 6103; J. Wayne Miller, Tom Durbin University of California Riverside.

EasyConnect II: Integrating Transportation, Information, and Energy Technologies at the Pleasant Hill BART Transit Oriented Development, TO 6104; Susan Shaheen, California PATH, Matt Barth, University of California Riverside.

Compliance and Commercial Vehicle Operators: A Systems Evaluation of the Problem & Virtual Solutions, TO 6105; Susan Shaheen, California PATH, Genevieve Giuliano, University of Southern California, John Harvey, University of California Davis.

Clean Hydrogen for Transportation Applications (Hydrogen Pathways), TO 6107; Are Gjellan, University of California Davis.

Designing a Policy Framework for a Statewide Transit Smart Card System, TO 6108; Brian Taylor, University of California Los Angeles.

Smart Parking at Transit: Phase Two Field Test Evaluation, TO 6109; Susan Shaheen, California PATH.

A GIS-based Tool for Forecasting the Travel Demands of Demographic Groups within California, TO 6110; Kostas Goulias, University of California Santa Barbara, Michael McNally, University of California Irvine.

Understanding Travel Behavior for Diverse Population Groups in California, TO 6111; Susan Handy, University of California Davis, Evelyn Blumenberg, University of California Los Angeles, Susan Shaheen, California PATH.

Low-Speed and Electric Modes to BART: Project Deployment and Evaluation, TO 6113; Susan Shaheen, California PATH.

Exploratory Field Test of Early Fleet Niches for Hydrogen Fuel Cell Vehicles and Fueling Infrastructure, TO 6114; Susan Shaheen, California PATH.

Seamless Travel: The Importance of Class I Bike Routes in Journey-to-Work Trips, Pedestrian/Bicycle Survey, and Research to Support the California Blueprint for Bicycling and Walking, TO 6117; David Ragland, University of California Berkeley.

Transportation Safety Research
Jim Misener, Program Leader

The Transportation Safety Research Program at PATH delivers to our sponsors at once high-tech, high-relevance and in-the-ground safety research results. The scope includes identification and quantification of roadside safety problems, and applies to those problems a host of Intelligent Transportation Systems solutions. A wide range of safety research projects, investigators, techniques and solutions are represented in the program, but the thread that ties them together is that the gamut of research is conducted within the program: entire problems can be posed, researched and solutions developed, prototyped and tested.

Some of the larger safety research efforts continue to extend traditional areas of systems excellence at PATH, focusing on vehicle-highway cooperation and communication. These efforts include "science of driving" investigations on driving behavior, efficient means to investigate crashes, rail-highway crossings, and importantly to Caltrans, means to understand high crash concentrations in order to embark on road safety improvements.

Specific project groupings include:
- Intersections and Cooperative Systems – crossing path vehicle crashes, safety aspects of cooperative driver-assist systems, Vehicle Infrastructure Integration (VII) with VII California
- Driver Behavior – modeling and applications for safety and countermeasure studies of car following and lane changes, at roadway intersections, at-grade crossings, onboard monitoring for commercial vehicle safety
- Safety for Vulnerable Road Users – problem assessment and technological tools for pedestrians, bicyclists
- Safety Improvements for Traffic Operations – problem assessment and technological tools for overall traffic.

In 2006, the US DOT Joint Project Office and Caltrans-sponsored Cooperative Intersection Collision Avoidance Systems Signalized Left Turn Assistance (CICAS-SLTA) project was begun. It represents, in one project, the aforementioned gamut of PATH skills and encompasses within its work scope system concepting, modeling, and conduct of controlled field tests and observations of intersection movements (vehicles and vulnerable road users alike) for input verification and output validation. Driver behavior will be observed, driver interface solutions will be developed, and in the end, a driver-based safety system will be prototyped. A follow-on effort may take this into a Field Operational Test.

In a Federal Motor Carrier Safety Administration- and Caltrans-sponsored project, PATH safety researchers have applied another high-tech approach to develop and test a prototype onboard monitoring system to understand and provide carrier and driver feedback for hazardous pre-crash driving behavior. In contrast,

PATH safety researchers have done just as rigorous but less futuristic studies to examine the effect of HOV lane ingress and egress methods in Northern California vis-à-vis methods in Southern California to baseline the best safety practices. Importantly, a PATH safety research group has provided invaluable crash data reduction and technical advice to the US DOT-mandated Strategic Highway Safety Plan.

What's in the future? Certainly, carrying out the legacy and program areas above and to leverage past and recent research excellence. For example, in 2006, PATH researchers developed for Caltrans a significant driver behavior / human factors workshop, bringing in experts throughout the PATH program and from around the United States. This directly addresses the primary issue in traffic safety, and bringing these issues to PATH – and PATH to this issue – will undoubtedly result in cutting-edge, life-saving research products.

Intersections and Cooperative Systems

California Cooperative Intersection Collision Avoidance System, TO 6607; James Misener, California PATH.

CICAS Urban and Suburban Assisted Left-turn (USUAL) System, TO 6608; James Misener, California PATH.

Red Light Running Avoidance, TO 5210 (6210); Wei-Bin Zhang and Kun Zhou, California PATH.

VII California Development and Demonstration Deployment (D3), TO 5217 (6217); James Misener, California PATH.

ITS Band Roadside to Vehicle Communications in a Highway Setting-Protocol Layer, TO 5214 (6214); Sue Dickey, California PATH, Raja Sengupta, University of California Berkeley and Mike Fitz, University of California Los Angeles.

Integrated Multi-Channel Vehicle-Vehicle and Vehicle-Roadside Communications for ITS, RTA 65A0177; Raja Sengupta, University of California Berkeley.

Cooperative Collision Warning, Sponsor: General Motors Research and Development Center; Raja Sengupta, University of California, Berkeley, Steve Shladover, Jim Misener, California PATH.

Safety and Convenience Evaluation Simulation (SCAESim), Sponsor: General Motors Research and Development Center; Joel VanderWerf, Tom Kuhn, James Misener, California PATH.

Driver Behavior

Effects of Cooperative Adaptive Cruise Control on Traffic Flow: Testing Driver's Choices to Following Distance, TO 5202 (6202); Delphine Cody, California PATH.

The Naturalistic Driver Model: Development, Integration, and Verification of Lane Change Maneuver, Driver Emergency, and Impairment Modules, TO 5500 (6500); Delphine Cody, California PATH and Jeff Caird, University of Calgary. UCB-ITS-PRR-2005-4

San Joaquin Rail Corridor Crossing Survey, TO 6210; Daniel Greenhouse, University of California Berkeley

Investigation of Driver Behavior at Rail Crossings, TO 5208; David Ragland, University of California Berkeley.

Animal Warning System Effectiveness, TO 6604; Delphine Cody, California PATH, Marcel Huijser, Montana State University (Western Transportation Institute).

California PATH Celebr

A good time was had by all as we li
future PATH research, reminis
and cut the 20th A

rates the First 20 Years

istened to talks on past, present and
ced with friends old and new
Anniversary Cake.

Onboard Monitoring and Reporting for Commercial Motor Vehicle Safety, TO 5609 (6609); James Misener, California PATH.

Reduce Accidents Involving Driver Fatigue, TO 6220; David Ragland, Traffic Safety Center.

Employee Safety

Optimizing the Message on the Changeable Message Sign, TO 5203; Theodore Cohn and Daniel Greenhouse, University of California Berkeley.

Workzone Safety Improvements through Enhanced Warning Signal Devices, TO 5205; Theodore Cohn and Daniel Greenhouse, University of California Berkeley.

Global Warning Signal Integration as a Tool for Workzone Safety and Efficiency, TO 5207; Theodore Cohn, University of California, Berkeley. UCB-ITS-PRR-2006-3

Methods for Assessing Vehicle Backing Accidents, TO 6206; David Ragland, Traffic Safety Center

Applying Safety Improvements to Fleet Vehicles, UCD 65A0139 TO 06-18; David Ragland, Traffic Safety Center

Safety for Vulnerable Road Users

Experimental Vehicle Platform for Pedestrian Detection, TO 5200; Ching-Yao Chan, California PATH. UCB-ITS-PRR-2006-16

Driver/Pedestrian Understanding and Behavior at Marked and Unmarked Crosswalks, TO 5209 (6209); David Ragland, Traffic Safety Center

Estimating Pedestrian Accident Exposure, TO 5211 (6211); David Ragland, Traffic Safety Center.

Bicycle Detection and Operational Concept at Signalized Intersections, TO 6203; Steve Shladover, California PATH.

Evaluate the Causes of Pedestrian and Bicyclist Traffic Fatalities and Injuries, and Establish Appropriate Countermeasures for use in California, TO 6221; David Ragland, Traffic Safety Center.

Safety Improvements for Traffic Operations

Assessing Automated Speed Enforcement (ASE) Systems in California, TO 5212 (6212); Caroline Rodier, California PATH.

Expedited Crash Investigation with the use of Technological Tools for Crash Documentation and Processing, TO 5216 (6216); Ching-Yao Chan, California PATH.

Methods for Identifying High Collision Concentration Locations for Potential Safety Improvements, TO 6215; Ching-Yao Chan, California PATH.

Evaluation of Traffic and Environment Effects on Skid Resistance and Safety Performance of Rubberized Open Graded Asphalt Concrete, TO 6218; David Ragland, Traffic Safety Center.

Safety of HOV Ingress/Egress along Limited Access Buffer Separated Facilities, TO 6601; Ching-Yao Chan, California PATH.

Evaluation of Wet Weather Accident Causation Criteria, TO 6602; David Ragland, Traffic Safety Center.

Methods to Address Headlight Glare, TO 6603; Daniel Greenhouse, University of California, Berkeley.

Radio Frequency ID Tags to Enhance Safety, RTA 65A0179; James Misener, California PATH.

Data Collection / Strategic Highway Safety Plan, TO 6610; David Ragland, Traffic Safety Center.
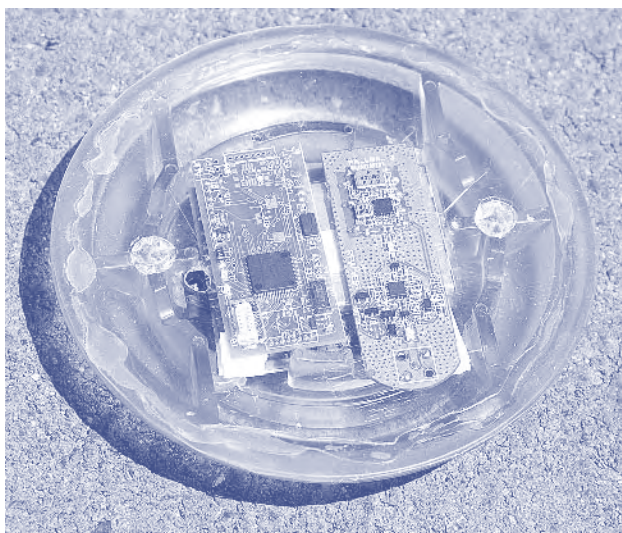
Traffic Operations Research
Alex Skabardonis, Program Leader

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 a statewide research team of nineteen faculty and more than 50 graduate students and staff working closely with the program sponsors. Currently, there are more than thirty ongoing research projects that fall in four major categories: traffic surveillance, algorithms for data processing, analysis and performance measurement, development and application of modeling tools, and formulation and testing of advanced operational strategies.

Results from ongoing Task Order (TO) 5000 and 6000 series and RTA projects include:

- Methods have been developed to perform loop detector diagnostics, and use detector data from conventional and advanced loop detector designs for vehicle re-identification, travel time estimation, and other ITS applications (TO 6300, TO 5302, TO 5304). Extensive testing of the new wireless MEMS sensor developed under PATH research (TO 5301 and TO 5328) on freeways and arterial streets demonstrated that it can replace loops and other conventional sensor systems at significantly less costs. A new non-intrusive laser sensor has been developed and successfully tested in the field (TO 5606). Work is underway on data fusion from multiple detector sources (TO 5327) and on the evaluation of portable data collection technologies (TO 6302).

- Work continues on enhancements to the freeway Performance Measurement System (PeMS) (RTA 15891) including algorithms for bottleneck identification, and estimation of the congestion causes and impacts based on empirical models developed in PATH studies (TO 5306 and TO 5321). Several studies explored the operating characteristics and effectiveness of High Occupancy Vehicle (HOV) lanes (TO 6301, TO 5315 and 5326/6326) using field data and simulation modeling. Another project investigated the relationships of freeway operating conditions and safety measures based on field data from the ATMS testbed in Orange County (TO 5307).

- Improved car-following and lane-changing algorithms for oversaturated traffic flow were developed as part of the NGSIM project, sponsored by FHWA (RTA 7214). The algorithms were validated using vehicle trajectories extracted from video data using machine vision algorithms, developed under previous PATH research. Improved analysis tools have been developed for calibration of microscopic simulation models (TO 5308). A new model, Netzone, has been developed for analysis and management of traffic at work zones (TO 5300). Ongoing work is developing TOPL, a macroscopic cell transmission based model that interfaces directly with the PeMS

system to analyze freeway operating conditions and alternative control strategies (TO 6611). PATH researchers are working on new modeling approaches for traffic corridors (RTA 7661) as part of the Integrated Corridor Management (ICM), a major ITS federal initiative.

- Improved ramp metering strategies for system-wide traffic responsive control have been developed and tested through simulation on a congested freeway in Los Angeles (TO 5503). The results indicate that the proposed strategies outperformed existing control approaches. Ongoing work focuses on the enhancement and field testing of the most promising strategies (TO 6329). In another study, the effectiveness of ramp metering to improve bottleneck discharge flows is investigated based on field measurements (TO 6331). Work continues on developing advanced strategies for adaptive traffic signal control on arterials (TO 5322/6322 and TO 5323/6323).

- PATH leads the research effort on two major traffic corridors: I-880 in San Francisco Bay Area (TO 6612) and I-15 in San Diego (TO 6613), as part of the Integrated Corridor Management initiative. Ongoing work focuses on the analysis of existing operating conditions and the development of multimodal ITS strategies on both the freeway and the adjacent surface street network, including traffic control, traveler information, incident management and transit priority treatments. Related projects include field testing of the Cartesius system that facilitates the coordination of operating agencies to minimize the response time to incidents along traffic corridors (TO 5324/6324) in Orange County, and the development of guidelines for displaying travel times on changeable message signs (TO 6303).

Traffic Surveillance

Conventional Surveillance and Communications Technologies

Extracting More Information from the Existing Freeway Monitoring Infrastructure, TO 5302; Pravin Varaiya, University of California, Berkeley, Ben Coifman, Ohio State University. UCB-ITS-PRR-2006-10

Maintaining the Health of the Caltrans Loop Detector System, TO 6300; Pravin Varaiya, University of California, Berkeley.

Systems Engineering Management Plan for Loop Fault Detection, TO 6327; Roberto Horowitz & Pravin Varaiya, University of California, Berkeley, Xiao-Yun Lu, California PATH.

New Detector Technologies

Low-Cost Vehicle Detection and Communication Systems for Freeways, Intersections and Parking Lots, TO 5301; Pravin Varaiya, University of California, Berkeley. UCB-ITS-PRR-2007-4

Corridor Investigation of Anonymous Vehicle Tracking for Real-Time Performance Measurement, TO 5304; Stephen Ritchie, University of California, Irvine.

Evaluation of IST-222 Detection System, TO 5314; Gabriel Gomes, University of California, Berkeley.

Low-Cost Wireless MeMS System for Measuring Dynamic Pavement Loads, TO 5328; Pravin Varaiya, University of California, Berkeley.

Data Fusion, I-405 TestBed, TO 5327; Art McCarley, Cal Poly San Luis Obispo.

Development and Field Testing of Laser Photodiode Array Based Vehicle Detection Systems on the Highway, TO 5606; Harry Cheng, University of California, Davis.

Evaluation of Portable Automated Data Collection Technologies, TO 6302, James Banks, San Diego State University.

Data Processing/Analysis/ Performance Measurement

Traffic Flow

New Approach to Bottleneck Capacity Analysis, TO 5309 (6309); James Banks, San Diego State University. UCB-ITS-PRR-2006-13

Next Generation Simulation (NGSIM): Developing Algorithms for Oversaturated Freeway Flow, RTA7214; Alexander Skabardonis, University of California, Berkeley.

What is the Excess Capacity of HOV Lanes, TO 6301; Pravin Varaiya, University of California, Berkeley.

Weave Analysis Evaluation and Refinement, TO 6304; Michael Cassidy and Alexander Skabardonis, University of California, Berkeley.

Performance Measurement

Causes of Freeway Productivity Decline and the Opportunities for Gain: A Quantitative Study, TO 5306; Pravin Varaiya, University of California, Berkeley.

Implementation of a Tool for Measuring ITS Impacts on Freeway Safety Performance, TO 5307; Tom Golob, University of California, Irvine.

Evaluation of PeMS to Improve the Congestion Monitoring Program, TO 5319; Pravin Varaiya, University of California, Berkeley.

Highway Traffic Data Sensitivity Analysis, TO 5320; Xiao-Yun Lu, California PATH, Ben Coifman, Ohio State University. UCB-ITS-PRR-2007-3

Finding and Analyzing the True Effect of Non-Recurrent Congestion on Mobility and Safety, TO 5321; Pravin Varaiya, University of California, Berkeley.

Optimal Sensor Requirements for Traffic Management, TO 6328; Alexandre Bayen, University of California, Berkeley.

Performance Measurement System (PeMS) Research and Support, RTA15981; Pravin Varaiya, University of California, Berkeley.

Modeling & Simulation

Development of a Path Flow Estimator for Deriving Steady-State and Time-Dependent Origin-Destination Trip Tables, TO 5502; Will Recker, University of California, Irvine, Antony Chen, Utah State University, Michael Zhang, University of California, Davis.

Integrated Construction Zone Traffic Management, TO 5300; Michael Zhang, University of California, Davis.

Integrated Ramp Metering Design, Evaluation and Optimization Platform with PARAMICS Simulation, TO 5305; Will Recker, University of California, Irvine.

Developing Calibration Tools for Microscopic Traffic Simulation, TO 5308; Michael Zhang, University of California, Davis.

Developing Large Network Tools for Microscopic Traffic Simulation, TO 5310; Jay Jayakrishnan, University of California, Irvine.

Development of Hardware-in-Loop Simulation and Paramics/VS Plus Integration, TO 5311; Susan Dickie, California PATH, Hongchao Liu, Texas Tech University, Henry Liu, University of Minnesota.

Development of an Integrated Microscopic Simulation and Optimization Tool, TO 5325; Wei-Bin Zhang, California PATH, Yafeng Yin, University of Florida. UCB-ITS-PRR-2007-2

Tools for Operations Planning, TO 6611; Pravin Varaiya, University of California, Berkeley.

Integrated Corridor Management (ICM): Analysis, Modeling and Simulation, RTA 7661; Alexander Skabardonis, University of California. Berkeley.

Traffic Control, Management and Traveler Information Systems

Design, Field Implementation and Evaluation of Adaptive Ramp Metering Algorithms, TO 5503; Roberto Horowitz, Pravin Varaiya, Alexander Skabardonis, University of California Berkeley, Michael Zhang, University of California Davis. UCB-ITS-PRR-2006-2

Field Deployment of an Agent-Based Multi-Jurisdictional Traffic Management System, TO 5313; Michael McNally, University of California, Irvine.

Evaluation of Hybrid Vehicle Usage in HOV Lanes, TO 5315; Will Recker, University of California, Irvine.

Measure and Field Test the Effectiveness of Adaptive Traffic Control for Arterial Signal Management, TO 5322 (6322); Alexander Skabardonis, University of California, Berkeley.

Optimal Control for Corridor Networks: A Mathematical Logic-Based Modeling and Solution, TO 5323 (6323); Will Recker, University of California, Irvine.

Cartesius and CTNET – Integration and Field Operational Test, TO 5324 (6324); Michael McNally, University of California, Irvine.

Determining the Effectiveness of HOV Lanes, TO 5326 (6326); Adolf May, University of California, Berkeley.

Optimal Use of CMS for Displaying Travel Times, TO 6303; Alexander Skabardonis, University of California, Berkeley.

Ramp Metering Design Tools and Field Test of Ramp Queue Control, TO 6329; Roberto Horowitz, University of California Berkeley.

Evaluation of Open Road Electronic Toll Collection for California Applications, TO 6330; Brian Taylor, University of California, Los Angeles and Hiroyuki Iseki, University of Toledo.

On Ramp Metering and Commuter Delay: A Before and "After" Study, TO 6331; Michael Cassidy, University of California Berkeley.

Northern California Integrated Corridor Management Demonstration (I-880 Alameda County), TO 6612; Wei-Bin Zhang, California PATH.

San Diego Integrated Corridor Management Demonstration, TO 6613; Alexander Skabardonis, University of California, Berkeley.

Transit Operations Research
Wei-Bin Zhang, Program Leader

T he transit research program at California PATH 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. PATH researchers, including faculty, staff, and students from across the State, are working closely with transit agencies within and outside of California to address real world problems and bring in advanced yet practical solutions, including planning and technological aspects of Bus Rapid Transit, innovative concepts for transit operations, Demand Scheduled and Responsive Transit, transit safety and rural ITS applications. PATH also initiated a new research direction to address integrated traffic and transit systems, as a result of collaborative efforts between PATH traffic and transit research programs

- We continue to devote significant efforts in the area of Bus Rapid Transit (BRT) investigating issues focusing on large impact solutions such as vehicle assist and automation technologies. Based on knowledge gained through a series of BRT planning projects in the past several years, we investigated deployment aspects of lane assist technologies that PATH and Caltrans developed. We are studing cost effective BRT systems using bidirectional dedicated lane and innovative pavement designs that will allow pavement to be durable against an unusually high rate of distress evolution in the pavement due to accurate guidance. Moving toward deployment, we will field test guided busses along an AC Transit route.

- PATH is conducting significant research on transit operations for a variety of applications, including field testing and evaluation of an adaptive signal priority system that allows busses to gain priority at signalized intersections while minimizing the disturbance to other traffic. We are exploring the concept of transit-taxi as a cost-effective means to fill the need for improvement in off-peak public transport. A new system, Efficient Deployment of Advanced Public Transportation Systems (EDAPTS), for suburban and rural applications is moving into deployment stage and will soon be field tested.

- Work continues on systems to improve transit safety. PATH studies are being conducted on vehicle/driver monitoring technology aiming to enhance manual driving safety of transit busses. A vehicle/driver monitoring system has been developed to give an early warning to drivers to alert them to their changing driving behavior due to inattentiveness and/or drowsiness.

- PATH transit research addresses multimodal needs. Studies are being conducted to investigate the interaction between urban/suburban rail and street traffic that is often problematic, resulting in delays on both systems. PATH has developed integrated solutions including methods for accurately predicting arrival time at the grade crossing and adaptive signal control strategies to minimize the delays to vehicular traffic while improving schedule adherence for rail operation. Another study is conducted to investigate approaches for improving intermodal connectivity at California airports.

- PATH began to address issues related to integrated transportation systems. Research focuses on ITS strategies for integrated operation of transit and traffic operations on urban corridors to encourage mode shift, reduce congestion, and ultimately improve the efficiency of the existing transportation infrastructure. This work is part of the Integrated Corridor Management (ICM) studies in Bay Area and San Diego.

- PATH began to address issues related to integrated transportation systems by participating with two consortium of agencies in the Bay Area and San Diego. Studies are being conducted to investigate how to integrated the existing ITS technologies to facilitate integrated operation in order to encourage mode shift, reduced congestions, and ultimately achieve higher efficiency for the existing transportation infrastructure.

In 2006 the PATH transit program embraced the following research areas in the Task Order (TO) 5000 and 6000 series, RTA's or outside funding sources:

Transit Operation

Field Operational Tests of Adaptive Transit Signal Priority (ATSP), TO 6400; Wei-Bin Zhang, Meng Li, California PATH.

Efficient Deployment of Advanced Public Transportation Systems (EDAPTS), TO 6401; Xudong Jia, California Polytechnic State University, Pomona, Edward Sullivan, California Polytechnic State University, San Luis Obispo.

Development of Performance-Based Specifications for Efficient Deployment of Advanced Public Transportation Systems (EDAPTS). TO 6402; Jeff Gerfen, California Polytechnic State University, San Luis Obispo, Xudong Jia, California Polytechnic State University, Pomona.

Stage 5 Test Deployment of Efficient Deployment of Advanced Public Transportation Systems

(EDAPTS), TO 6403; Jeff Gerfen, California Polytechnic State University, San Luis Obispo, Xudong Jia, California Polytechnic State University, Pomona.

Improving Mobility through Enhanced Transit Services, 6408; Brian Taylor, University of California Los Angeles, Mike Cassidy, University of California Berkeley.

Bus Rapid Transit

Establish Infrastructure Requirements for Lane Assist/Precision Docking, TO 6605; Wei-Bin Zhang, Steven Shladover, Fanping Bu, California PATH.

Field Demonstration and Tests of Lane Assist/Guidance and Precision Docking Technology, TO 6606; Wei-Bin Zhang, Fanping Bu, Hanshue Tan, California PATH.

Evaluation of Cost-Effective Planning and Design Options for Bus Rapid Transit in Dedicated Bus Lanes, TO 6404; Mark Miller, Steven Shladover, Wei-Bin Zhang, California PATH.
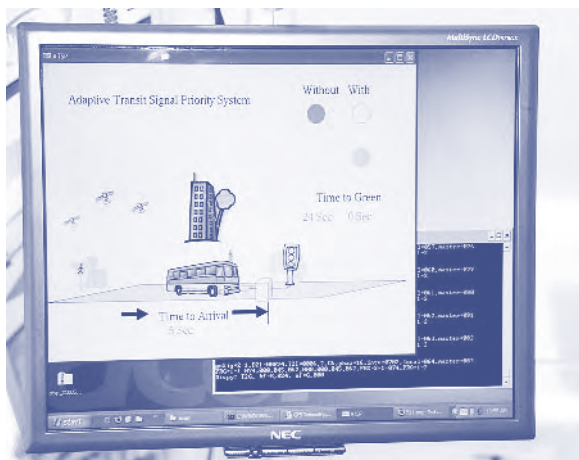
Transit Safety

Vehicle/Driver Monitoring for Enhanced Safety of Transit Buses, TO 5400; Masayoshi Tomizuka, University of California Berkeley.

Multimodal and Integration

A Combined Quantitative and Qualitative Approach to Planning for Improved Intermodal Connectivity at California Airports, TO 6406; Xiao-yun Lu, California PATH.

Relieve Congestion and Conflicts Between Railroad and Light Rail Grade-Crossing Intersections, TO 6407; Wei-Bin Zhang, Meng Li, California PATH.

SPRINTER Rail Project – Grade Crossing/Traffic Signal Optimization Study, TO 6409; Wei-Bin Zhang, Meng Li, California PATH.

Northern California Integrated Corridor Management Demonstration (I-880 in Alameda County), TO 6612; Wei-Bin Zhang, Steven Shladover, Irene Li, California PATH.

San Diego Integrated Corridor Management Demonstration (I-15 in San Diego County), TO 6613; Alex Skabardonis, Linda Novik, Yuwei Li, Mark Miller, California PATH.

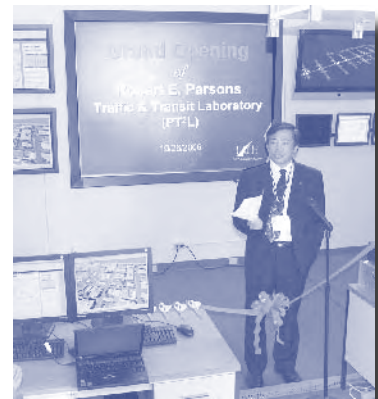# Some of our Domestic and Foreign Visitors, and Presentations

Demo of VII California and Signal Priority at APTA meeting

Dr. Ashok Kaveeshwar: First RITA Administrator USDOT visits PATH

ABC News Films Demonstration of Automated Bus

Gloria Jeff, General Manager Los Angeles DOT

Grand Opening of Parsons Traffic and Transit Lab

Human Factors Conference

International Symposium on Freeway and Tollway Operations

Delegation from Shanghai visit to hear about carsharing

Visitors from France

Demonstration of VII California

Italian Visitors

Jim Misener gets interviewed by CNN

Briefing to Caltrans on VII California

Rollout of EasyConnect

Policy and Behavior

ENHANCED TRANSIT STRATEGIES: BUS LANES WITH INTERMITTENT PRIORITY AND ITS TECHNOLOGY ARCHITECTURES FOR TOD ENHANCEMENT

Michael Todd, Matthew Barth, Michael Eichler, Carlos Daganzo, Susan A. Shaheen

Due to increases in congestion, transportation costs, and associated environmental impacts, a variety of new enhanced transit strategies are being investigated worldwide. The transit-oriented development (TOD) concept is a key area where several enhanced transit strategies can be implemented. TODs integrate transit, residential, retail and/or commercial entities into a compact, pedestrian-friendly community, thereby reducing private car usage and increasing transit use. This research report addresses two enhanced strategies within the TOD framework: 1) using Bus Lanes with Intermittent Priorities (BLIPs) to enhance bus transit; and 2) addressing how and what Intelligent Transportation System (ITS) technology can be used within TOD system architectures. With respect to 1), it has been shown that the implementation of BLIPs for bus rapid transit can greatly increase system efficiencies without compromising the level of service for other facility users. The basic analysis in this report shows that both conservative and liberal approaches have similar impacts to traffic and identical benefits. The macroscopic analysis illustrates that traffic disturbances caused by BLIP activation will not slow down subsequent buses, and that roads with medium traffic demand can easily support a BLIP implementation. The microscopic analysis provides some quantitative equations that can help decision makers determine whether a given intersection can be outfitted with a BLIP implementation within predefined parameters. A framework for cost-benefit analysis was provided for BLIP implementation. With respect to 2), it has been shown that transportation efficiency and

effectiveness within a TOD can certainly be enhanced with the integration of ITS technology. This project report has identified technology bundles and architectures that have the greatest potential for increasing mobility. Further, it has demonstrated that ITS technologies implemented in a well-integrated fashion will promote transit efficiency and convenience and lead to transit usage beyond levels currently observed.
UCB-ITS-PRR-2006-2
February 2006, 108 pp

CALIFORNIA TRAINS CONNECTED

Bensen Chiou, Dr. Jean-Luc Ygnace, Kazuhiro Yamada, Adam Dankberg

This California PATH project is to assist the Capitol Corridor Joint Power Authority (CCIPA) and the California Department of Transportation (Caltrans) assemble a decision framework for selecting wireless Internet access on behalf of customers riding the three California State sponsored Intercity Rail Services. To accomplish this objective, we researched the state of worldwide deployment of service based on the wireless technologies, such as wireless fidelity (WiFi) and Worldwide Interoperability for Microwave Access (WiMAX), conducted a survey of the WiFi service at San Francisco Airport, and examined the historical ridership data on train routes of the Intercity Rail service. In addition, we conducted a survey on the trains offering trial Internet access based on low bandwidth communication infrastructure. The results are used with other data to develop business model options. To support the business mode options, the project technical team researched the wireless technology landscape, examined the technology trends and options, and the specific characteristics of the operating environment of the target rail service, researched the emerging technology for enabling the mobile connectivity, and researched the vulnerability and viable security technologies. The business model options and the technical guidelines can be used to formulate a performance specification for a high-bandwidth trackside infrastructure to connect end user devices to Internet. The specification, in turn, can be used for writing a Request for Quotation (RFQ) to solicit qualified ser-

vice providers for the Internet service on trains.
UCB-ITS-PRR-2006-4
April 2006, 292 pp

SURVEY ON STATUS OF KNOWLEDGE AND INTEREST OF SMART-CARD FARE COLLECTION SYSTEMS AMONG US TRANSIT AGENCIES

Hiroyuki Iseki, Allison C. Yoh, Brian D. Taylor

This study analyzes data collected from an on-line survey of U.S. transit agencies to (1) gauge current levels of interest in smart card technologies, (2) document the current status of smart card system adoption among transit agencies, the degree of planning and implementation, and levels of participation in interagency collaborations, and (3) examine factors common to agencies that have adopted smart card technology and those that have not. Reflecting significant diversity in their goals and objectives, operating environments, financial conditions, and clients served, transit agencies have different levels of need and interest in smart card technology and interoperability. We find that: (1) the extent of consideration and adoption of smart card technology and interoperable systems varies by a number of factors, such as funding availability and partnerships with other operators for other ITS technologies, and (2) the perceptions of benefits, costs, and risks of smart card technologies vary by the extent of smart card system planning and implementation. These findings suggest that transit system managers are often uncertain about the costs and, particularly, the benefits of moving to smart cards; this is especially the case for the often complex interoperable smart cards systems.
UCB-ITS-PRR-2006-12
June 2006, 67 pp

STRATEGIES FOR SUCCESSFUL IMPLEMENTATION OF VIRTUAL WEIGH AND COMPLIANCE SYSTEMS IN CALIFORNIA

Amelia Regan, Minyoung Park, Srinivas Nandiraju, Choon-Heon Yang

California Department of Transportation (Caltrans) recently initiated a program aiming at the development of a virtual weigh and

compliance system (VWCS) for better commercial vehicle monitoring and weight enforcement. For the successful development of the VWCS, it is first necessary to enhance knowledge baseline associated with the virtual WIM systems. This can be achieved by evaluating the current state of the practice that could aid enforcement agencies in the selection of appropriate operating methods and technologies. As an initial step of the program, Caltrans has teamed up with the Institute of Transportation Studies at the University of California at Irvine to document a synthesis for successful implementation of the virtual weigh and compliance systems.

UCB-ITS-PRR-2006-19
October 2006, 61 pp

INSTITUTIONAL ISSUES AND ARRANGEMENTS IN INTEROPERABLE TRANSIT SMART CARD SYSTEMS: A REVIEW OF THE LITERATURE ON CALIFORNIA, UNITED STATES, AND INTERNATIONAL SYSTEMS

Allison C. Yoh, Hiroyuki Iseki, Brian D. Taylor, David A. King

Public transit agencies in California have implemented or are in the process of implementing smart card fare collection systems. Smart cards can provide riders with a convenient fare medium that eliminates the need for exact change, and offers riders one fare card that can be used across multiple modes, operators, and even different jurisdictions. For transit operators, smart cards can minimize fare fraud and pilfering, reduce operating and maintenance costs, speed up boarding times, and enhance data collection for planning purposes. One important objective of transportation planning in California has been to increase transit ridership, and smart cards are widely viewed as a way to make transit use more convenient and appealing.

UCB-ITS-PWP-2006-2
March 2006, 74 pp

CLEAN HYDROGEN FOR TRANSPORTATION APPLICATIONS: REPORT

Marshall Miller, Jonathan Weinert, Michael Nicholas

The California Department of Transportation, as part of their involvement in the California Hydrogen Highway initiative, is planning to construct a hydrogen station at their new maintenance facility in Sylmar, CA (Shop 7, at the junction of I-5 and I-405). This report was written to provide Caltrans information on the design and cost of various hydrogen station types. This information will be used to guide decision-making in choosing the station type and size to meet the anticipated hydrogen vehicle demand at their new facility.

UCB-ITS-PWP-2006-5
March 2006, 52 pp

EASYCONNECT: LOW-SPEED MODES LINKED TO TRANSIT PLANNING PROJECT

Susan A. Shaheen, Caroline J. Rodier

The EasyConnect Low-Speed Modes Linked to Transit Planning Project (TO 5113) project represents the integration of innovative strategies to enhance transit use during the development and construction of a suburban transit oriented development at the Pleasant Hill Bay Area Rapid Transit (BART) District station in the East San Francisco Bay Area. This planning project brings together a unique partnership including small technology businesses, transportation agencies, city and county government, and academia. The project components include the introduction of shared-use low speed mode vehicles and electronic lockers at the proposed TOD. The evaluation of the EasyConnect field operational test (TO 6113-the next phase of this initiative) will provide insights into whether the introduction and integration of low-speed modes and elockers at the Pleasant Hill BART station can significantly increase transit access/use and cost effectively provide a last mile solution.

UCB-ITS-PWP-2006-7
July 2006, 15 pp

SMART PARKING MANAGEMENT FIELD TEST: A BAY AREA RAPID TRANSIT (BART) DISTRICT PARKING DEMONSTRATION

Susan A. Shaheen, Caroline Rodier

Smart parking management technologies may provide a cost-effective tool to address near-term parking constraints at transit stations. Smart parking management systems have been implemented in numerous European, British, and Japanese cities to more efficiently use parking capacity at transit stations by providing real-time information via changeable message signs to motorists about available parking spaces in park-and-ride lots. This working paper describes the interim results of a smart parking field operational test, which operated at a San Francisco Bay Area Rapid Transit (BART) District station in Oakland, California from December 2004 to April 2006. This working paper includes a literature review on the travel effects of smart parking-related systems, a description of the smart parking field operational test, user analyses (focus groups and surveys), and preliminary cost estimates of the field test.

UCB-ITS-PWP-2006-10
August 2006, 82 pp

Safety

GLOBAL WARNING SIGNAL INTEGRATION AS A TOOL FOR WORK ZONE SAFETY AND EFFICIENCY

Theodore E. Cohn, Joseph E.Barton, Daniel S. Greenhouse, Kent B. Christianson

A work zone (WZ) is visually confusing, and while no WZ looks like any other, they all share a common feature. All of them present an array of flashing light signals which are especially prominent at night. These signals ignite with no relation to one another. Each, by itself, is designed to be highly visible, attention-getting and salient, being positioned high on vehicles, along barriers and on other equipment. In this two-part study we investigated ways to make the overall visual appearance of a WZ more compatible with the needs of passers-by. The first part consisted of psychophysical tests to assess the effect on lane keeping ability when the WZ signals were ignited synchronously, as opposed to asynchronous ignition. The second part investigated the feasibility of using wireless communication to coordinate light ignition times and to create coherence among the warning lights. The feasibility of triggering the signals in sequence to create a visible pattern that is instructive to the passing driver was also considered.

UCB-ITS-PRR-2006-3
March 2006, 25 pp

MULTI-CHANNEL MEDIUM ACCESS CONTROL FOR DEDICATED SHORT RANGE COMMUNICATIONS

Tony K. Mak, Kenneth P. Laberteaux, Raja Sengupta, Mustafa Ergen

This paper describes a medium access control (MAC) protocol to Enable multi-channel operation for dedicated short range communication (DSRC). In particular, we focus on the challenge of supporting potentially high-bandwidth commercial or infotainment communications between vehicle and roadside in hotspots over several service channels, while concurrently enabling time-critical vehicle-vehicle communication for safety in a separate channel. In our architecture, within hotspots, communication is aided by one of the access points in the hot spot. This access point is designated the Coordinating Access Point (CAP). Outside hotspots, communication is for safety and is conducted in an ad-hoc fashion. The CAP protocol design is a variant of IEEE802.11 PCF, modified for multi-channel operation. The design objective is to maximize utilization of the service channel used for non-safety communication while meeting the Quality of Service (QoS) constraints of the safety communications. The performance of 802.11 DCF, PCF, and the CAP extensions quantified by simulation in NS-2. The mobility model represents a 4-lane freeway at maximum vehicular traffic flow derived from theSHIFT traffic simulator. The CAP design is shown to significantly enhance both safety and non-safety communication relative to DCF and PCF only.

UCB-ITS-PRR-2006-5
May 2006, 27 pp

COOPERATIVE COLLISION WARNING SYSTEMS: CONCEPT DEFINITION AND EXPERIMENTAL IMPLEMENTATION

Raja Sengupta, Shahram Rezaei, Steven E. Shladover, Delphine Cody, Susan Dickey, Hariharan Krishnan

The concept of cooperative collision warning (CCW) systems is introduced and explained, followed by presentation of experimental results showing the performance of a first prototype CCW system. The CCW concept provides warnings or situation

awareness displays to drivers based on information about the motions of neighboring vehicles obtained by wireless communications from those vehicles, without use of any ranging sensors. This has the advantages of a potentially inexpensive complement of onboard vehicle equipment (compared to ranging sensors that could provide 360 degree coverage), as well as providing information from vehicles that may be occluded from direct line of sight to the approaching vehicle. The CCW concept has been tested on a fleet of five prototype vehicles, supporting a variety of safety services (forward collision warning, blind spot and lane change situation awareness and several modes of intersection threat assessment). The performance of the vehicle position estimation and wireless communication subsystems are demonstrated using samples of experimental data from test sites with both good and bad GPS signal availability.

UCB-ITS-PRR-2006-6
May 2006, 31 pp

Automatic Steering For Conventional Truck Trailers: Development And Assessment Of Operating Concepts For Improving Safety, Productivity And Pavement Durability

H.-S. Jacob Tsao, Yasser Dessouky, Krishna Rangavajhula, Joseph Benjamin Zeta and Lihong Zhou

Trucking productivity can be significantly increased by moving freight with longer combination vehicles (LCVs). However, LCV operations not only raise safety concerns for the surrounding traffic and the LCV drivers themselves but also can damage roadways and bridges not equipped to support the operations. All the discussion about truck size and weight limitations or about the pros and cons of LCV operations is predicated on the use of conventional tractors and trailers. We however observed that a root cause of several major issues associated with LCV operations is the problem of off-tracking. Through this project, we have demonstrated that this off-tracking problem can be drastically reduced with a new partial-automation technology: automated trailer steering (ATS). Although ATS can reduce

the cost of infrastructure modification, it may significantly increase the safety of LCV operations in denser-traffic areas or non-Interstate roadways. ATS can be used to create a new mode of operations in which a tractor can pull a larger number of short trailers - Shorter Trailer Combination Vehicles (STCVs). We demonstrated the benefit of STCV operations for the household-goods moving industry.

UCB-ITS-PRR-2006-8
May 2006, 496 pp

Commercially-off-the-Shelf (COTS) and Emerging Technologies Sensor Testing and Evaluation

Ashkan Sharafsaleh

This report addresses Task S of the Intersection Decision Support (IDS) project funded by Federal Highway Administration (FHWA) and Caltrans. The objective of Task S is to evaluate and select Commercially-Off-The-Shelf (COTS) and emerging technology products that could eventually be deployed at intersections as part of the IDS system. Many sensors were considered and every plausible detection technology was reviewed for this task. The emphasis was on finding sensors that detect and track vehicle movementsFor each sensor type, a set of experiments were set up. After each experiment, the data was analyzed and the results can be found in this report. The following sensors were evaluated in-depth: Conago Microloops by 3M, VDS240 by Sensys Networks, Traficon Video Detection system by Traficon, RTMS by EIS, and stand in-pavement loops. It should be noted that all of COTS products are designed for conventional traffic monitoring purposes and therefore are not intended for the types of functionalities and specifications required by IDS applications. With that in mind, after the results of our experiments were finalized, we found no single detection system can, by itself, meet the detection requirements of IDS system. It is our belief that a combination of different sensors need to be assembled together to provide a reliable detection system to be used in our warning algorithm.

UCB-ITS-PRR-2006-15
July 2006, 54 pp

Experimental Vehicle Platform for Pedestrian Detection

Ching-Yao Chan, Fanping Bu, Steven Shladover

This report documents the work conducted for the evaluation of sensor technologies for pedestrian detection. A survey of recent and available sensor products were selected and evaluated to assess their applicability for vehicle-based solutions. The performance characteristics and limitations of various products and technological approaches were investigated. Subsequently, demonstrative experimental vehicle platforms and testing facilities were developed to illustrate the concept of vehicle infrastructure integration.

UCB-ITS-PRR-2006-16
August 2006, 74 pp

Development of the Advanced Rotary Plow (ARP) for Snow Removal Operations

Han-Shue Tan, Fanping Bu, Bénédicte Bougler, Shiang-Lung Koo, David Nelson, Joanne Chang, Thang Lian

This final report describes the development and the initial field test of an automated snowblower, focusing on one of the more difficult snow removal operations: blowing snow off the freeway along side a guardrail without touching the guardrail. The objective is to minimize damage to the snowblower, guardrail, and other elements of the infrastructure by deploying highly accurate and robust automated steering. The automatic steering is accomplished by following magnets embedded under the roadway. The development process includes transforming this real-world automated highway winter maintenance operation into a control problem, modeling snowblower, designing control algorithms, devising human machine interface, instrumenting a 20-ton snowblower, and conducting demonstration and field tests. The modified snowblower was equipped with add-on sensors, actuator, computer and driver interfaces; the test site includes eight guardrail sections between Kingvale and Soda Springs on the shoulders of Interstate-80 in the Sierra Mountain region near Donner Summit in California, USA. The ride-along and

test data demonstrated that the prototype system achieved all initial performance goals, and very positive feedback has received from various stakeholders as well as the operators who tried it.

UCB-ITS-PRR-2006-17
August 2006, 191 pp

Traffic

Evaluation of the Bay Area Incident Response System (BAIRS)

Michael Mauch, Koohong Chung, Soyoung Ahn, Alexander Skabardonis

The Bay Area Incident Response System (BAIRS) is an integrated Web and GIS based incident racking system that provides tools to improve California's Department of Transportation (Caltrans) incident management capabilities. Currently, BAIRS aids District 4 Maintenance respond to and rack over 33,000 incidents per year throughout the San Francisco Bay area. The report resents the findings from the evaluation of the BAIRS system based on field data on incidents and traffic conditions. Through the implementation of BAIRS, incident response and clearance times were reduced by about 15%. Incident related delays were reduced by 210,000 vehicles-hours annually. The estimated BAIRS benefit-cost ratio is 5:1 based on the incident delay savings. Other benefits that are not reflected in the benefit-cost ratio include reduced fuel consumption and mobile emissions, and improved safety and access for emergency response vehicles.

UCB-ITS-PRR-2006-1
January 2006, 67 pp

Extracting More Information from the Existing Freeway Traffic Monitoring Infrastructure

Benjamin Coifman

This report presents the results of TO 5302, Extracting More Information from the Existing Freeway Traffic Monitoring Infrastructure. This report represents significant advances in the PATH sponsored research into vehicle reidentification from conventional loop detectors, first by extending the meth-

odology across major merge and diverge freeway sections. Second, it extends the methodology to single loop detectors. The report also extends the understanding of traffic phenomena impacting both traffic flow and the performance of the reidentification algorithms. It examines the impacts of lane change maneuvers on delay and develops a model to capture these impacts.
UCB-ITS-PRR-2006-10
May 2006, 80 pp

New Approach to Bottleneck Capacity Analysis: Final Report

James H. Banks

A capacity analysis approach intended as an alternative to the traditional Highway Capacity Manual (HCM) method was evaluated. One- and two-stage models of pre-queue and queue discharge flow (each of which might be thought of as representing "capacity" in some sense) were developed and compared with one another and the HCM method. Two-stage models related capacity flows to intervening variables, including average time gaps (average time separations between the rear of a vehicle and the front of one following it) in the critical lane (that with the highest flow rate) and the critical lane flow ratio (the flow in the critical lane divided by the average flow per lane), and then related these intervening variables to the geometric, vehicle population, and driver population characteristics of bottleneck sites. One-stage models involved direct relationships between capacity flows and site characteristics. Differences in capacity flow among study sites were primarily the result of differences in average critical lane time gaps; however, critical lane flow ratios were also important. The performance of the one-stage and two-stage models was similar. For the sites used to develop the models, both were better able to predict pre-queue and queue discharge flows than was the HCM method. In particular, the HCM method tended to overestimate actual bottleneck flows, especially in queue discharge. However, neither type of model was successful in explaining variations in capacity flows at additional sites used for verification. Once apparently anomalous data were eliminated,

the only significant explanatory variable in the models was the number of lanes. Consequently, it is recommended bottleneck capacity analyses continue to be based on existing HCM methods but that these be supplemented by use of a look-up table based on the means and standard deviations of pre-queue and queue discharge flows for sites with particular numbers of lanes.
UCB-ITS-PRR-2006-13
July 2006, 103 pp

New Approach to Bottleneck Capacity Analysis: Second Interim Report, Work Accomplished During Fiscal Year 2004-2005

James H. Banks

This report documents work accomplished during Fiscal Year 2005-2005 as a part of a research project entitled "New Approach to Bottleneck Capacity." This project is developing an alternative to the traditional Highway Capacity Manual approach to capacity analysis in which capacity flow [either pre-queue flow (PQF) or queue discharge flow (QDF)] is related to a set of intervening variables, including the average time gaps in the critical lane (i. e., that with the highest flow rate) and the distribution of flow across the lanes, represented by the critical lane flow ratio (i. e., the flow in the critical lane divided by the average flow per lane). These intervening variables, in turn, are to be related to the geometric characteristics of bottleneck sites, their vehicle populations, and their driver populations. Work to date has included the collection and analysis of data, analysis of traffic data to document flow characteristics at individual study sites, and an analysis of the relationships among the various traffic flow characteristics, including relationships among the intervening variables and between the intervening variables and capacity flows. Major findings to date are that (a) there are significant differences in the mean values of the flow characteristics during different episodes of PQF and QDF at individual sites; (b) means of flow characteristics are significantly different among the sites (with the exception of critical lane average time gaps in PQF); (c) flow variances also differ significantly

among the sites; (d) QDF appears to vary by time of day at some sites; (e) critical lane average time gaps and critical lane flow ratios are not correlated with one another in either PQF or QDF; (f) there is a significant negative correlation between the time gaps and the flow per lane; and (g) there is a very strong negative correlation between flow in the critical lane and critical lane average time gaps; when plotted, this relationship is virtually linear. On the basis of these findings, models relating flow per lane (for PQF and QDF) to critical lane flow ratios and critical lane average time gaps are proposed for use in the next stage of the research, which will focus on relating the flow ratios and time gaps to the geometric, vehicle-population, and driver population characteristics of the study sites.
UCB-ITS-PRR-2006-18
August 2006, 51 pp

Expediting Vehicle Infrastructure Integration (EVII)

Xuanming Dong, Kang Li, Jim Misener, Pravin Varayia, Wenbing Zhang

This research effort between Caltrans, California PATH and DaimlerChrysler RTNA that demonstrated two potential VII services, one in traffic data probes and another with safety, using real cars and on Caltrans roadways. It presages an operational test and a deployment, and it lays the groundwork for technical and institutional know-how that will be leveraged onto the much larger VII California effort. As such, this project explores and resolves key engineering issues associated with the point deployment of these services in a realistic setting, California roadways and the first-ever private vehicle (owned by an automobile manufacturer's laboratory, DaimlerChrysler Research Technology North America) that "talked" to the roadside, with the roadside backhaul interfacing into an existing Caltrans database and archival application, the Performance Measurement System. In the end, the project demonstrated that Caltrans can do VII and create VII champions, within and outside of Caltrans,
UCB-ITS-PRR-2006-20
October 2006, 70 pp

Design, Field Implementation and Evaluation of Adaptive Ramp Metering Algorithms: Final Report

Roberto Horowitz, Xiaotian Sun, Laura Muñoz, Alex Skabardonis, Pravin Varaiya, Michael Zhang and Jingtao Ma

The main objective of Part I is to develop improved algorithms for freeway on-ramp metering control. Toward this end, two macroscopic traffic models are first introduced and analyzed. The first is a modification of the cell transmission model (CTM) developed by Daganzo. This modified CTM uses cell vehicle densities as its state variable and allows non-uniform cell lengths. The second is a piecewise linearization of the modified CTM, which results in a switching-mode model (SMM). The linear structure of the SMM simplifies system analysis, data estimation, and control design. Furthermore, different observability and controllability properties in different modes motivate the design of a switching ramp-metering controller. In Part II of this research project, we developed several integrated corridor traffic control strategies and applied them to two networks, one is a real network from the Dallas-Fort Worth are a and another a synthetic network constructed to highlight some key issues in the design, implementation, and evaluation of integrated corridor control systems. The two corridor control strategies developed in this research, the local synchronization control and the global optimal control, were implemented in a traffic loading platform developed by UC Davis researchers in another research, with modifications to its junction flow updating rules that incorporates signal and ramp meter operations. The local synchronization control, designed to manage queues effectively through coordinating ramp meters with neighboring traffic signals, is rule-based and easy to implement. The more complex global optimal control, on the other hand, optimizes traffic control settings while taking traffic conditions in the entire network into consideration. It is solved by two heuristic global search algorithms, Genetic Algorithm and SPSA. The local synchronization and global optimal control algorithms, together with an isolated traffic control

algorithm where each control element is optimized individually, are evaluated on the two networks under different demand patterns and traffic loads. These algorithms are evaluated from two different perspectives, namely their efficiency in terms of travel time savings and equity in terms of the distribution of the travel time savings to different traveler groups.
UCB-ITS-PRR-2006-21
October 2006, 174 pp

Traffic Management System Performance Using Regression Analysis

David Levinson, Wei Chen

This study can be viewed as a preliminary exploration of using regression analysis to evaluate long-run traffic management system performance. Four main traffic management systems in the Twin Cities metro area - Ramp Metering System, Variable Message Signs (VMS), Highway Helper Program, and High Occupancy Vehicle (HOV) System were evaluated based on multiple regression models. Link speed and incident rate were employed as the response variable separately. Consequently, regression analysis can be a simple and effective research method for testing the macroscopic association between traffic management and traffic system performance; however, additional research is still necessary to obtain an overall evaluation of each of the traffic management systems. Furthermore, improvements could be made through model improvement, adding relevant predictor variables, and decreasing data-limitations.
UCB-ITS-PWP-2006-3
March 2006, 43 pp

Effectiveness of VMS Using Empirical Loop Detector Data

Hong Huo, David Levinson

Variable message signs (VMS) (also called Changeable Message Signs (CMS) or Electronic Message Signs (EMS)), are devices installed along the roadside to display messages of special events. They give warning of congestion, incidents, roadwork zones or speed limits on a specific highway segment. A complete message on a panel generally includes a problem statement indicating incident, roadwork, stalled vehicle

etc; a location statement indicating where the incident is located; an effect statement indicating lane closure, delay, etc and an action statement giving suggestion what to do. They may ask vehicles to take alternative routes, limit travel speed, warn of duration and location of the incidents or just inform of the traffic conditions.
UCB-ITS-PWP-2006-4
March 2006, 25 pp

A Paramics Plugin for Actuated Signal Control and First Generation UTC

Gabriel Gomes, Alexander Skabardonis

This report serves as a user manual for a plugin developed under the Paramics API for simulating standard surface street traffic controllers. The strategies included are time-of-day, actuated signal control, traffic responsive, and traffic responsive with critical intersection control.
UCB-ITS-PWP-2006-8
July 2006, 21 pp

Evaluation of Portable Automated Data Collection Technologies: Interim Report, Work Accomplished During Fiscal Year 2005-2006

James H. Banks

This report documents work accomplished during Fiscal Year 2005-2006 as a part of a research project entitled "Evaluation of Portable Automated Data Collection Technologies." Major activities during this period included a literature survey, surveys of potential users and vendors, preliminary evaluation of portable data collection technologies to select candidate systems for demonstration, and development of demonstration plans. There is demand for portable automated data collection systems for uses related to planning, traffic operations, traffic census, and traffic surveillance functions. Potential users are interested in volume count, speed, occupancy, travel time, vehicle-length classification, and axle-based vehicle classification data. Potential uses require systems to remain installed from a few hours up to several years. Potential users want systems that minimize traffic disruption and exposure of crews to traffic, are

"plug-and-play," have IP-addressable communications capability, can provide data in a variety of formats, and have flexible power supplies. Candidate systems for demonstration are expected to consist of combinations of different sensors with different power supply and mounting system options. Current plans call for nine separate demonstrations. These demonstrations include tests of systems based on EIS microwave radar sensors that are currently underway in Caltrans District 11, demonstrations of other systems based on EIS and Wavetronix microwave radar sensors to be designed by the study team and carried out by District 11, and a demonstration of The Infra-Red Traffic Logger (TIRTL) that is planned by District 7.
UCB-ITS-PWP-2006-9
August 2006, 35 pp

Transit

Development of Bus Rapid Transit Information Clearinghouse

Mark A. Miller, Graham Carey, Ian McNamara, Sam Zimmerman

This report documents the development of the bus rapid transit information clearinghouse, which is a web-based informational tool on bus rapid transit systems. It may be accessed at the following website address: http://path.berkeley.edu/informationclearinghouse/. This web-based tool provides users with a comprehensive and organized first-stop way of performing bus rapid transit-related research and investigations. The initial version of the BRT Information Clearinghouse has three primary elements consisting of the Planning Support Tool, the Publications Database, and BRT Resources. The Planning Support Tool provides users directly with or pointers to information resources by walking users through the scope of a given situation and the nature of the issues being addressed to arrive at a set of resources to provide the necessary support. The Publications Database provides access to fully abstracted records of published and/or otherwise publicly available materials from professional journals, technical

and trade magazines, academic publications, conference proceedings, technical reports, government documents, and links to related websites. Direct links to the documents (in PDF) are provided where available. In BRT Resources users will find access portals to BRT-related information including links for site-specific BRT systems around the world, BRT-focused websites, organizations, search engines and research databases, and technical information, assistance and training. We designed and administered a survey to transit industry professionals to review the Information Clearinghouse prior to its official release. Survey responses show that, overall, the Information Clearinghouse fills a gap in the set of informational tools that currently exist in the arena of bus rapid transit systems and that the Information Clearinghouse website is a valuable and useful part of this informational tool collection.
UCB-ITS-PRR-2006-7
May 2006, 108 pp

Development of Deployment Strategy for an Integrated BRT System

Mark A, Miller, Chin-Woo Tan, Aaron Golub, Mark Hickman, Peter Lau, Wei-Bin Zhang

BRT mixes the flexibility of traditional bus transit service with an array of higher performance rail transit features. One of its advantages over rail, however, is its possibility for incremental and flexible deployment. With this flexibility and incremental nature comes a deployment process for BRT that is highly complex because numerous elements can be incorporated in any number of distinct phases. In almost all BRT deployments, ITS and advanced bus technologies have been applied to BRT, however, in less than a fully integrated manner. This project explores how deployment decisions can be made easier, perhaps more rational, and in a more integrated fashion by clarifying the relationships between different BRT elements, and how the different planning-level goals of deployment are affected by decisions regarding particular elements. Both a system architecture and a prototype visual tool have been developed, showing the relationships between and among

common BRT elements and major decision areas.
UCB-ITS-PRR-2006-9
May 2006, 195 pp

DEVELOPMENT OF BRT ARCHITECTURE: A SYSTEM ENGINEERING APPROACH

Mark Hickman, Chin-Woo Tan, Peter Lau, Wei-Bin Zhang

This report discusses the development of system architecture for Intelligent Transportation systems (ITS) applications for Bus Rapid Transit (BRT) systems. In the course of the development of system architecture, it is critical to take a system engineering approach in the development of BRT architecture to assess BRT service needs (or features), the functional realization of these service needs and the means of technological implementation. Motivated by the National ITS architecture, the BRT architecture has a hierarchy of three layers: application, physical, and logical. The application layer consists of the BRT service needs or features. For the physical layer, we first discuss a functional analysis that begins with the identification of system operational features, followed by an identification of the functions that are needed to achieve these operational features. We create a physical architecture modeled around each of the BRT features. In the final step, the logical architecture is traced or mapped from the physical architecture in such a way that the physical layer will implement the processes identified in the logical architecture and assign them to subsystems, and the data flows that originate from one subsystem and end at another are grouped together into architecture flows.
UCB-ITS-PRR-2006-11
June 2006, 81 pp

DEVELOPMENT OF A MODELING FRAMEWORK FOR ANALYZING IMPROVEMENTS IN INTERMODAL CONNECTIVITY AT CALIFORNIA AIRPORTS

Xiao-Yun Lu, Geoffrey D. Gosling, Steven E. Shladover, Jing Xiong, Avi Ceder

This report has been prepared as part of a research project developing a combined quantitative and qualitative approach to planning for improved intermodal connectivity at California air-

ports. The quantitative approach involves the development of an Intermodal Airport Ground Access Planning Tool (IAPT) that combines an air passenger mode choice model, a model of transportation provider behavior and a traffic network analysis model. The qualitative approach will be used to enhance the quantitative analysis to account for those factors which are difficult to quantify and to provide recommended policy and planning guidelines. This report concentrates on the modeling and IAPT design. The modeling includes two main components of the IAPT, i.e. air passenger mode choice model and transportation provider behavior model. The IAPT design includes detailed software structure and functions, user interface, data base, and data flow. Plans for further development of the IAPT and recommendations for future study of airport ground access planning issues are presented.
UCB-ITS-PRR-2006-14
July 2006, 204 pp

OPPORTUNITIES FOR IMPROVED INTERMODAL CONNECTIVITY AT CALIFORNIA AIRPORTS

Xiao-Yun Lu, Geoffrey D. Gosling, Jing Xiong

This working paper has been prepared as part of research to develop a combined quantitative and qualitative approach to planning for improved intermodal connectivity at California airports. The quantitative approach involves the development of an Intermodal Airport Ground Access Planning Tool that combines an air passenger model choice model, a model of transportation provider behavior and a traffic network analysis model. The qualitative approach will be used to enhance the quantitative analysis to account for those factors which are difficult to quantify and to provide recommended policy and planning guidelines.
UCB-ITS-PWP-2006-1
March 2006, 135 pp

IMPROVING MOBILITY THROUGH ENHANCED TRANSIT SERVICES: REVIEW OF THE LITERATURE FOR TRANSIT TAXIS

Rachel J. Factor, Mark A. Miller

This report, an interim deliverable for Task Order 5408:

"Improving Mobility through Enhanced Transit Services", reviews the literature on the background and current potential for transit-taxi services in the United States and abroad. It documents the early tasks of a project aimed at improving the mobility of people during off-peak, low demand times of the day through innovative and alternative public transport services. To identify optimal transit-taxi concepts, we have designed a classification system defined by combinations of three service design options - fixed route, fixed-route with deviation, or hybrid/feeder service - and three operational strategies - using in-house vehicles and labor, contracting out services, or relying on the private market to meet demand. We also conducted case studies investigating these various possibilities. The research shows that most combinations of these three transit-taxi service concepts and operational strategies have been implemented in actual nighttime transit-taxi service and are currently still in use. The literature clarifies that there is no "one size fits all" approach to planning or operating transit taxi service. The service design and operating strategy will depend greatly on the respective financial and regulatory environments, as well as, demographic and land-use characteristics. The research conducted thus far, in concert with forthcoming institutional interviews and modeling, will help determine a specific transit-taxi pilot project implementation in California.
UCB-ITS-PWP-2006-6
May 2006, 74 pp

IMPROVING MOBILITY THROUGH ENHANCED TRANSIT SERVICES: CASE STUDIES FOR TRANSIT-TAXIS

Joshua H. Widmann, Mark A. Miller

In the study we have performed a review of the literature and conducted a small number of site-specific case studies for transit agencies in North America identified from the literature review as either currently having or in the past having had transit-taxi service implemented in their agency's jurisdiction. We initially classified alternative concepts of transit-taxis into a typology of three service design options based on a review of the literature: 1) fixed route, 2) fixed-route with devia-

tion, or 3) hybrid/feeder service and three operational strategies: 1) using in-house vehicles and labor, 2) contracting out services, or 3) relying on the private market to meet demand. After the literature review, we performed the transit-agency-based case studies using a question-and-answer interview style over the telephone.
UCB-ITS-PWP-2006-11
September 2006, 67 pp