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California PATH Annual Report 2008

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California Partners for Advanced Transit and Highways



California PATH

2008 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.

California PATH Headquarters
1357 South 46th Street Building 452
Richmond, CA 94804-4648

tel. (510) 665-3406
fax. (510) 665-3537

<http://www.path.berkeley.edu>
publications@path.berkeley.edu

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As this 2008 annual report illustrates, the California PATH Program had an outstanding year, and continues to be the leading research, development and delivery (R&D&D) organization in Intelligent Transportation Systems (ITS). We made significant advances in core research and had several exciting new developments as well. Highlights include:

The Connected Traveler Project led by PATH and Caltrans in partnership with public agencies and private industry was selected after a highly competitive process, as the initial project for SafeTrip-21, a USDOT Initiative to improve efficiency and safety delivered over existing consumer devices. In November, PATH researchers successfully demonstrated at the ITS World Congress in New York City, a host of complex mobility and safety related applications delivered to travelers and vehicles through multiple wireless links. The concepts behind this effort have their origins in our extensive research in vehicle-to vehicle and vehicle-to-roadside communications on our IntelliDrive (formerly VII) testbed, but the actual demonstrations for the World Congress were developed and delivered in less than six months. PATH researchers working around the clock implemented several distinct demonstration applications on a New York City transit bus operating in the streets of midtown Manhattan.

In September, our research on the Vehicle Assist and Automation (VAA) reached a major milestone: for the first time the magnetic guidance technology for busses was successfully demonstrated in a real transit route in San Leandro, California mixed with auto traffic. Our research continues under a new \$1.9M contract from the Federal Transit Administration (FTA). PATH in partnership with Caltrans, transit agencies and private industry will demonstrate the benefits of VAA applications in regular bus rapid transit (BRT) revenue services.

PATH researchers developed tools for analysis of surveillance data and for performance measurement on freeways and arterials. The algorithms for microscopic modeling of oversaturated traffic flow developed as part of the Federal Highway Administration's NGSIM (Next Generation SIMulation) project are being implemented in existing simulators and extended to model cooperative vehicle systems. PATH researchers are working on new modeling approaches for traffic corridors as part of the USDOT Integrated Corridor Management (ICM) initiative. Also this year, under the FHWA Exploratory Advanced Research Program, PATH initiated new research in using vehicle-vehicle and vehicle-infrastructure communications to support active traffic management strategies.

Research on transit operations and modal integration continues the field testing and evaluation of adaptive transit signal priority systems with support from Caltrans and several transit agencies, and the development of an arterial performance measurement system for busses and auto traffic based on real-time data from multiple sources.

PATH researchers are in the forefront of active safety research. The Cooperative Intersection Avoidance Systems—signalized left turn assist (CICAS STLA) project developed concepts and driver based prototype systems for active left-turn countermeasures at signalized intersections. Furthermore, approaches for avoiding red-light-running accidents have been developed and demonstrated at the PATH Smart Intersection in the Richmond Field Station.

The second PATH-UTC Conference in Los Angeles in November attended by more than 150 participants was hailed for its combined planning and technical content on the theme of tackling congestion in the era of climate change, putting transportation technology developers and implementers at the same table.

In October, California PATH received the IEEE ITS Society Institution Lead Award for excellence in ITS research. This is the first award given to organizations performing research on ITS.

Our researchers, faculty, students, and public- and private-sector partners have kept California PATH's work at the forefront of national ITS research and deployment. We look forward to another year of working closely with our Caltrans partners to make tomorrow's technology come alive today.

A stylized, handwritten signature in black ink, likely belonging to Alexander Skabardonis.

Alexander Skabardonis
Director, California PATH

If I were to pick one major theme that exemplifies the strength of the partnership between Caltrans and PATH, it would be our joint leadership of the Connected Traveler Project under the USDOT's SafeTrip-21 Initiative over the past year. It is just a little over a year ago when the then Research and Innovative Technology Administration (RITA) Administrator Paul Brubaker challenged us to help him explore ways to accelerate the deployment of IntelliDrive (formerly VII) safety and mobility services using after-market mobile consumer devices instead of equipment deeply embedded into cars. We accepted that challenge, gathered strong partners, such as Navteq, Nissan, and Santa Clara VTA, and put together a bold proposal that was selected, after a highly competitive process, as the initial project for SafeTrip-21.

The need for the safety and mobility benefits that will be enabled by SafeTrip-21 and the Connected Traveler could not be more apparent anywhere than it is here in California. Each year, our State suffers a societal cost of more than \$46 billion in terms of car crashes and traffic congestion. Car crashes here cause more than 4,000 deaths and 300,000 serious injuries annually. Traffic congestion leads to a loss of economic productivity, wasted fuel, adverse environmental impacts, and disrupted goods movement, and these costs continue to rise as well. We sincerely believe that SafeTrip-21 and the Connected Traveler will help us significantly improve safety and reduce traffic congestion, and together with PATH, we are committed to investigating the benefits of implementing them.

Our \$12.4 million Cooperative Agreement with RITA for the Connected Traveler Project was signed on May 1, 2008. We came out of the starting blocks running, as we had committed to showing various demonstrations of our progress early on. We had major demonstrations at PATH in August, for the AASHTO Subcommittee on System Operations and Management, and the ITS America Board of Directors, respectively.

In November, these demonstrations were followed in grand style by an encore at the ITS World Congress in New York City, which was the first public unveiling of the SafeTrip-21 Initiative, in the eyes of the world. There, Caltrans and PATH outfitted a New York City transit bus with the on-board equipment and handheld Smart Phones that showed the experience of providing safety and mobility applications for both drivers and transit riders. This successful demonstration was one of the highlights of the ITS World Congress, and its success was a tribute to the hard work and dedication of the PATH staff that spent nearly day-and-night for two weeks prior while preparing for the show.

Now that the ITS World Congress is over, we will spend the next year working on the field operational test for the Connected Traveler in the San Francisco Bay Area. It is also worth noting that in November our team was awarded an additional \$1 Million in funding to incorporate a Smart Parking component into the Connected Traveler. This Smart Parking work will explore the hypothesis that providing drivers with transit parking availability and real-time scheduling information can be the incentive needed to convince them to park their car and take public transportation instead.

Additionally, the Vehicle Assist and Automation (VAA) program, led by Caltrans in partnership with PATH, including progressive transit agencies and innovative private industries, made significant progress during 2008. After many years of effort by PATH, the magnetic bus-guidance system was, for the first time, demonstrated in San Leandro along an active transit bus route mixed with busy city traffic. Early 2008, the Federal Transit Administration (FTA) awarded a \$1.9 million grant to the California VAA Team, based upon the success on the previous VAA projects and the merits of the grant proposal. The Team is now conducting a pilot program to demonstrate the benefits of VAA applications in regular BRT transit revenue services.

With support of PATH researchers, the Division of Research & Innovation, Division of Mass Transportation, and District 7 in Southern California are working together to identify issues that arise as a result of implementing BRT systems on a conventional State highway. The results from this study will lead to possible language changes to Department Guidelines.

We are truly excited about the work underway as part of our partnership with PATH, and look forward to another year of productive research that will help us improve mobility across California.

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 mobility and safety, with advanced ideas, technologies and a deployment focus. Collateral benefits from PATH's research include traveler information, regardless of the mode or modes taken, reduced energy consumption and lesser environmental impacts. PATH's research is also directed at 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 much of 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 engineering 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 and 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, and PATH is headquartered at the University's Richmond Field Station.



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.

About forty full-time staff members, including a core group of research staff members, plus program leaders and administrators work at PATH's headquarters. 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. We have also entered into cooperative research agreements with a variety of public and private organizations, both domestic and international. Normally, the product-development focused 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 several PATH research projects on traffic and transit operations 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/VIS-PLUS Integration," and "Development of an Integrated Simulation and Optimization Tool".

The lab has become a unique facility, which collects, stores and processes real-time or quasi real-time data from several signalized arterials throughout the State. Data include traffic data from surveillance systems (inductive loops, video), signal status data from field controllers, and transit operation and movement data from automatic vehicle location (AVL) systems. Currently, PATH researchers are developing a set of software 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 multimodal transportation operations, hardware in the loop simulation, field testing and evaluation of signal control algorithms, and student workshops and training.

The Vehicle-Infrastructure Transportation Applications Laboratory (VITAL)

The Vehicle-Infrastructure Transportation Applications Laboratory (*VITAL*) is a place where the idea of information exchange – a prime enabler for emerging safety and mobility applications – between vehicles, from the roadside-to-vehicle or from the vehicle-to-roadside becomes real. That's because *VITAL* is part of PATH where the idea of information exchange – a prime enabler for emerging safety and mobility applications – between vehicles, from the roadside-to-vehicle or from the vehicle-to-roadside becomes real.

VITAL researchers are PATH researchers. Since its inception, PATH has been in the forefront of vehicle-infrastructure and vehicle-vehicle communication, initially for mobility with potential safety benefits. This legacy of understanding, expertise and talent from concept to prototyping to evaluation is available to *VITAL*.

The national IntelliDrive (SM) program and the related first-of-its-kind Caltrans roadside deployment and experimentation of wireless connectivity, implemented at first with Dedicated Short Range Communication (DSRC) and WiFi and now with long- and short-range communications to include mobile phone links, brings to focus the historical and ongoing PATH leadership in using communications – and information – to facilitate mobility and safety concepts. Some PATH researchers associated with *VITAL* trace their expertise all the way back to the National Automated Highway Systems Consortium and others have joined on through a host of vehicle-infrastructure transportation applications efforts, through Cooperative Intersection Collision Avoidance Systems (CICAS), VII California (see www.viocalifornia.org), the regionally- and nationally-significant Vehicle-Infrastructure Integration on-the-“real road” research testbed. Current *VITAL* activities include the Networked Traveler aspects of the RITA- and Caltrans-sponsored SafeTrip-21, where we explore how connectivity to smart phones help travelers determine modal alternatives and safely get there from here...

VITAL facilities are PATH facilities. This includes suite of wirelessly equipped vehicles – from passenger vehicles to heavy trucks and buses – and roadside equipment (with a host of DSRC transceivers, WiFi and others), traffic controllers to include an intelligent intersection. *VITAL* also has a laboratory with a server link real time data from VII California in the San Francisco Peninsula. *VITAL* is also linked to the Parsons Traffic and Transit Laboratory, which gives researchers high resolution, real-time traffic and transit data from a number of arterials, urban areas and transit systems from Northern and Southern California.

A VITAL future. *VITAL* now gives to PATH and its sponsors and donors:

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

The *VITAL* organization not directly funded by our primary research partner, Caltrans; instead, and to underscore, *VITAL* gives 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 more than 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, The University of Southern California, and others. We also contract with or subcontract with many private companies and corporations.

PATH Activities in National ITS Programs

PATH activities in National ITS Programs continues at a very high level. This year, PATH's proposed work on improving mobility and safety in partnership with Caltrans and other organizations was selected by USDOT RITA Administration as the first project of the Safe and Efficient Travel through Innovation and Partnerships in the 21st Century (SAFE TRIP-21) initiative. In less than six months following the award, the PATH research team was able to successfully demonstrate systems to improve mobility and safety during the ITS World Congress in New York City. Ongoing work focuses on field operational tests. PATH and partners were also awarded a supplemental grant for Smart Parking under the Safe-Trip 21 effort.

PATH also participates actively with our Federally- and Caltrans-funded Cooperative Intersection Collision Avoidance System – Signalized Left Turn Assistance (CICAS-SLTA) project. The CICAS program is one of the ITS Joint Program Office's original 'Nine Major Initiatives', in recent years conceptually reconstituted as a primary safety application enabled by the Vehicle-Infrastructure Integration (VII) effort. The VII – or Dedicated Short Range Communication (DSRC)-connected vehicle and infrastructure – work conducted at PATH is Caltrans-funded but has contributed significantly to the national ITS program via our accomplishment; in 2008, our work has led to further expansion of the California Development Test Environment, linked to the Federal VII and now, IntelliDrive (SM), program. In addition, our work and ideas have contributed significantly to SAFE TRIP-21. This work has matriculated to international recognition. On the VII topic alone, public sector delegations from Canada, Japan, Korea, the Netherlands and a host of private companies have come to observe our VII California testbed (see www.viicalifornia.org) and to discuss emerging, innovative ideas with regard to connected vehicle, connected traveler and VII research.

PATH in partnership with Caltrans was awarded a major grant from the Federal Transit Administration (FTA) for continuation of our highly successful research on Vehicle Assist and Automation (VAA). For the first time, the PATH developed magnetic bus-guidance system was successfully demonstrated in real-world conditions on East 14th arterial in San Leandro.

PATH also participates in several national major efforts in the area of traffic operations. PATH has led the development of the concept of operations, sample data and technical requirements for the San Francisco I-880 and San Diego I-5 corridors, two of the pioneer sites of the USDOT's Integrated Corridor Management (ICM) Program. PATH is working on the analysis, modeling and simulation approaches, and supports the modeling efforts in the San Diego I-15 corridor in the second phase of the ICM. Initiative. Under sponsorship from the FHWA Office of Operations, PATH performed an analysis of traffic characteristics and congestion for general purpose and toll lanes on SR91, and provides support in the independent validation of the oversaturated flow algorithm developed by PATH for the Next Generation Simulation (NGSIM) project.

Other Projects

PATH attracted research support from a variety of other sources during the past year.

Some of these projects include:

- AudiStreets: a significant effort in environmentally-friendly navigation, both for “green

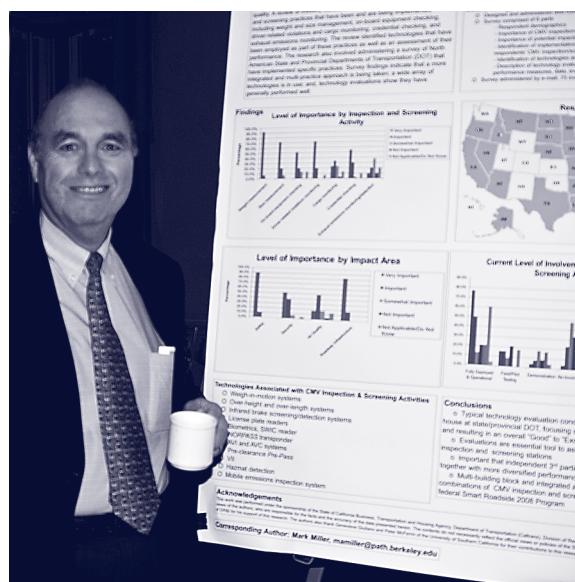
- routing” and for fine tuning engine parameters in response to driving conditions
- NEC: support for the Vehicle Infrastructure Transportation Application Laboratory (VITAL)
- Through our reputation, we continue to have a host of other privately-financed projects from vehicle manufacturers and other ITS industrial partners; including grants from General Motors on interactions of driver behavior and automated driver assistance systems

Highlights

- California PATH received the IEEE ITS Society Institution Lead Award for excellence in ITS research. This is the first award given to organizations performing research on ITS.
- PATH researchers made several invited presentations at major Conferences and professional meetings nationally and internationally: 87th TRB Annual Meeting, Washington DC, January 2008, 10th Conference of Advanced Technologies in Transportation Engineering, Athens, Greece, May 2008, APTA Annual Meeting, Austin, Texas, May 2008, ITS Canada Annual Meeting, Toronto, June 2008, Hellenic Institute of Transport, Greece, May 2008, TRB Freeway & Tollway Operations Conference, Miami, Florida, June 2008, ITE Annual Meeting, Anaheim, August 2008, International Workshop on Traffic Data Collection, Barcelona, Spain, September, 2008, IEEE ITSC Conference, Beijing, China October 2008, and ITS California Annual Meeting, Sacramento, December 2008.
- Audi AG motor company donated two Audi A3 vehicles for use in PATH research
- Nissan Motor Co donated two Nissan Altima vehicles for use in PATH research
- Mr. Scott Belcher, President and CEO of ITS America visited PATH on March 20, 2008. We presented PATH ongoing research highlighted with demonstrations.
- A high level delegation from the research division of Nissan Motor Co visited PATH on March 11, 2008 for discussions on possible joint work on ITS applications.
- In May of 2008, PATH staff made presentations and several demonstrations including transit precision docking, intersection left-turn warning, and truck onboard monitoring systems to a 15 member delegation of the US Congress as part of the US DOT RITA Transport Innovation Tour.
- PATH research was presented to several European delegations including a delegation of the Belgium Parliament on June 27, 2008, Swedish Parliament on August 21, 2008, Finnish Parliament on November 21, 2008, and representatives of the city of Milan, Italy on December 3, 2008.
- On August 6, 2008, PATH staff made presentations and several highly successful demonstrations including transit precision docking, intersection left-turn warning and mobility applications as part of the Safe-Trip 21 project to the ITS America Board of Directors
- In August 12-13, 2008, PATH participated in the AASHTO SSOM meeting in San Francisco, and demonstrated ongoing research as part of the Safe-Trip 21 project.
- On September 5, 2008, the magnetic guidance technology for bus precision docking developed by PATH was successfully demonstrated into a real world setting on East 14th street in San Leandro, California. The demonstration attracted significant media coverage including local TV stations and newspapers.
- PATH leadership met with Ms. Shelley Row, Director and staff members of the US-DOT ITS Joint Program Office at the USDOT headquarters in Washington DC on

September 25, 2008. Discussions focused on the current PATH research as relates to the national ITS program and opportunities for future research.

- ITS World Congress, New York City, November 16-18: PATH staff made several presentations and several highly successful demonstrations in the streets of Manhattan, including transit signal priority, traveler information and other safety and mobility applications as part of the Connected Traveler project of Safe-Trip 21.
- The second PATH-UTC Conference took place in Los Angeles on November 6-7, 2008. The theme of the Conference was “Tackling Congestion in an Era of Climate Change”.
- PATH hosted a meeting with researchers of INRETS, France research center on December 2, 2008 to discuss ways and opportunities for collaboration.
- PATH hosted a one-day visit for Dr. Joe Peters, Technical Director of the FHWA R&D Office of Operations on December 19, 2008. We presented PATH ongoing research highlighted with demonstrations.



The second PATH-UTC Conference took place in Los Angeles on November 6-7, 2008.

Networked Traveler portion of SafeTrip21 demonstrated at ITS World Congress in New York City

Jim Misener, PATH Executive Director

The Networked Traveler World Congress Development and Demonstration, was given in New York City in November, 2008. To conceive and deliver the demonstration resulted in development of three main services. “Tell me about my trip” assists trip planning with traffic information, transit connections, and driving choices for an eco-route and a fastest route. “Tell me about my route” can provide travelers with real-time road-safety conditions, real-time traffic and parking conditions, schedule-driven transit information, real-time GPS-based transit status, road signage. “Watch out for me!” includes services such as the pedestrian-to-vehicle safety alert, the vehicle-to-pedestrian safety alert, road-to-vehicle road safety information, road hazard alerts, and work zone alerts.

Within this framework, a plethora of smartphone-delivered services were provided: Pedestrian alerts allowed slow-moving pedestrians to signal drivers to watch out; a work zone alert signaled phones on the demo bus to slow down for its approach to the cone area; centralized, real-time transit information helped virtual commuters meet their trains and buses on time; and smart parking simplified a modal switch by helping drivers find and reserve available parking in real-time. Other items in the demo included updated travel time estimates, next-stop alerts, and a hydrocarbon-savings calculator for transit riders and speed zone and signal priority alerts for drivers.

The objective was to show what could happen in a Networked Traveler ethos, then put it on the road to illustrate and punctuate the reality. Another objective is that the research team associated with Networked Traveler was able to learn significantly and the mid-term result of bringing selected applications into a field evaluation was brought closer to reality.



Safetrip Demo New York City

California PATH receives the first institutional lead award at the 2008 IEEE Intelligent Transportation Systems Conference (ITSC) for:

“Significant contributions in research and development in Intelligent Transportation Systems”



Left to Right: Dr. Matthew Barth, ITSC 08 Program Co-chair;
Wei-Bin Zhang; Accepting the award on behalf of the PATH Program
Dr. Fei-Yue Wang, ITSC 08 General Chair

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 fifteen faculty and more than 40 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, methodologies 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:

Several projects related to traffic surveillance have been successfully completed this year. Methods have been developed to use detector data from conventional and advanced loop detector designs for vehicle re-identification, travel time estimation, and other ITS applications (TO 5304). Systematic methods for detector diagnostics and data fusion from multiple detector sources were developed and tested in the I-405 Orange County testbed (TO 5327). An evaluation was performed on portable data collection technologies (TO 6302). New loop detector cards (IST-222) were evaluated at the I-80 Berkeley Highway Laboratory (BHL) site. In another study, promising results were obtained from testing wireless MEMS sensor to measure pavement loads (TO 5328). A new non-intrusive laser sensor has been developed and successfully tested in the field (TO 5606). In an ongoing study, analysis and visualization tools are being developed for detector diagnostics (TO 6327). Alternative sensing technologies are being developed for detecting pedestrian and bicycles at traffic signals (TO 6203).



Ongoing enhancements to the freeway Performance Measurement System (PeMS) (RTA 15891) include improved visualization tools, incorporation of other data sources (e.g., toll tag data in the San

Francisco Bay Area, census stations), and improved algorithms for estimating congestion causes and impacts. Ongoing research investigates the optimal sensor placement for freeway traffic management (TO 6328), and the use of both sensor and signal controller status data to improve the performance of signal systems on arterials (TO 6332). The performance of mixed flow and toll lanes on SR91 freeway were evaluated based on field data.

The improved car-following and lane-changing algorithms for oversaturated traffic flow developed as part of the NGSIM project, are being implemented into the state of the art traffic simulators under FHWA sponsorship. A new microscopic traffic flow theory was developed and validated using the NGSIM vehicle trajectory data. Improved analysis tools have been developed for calibration of microscopic simulation models (TO 5308). A new model, Netzone, has been developed for traffic analyses at work zones (TO 5300). Work has been completed on a tool to produce origin-destination matrices for input to traffic simulation models (TO 5502). In another study, a suite of software modules was developed to simulate ramp metering algorithms with the Paramics model (TO 5305). The first version of the macroscopic cell-transmission based TOPL model has been successfully completed and demonstrated. Ongoing work (TO 6614) focuses on the extension of TOPL model to simulate traffic corridors.

Ongoing work on freeway ramp metering strategies developed improved algorithms for traffic responsive control and on-ramp queue control (TO 6329). Another study focuses on assessing the effectiveness of ramp metering to improve bottleneck discharge flows based on detailed field data from video recordings “before” and “after” implementation of ramp metering (TO 6331). Work continues on developing advanced strategies for adaptive traffic signal control on arterials (TO 5322/6322 and TO 5323/6323); a simulation testbed was developed to evaluate adaptive signal control strategies (TO 6322) and new algorithms are proposed for control of traffic signals with adjacent ramp meters (TO 6323).

PATH led 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 US DOT Integrated Corridor Management (ICM) initiative. Work focused 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. Some of these strategies are tested through simulation in ICM Phase 2 (TO 6333). Related projects include further field testing of the Cartesius system that facilitates the coordination of operating agencies to minimize the response time to incidents along traffic corridors (TO 6324) in Orange County, and the development of guidelines for displaying travel times on changeable message signs (TO 6303). PATH researchers are developing active traffic management strategies including variable speed limits as part of a major research grant sponsored by FHWA under the US DOT Advanced Research initiative.

Traffic Surveillance

Conventional Surveillance Technologies

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

Corridor Investigation of Anonymous Vehicle Tracking for Real-Time Performance Measurement, TO 5304; Stephen Ritchie, University of California, Irvine. UCB-ITS-PRR-2008-23.

Evaluation of IST-222 Detection System, TO 5314; Gabriel Gomes, University of California, Berkeley. UCB-ITS-PRR-2009-17.

Low-Cost Wireless MeMS System for Measuring Dynamic Pavement Loads, TO 5328; Pravin Varaiya, University of California, Berkeley. UCB-ITS-PRR-2008-36.

Data Fusion, I-405 TestBed, TO 5327; Art McCarley, Cal Poly San Luis Obispo. UCB-ITS-PRR-2008-21.

Development and Field Testing of Laser Photodiode Array Based Vehicle Detection Systems on the Highway, TO



5606; Harry Cheng, University of California, Davis. UCB-ITS-PRR-2008-28.

Evaluation of Portable Automated Data Collection Technologies, TO 6302, James Banks, San Diego State University. UCB-ITS-PRR-2008-15.

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

Data Processing/Analysis/ Performance Measurement

Traffic Flow

Next Generation Simulation (NGSIM): Validation of the Oversaturated Freeway Flow Algorithm, RTA7214; Alexander Skabardonis, University of California, Berkeley.

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

Performance Measurement

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

Improving the Performance of Signal Systems Using Signal and Loop Data, TO 6332, Wei-Bin Zhang, California PATH.

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

Speed and Throughput Analysis on SR91, Federal Highway Administration, Office of Operations US DOT DTFH61-08-P-00144.

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. UCB-ITS-PRR-2008-10.

Integrated Construction Zone Traffic Management, TO 5300; Michael Zhang, University of California, Davis. UCB-ITS-PRR-2008-9.

Integrated Ramp Metering Design, Evaluation and Optimization Platform with PARAMICS Simulation, TO 5305; Will Recker, University of California, Irvine. UCB-ITS-PRR-2009-10.

Developing Calibration Tools for Microscopic Traffic Simulation, TO 5308; Michael Zhang, University of California, Davis. UCB-ITS-PRR-2008-7, UCB-ITS-PRR-2008-08.

Tools for Operations Planning Phase II TO 6614; 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

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.

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.

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. UCB-ITS-PRR-2008-30.

San Diego Integrated Corridor Management Demonstration, TO 6613; Alexander Skabardonis, University of California, Berkeley. UCB-ITS-PRR-2008-33.

San Diego Integrated Corridor Management Demonstration, Phase II: Modeling and Simulation, TO 6333; Alexander Skabardonis, University of California, Berkeley.

Development and Application of Selected Mobility Applications for VII, Steven Shladover, California PATH, US DOT DTFH61-07-0038.



Transportation Safety Research

Ching-Yao Chan, Program Leader

This past year, transportation safety research at PATH continued to expand in depth and breadth, with continuing emphasis in the proposition that communications technologies will be the enabler for transportation safety and mobility – the basic premise and promise of IntelliDrive (<http://www.intelldriveusa.org/>), formerly known as Vehicle-Infrastructure Integration (VII). Built upon previous projects that centered on the Vehicle-Infrastructure Transportation Applications Laboratory (VITAL), the PATH safety team remains active in the IntelliDrive program, including a successful, ground-breaking Safe-Trip 21 demonstration at the 15th World Congress of Intelligent Transportation Systems in New York in November 2008. Safe-Trip 21 is a US DOT initiative headed by RITA (Research and Innovation Technology Administration) and designed to improve safety and reduce congestion by identifying and harnessing existing technology and adapting it for transportation needs. Currently, the PATH team is implementing and preparing for Safe-Trip 21 safety field experiments in the San Francisco Bay Area under the Networked Traveler project, with joint sponsorships from US and California DOT and partnerships with private and public organizations. The PATH team is also actively conducting technology and human-factor research, and spearheading the implementation and deployment of Cooperative Intersection Collision Avoidance Systems (CICAS), which is a primary application within the framework of IntelliDrive.

To complement the thrust of cooperative safety systems, a solid foundation of work that addresses various aspects of safety among transportation modes continues to be performed. Specific project groupings are:

- Intersection Safety and Cooperative Safety Systems
- Driver Behavior – modeling and applications for safety and countermeasure studies
- Highway Network Safety Assessment – Ramps & Junctions & HOV Facilities
- Pedestrian and Bicyclist Safety
- Development of Tools, Techniques and Data

In 2008, significant accomplishments include our understanding of HOV entry/exit criteria and design on safety, which won the award of Best Applied Research from the TRB HOV Committee. The activities of IntelliDrive and Safe-Trip 21 projects were nominated for IT'S America's "Best of ITS" in the area of research.



Limited (left) and Continuous (right) Access HOV Lanes

Intersections and Cooperative Safety Systems

Connected Traveler and Safe-Trip 21; TO 6615; Jim Misener, California PATH.

CICAS, TO 6608; Jim Misener, California PATH.

Effects of Cooperative Adaptive Cruise Control on Traffic Flow: Testing Drivers' Choices to Following Distance, TO 6202; Steven Shladover, California PATH.

Development and Evaluation of Selected Mobility and Safety Applications for VII TO 6224; Steven Shladover, California PATH.

Red Light Running Avoidance, TO 6210; Wei-Bin Zhang, California PATH.

ITS Band Roadside to Vehicle Communications in a Highway Setting, TO 6214; Raja Sengupta, University of California Berkeley.

Driver Behavior

The Naturalistic Driver Model: Development, Integration, and Verification of Lane Change Maneuver, Driver Emergency, and Impairment Modules, TO 6500; Delphine Cody, California PATH.

Reduce Accidents Involving Driver Fatigue, TO 6220; David Ragland, University of California Berkeley.

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

Evaluation of an Animal Warning System Effectiveness, TO 6604; Ashkan Sharafsaleh, California PATH.

Pedestrian and Bicyclist Safety

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

Estimating Pedestrian Accident Exposure, TO 6211; David Ragland, University of California Berkeley.

Evaluate the Effectiveness of Ladder Style Crosswalks, TO 6219; David Ragland, University of California Berkeley.

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

Identifying Factors that Determine Bicycle and Pedestrian-Involved Collision Rates and Affect Bicycle and Pedestrian Demand at Multi-Lane Roundabouts, TO 6222; David Ragland, University of California Berkeley.

Tools, Techniques and Data

Assessing Automated Speed Enforcement Systems in California, TO 6212; 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, University of California Berkeley.

Quantifying the Performance of Countermeasures for Collision Concentrations Related to Ramp/Freeway Mainline Junctions, TO 6600; Ching-Yao Chan, California PATH.

Safety of HOV Ingress/Egress, TO 6601; Ching-Yao Chan, California PATH.

Evaluation of Wet Weather Accident Causation Criteria, TO 6602; David Ragland, University of California Berkeley.

Data Collection: Strategic Highway Safety Plan, TO 6610; David Ragland, University of California Berkeley.

Implementation and Evaluation of Automated Vehicle Occupancy Verification, RTA 77754; Ching-Yao Chan, California PATH.



Transit Operations Research

Wei-Bin Zhang, Program Leader

The PATH transit program researches new service concepts, methods and ITS technologies for innovating and enhancing public transit systems that will make public transportation more attractive to choice riders and ultimately help to reduce traffic congestion. We are working toward bringing advanced yet practical solutions to real-world problems. While addressing research on transit subjects, PATH has devoted significant efforts to investigate strategies and technologies for integrating transportation networks to reduce congestion and improve efficiency across the transportation system as a whole. These efforts have been a collaboration among different programs within PATH. Under the collaborative efforts, PATH researchers, including faculty, staff, and students from across California, are working closely with transit and traffic operation agencies to address real world problems in the areas of Bus Rapid Transit, innovative concepts for transit operations, integrated corridor management, connection among different mode of transportation systems, transit safety and rural ITS applications. Below are highlights of the projects conducted in 2008.

- **Modal Integration:** PATH research address issues related to integrated transportation systems. Participating in two consortium of agencies in the Bay Area and San Diego, studies on Integrated Corridor Management 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. Studies are also 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 practical means for predicting Time-to-Arrival at the grade crossing and adaptive signal control strategies to minimize the delays to motor vehicle traffic while improving schedule adherence for rail operation. In another project, a multimodal traveler information system is being developed. Investigation of approaches for improving intermodal connectivity at California airports is also being conducted.
- **Bus Rapid Transit:** Building upon the extensive research on Bus Rapid Transit (BRT), PATH continues to devote efforts in the area of BRT, investigating issues focusing on large impact solutions such as vehicle assist and automation (VAA) technologies. PATH successfully demonstrated bus precision docking into a real world setting on East 14th street in San Leandro, California. Under a new major award from FTA, PATH researchers will demonstrate the technical merit and feasibility VAA technology applications in transit revenue services, and to identify and document their costs and benefits. Additionally, studies have been conducted to evaluate cost effective BRT system 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.
- **Innovative Transit Operations:** PATH has been conducting significant research on transit operations for a variety of applications, including field testing and evaluation of Adaptive signal priority system that allows buses to gain priority at the intersection while minimizing the disturbance to other traffic. Concept of cost effective transit-taxi as a means to fill the need for improvement in off-peak public transport is being explored. Efficient Deployment of Advanced Public Transportation Systems (EDAPTS) for suburban and rural applications is moving into deployment stage and will soon be field tested.

In 2008 the PATH transit program embraced the following research areas in the Task Order (TO) 6000 series, RTA's or outside funding sources:

Multimodal and Integration

A Combined Quantitative and Qualitative Approach to Planning for Improved Intermodal Connectivity at California Airports, TO 6406; Xiaoyun 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.

Improving Performance of Coordinated Signal Control Systems Using Signal and Loop Data, TO 6332; Meng Li, Liping Zhang, California PATH.

Dynamic Passenger Information System, RTA 77752; Wei-Bin Zhang, California PATH

Transit Operations

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, Cal Poly State University Pomona, Edward Sullivan, Cal Poly State University San Luis Obispo.

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

Stage 5 Test Deployment of Efficient Deployment of Advanced Public Transportation Systems (EDAPTS), TO 6403; Jeff Gerfen, Cal Poly State University San Luis Obispo, Xudong Jia, Cal Poly State University Pomona.

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

Bus Rapid Transit

Vehicle Assist and Automation, FTA RTA 77830; Wei-Bin Zhang, 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.

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.

BRT ToolBox, TO 6410, Wei-Bin Zhang, Mark Miller, California PATH.

Advanced Bus Rapid Transit

In September PATH successfully demonstrated bus precision docking in a real world setting on East 14th street in San Leandro, California.



Policy Research

Karen Frick, Program Leader

The PATH Policy 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 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, and land use.

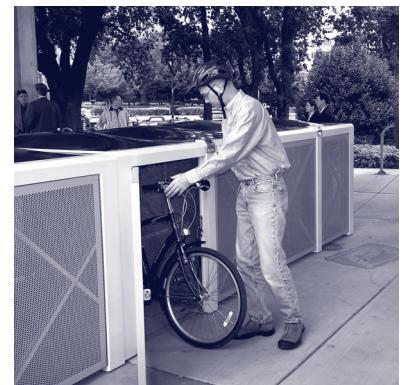
Projects involve faculty, staff, and students from across the State. These include: innovative strategies to enhance transit services and increase ridership, such as carsharing and low-speed modes; smart parking linked to transit; hydrogen transportation applications for the State and Caltrans; smart cards for transit; wireless Internet access on trains; ITS solutions to goods movement; and understanding travel behavior of diverse population groups.

Safety Roadside Rest Areas (SRRAs) Hot Spots: Field Test Evaluation (TO 6100): Caltrans launched a field operational test of wireless Internet access (WiFi) at two SRRAs State Route SR-99. In this study, the potential of providing WiFi at California's SRRAs was evaluated through (1) expert interviews with public agency representatives and private WiFi service providers to identify the range of possible business models and lessons learned to date; (2) focus groups conducted throughout California to understand the traveling public's need for WiFi services at SRRAs; (3) analysis of data that recorded the actual use of WiFi service at the pilot demonstration; and (4) a survey of the users of the WiFi pilot demonstration.

Removing Barriers for Seniors at Transit Stops and Stations and the Potential for Transit Ridership Growth (TO 6102): This research is designed to determine seniors' perspectives of, and behavior around, bus stops and transit stations, and develop and test the impact of various design improvements and interventions to increase transit ridership among seniors. The research plan includes gathering baseline measurements of ridership and perception of bus stops and transit stations at two study sites – Rossmoor, a planned suburban community of older adults and along San Pablo Avenue, an urban area with fixed route transit.

Feasibility Study for the Use of Biodiesel in the CalTrans Fleet (TO 6103): The research addresses several factors relating to the use of biodiesel fuel in fleet operations, including: (1) biodiesel compatibility with a diverse fleet of engines and exhaust retrofits, (2) emissions benefits and/or disbenefits, (3) commercial availability and pricing of biodiesel for purchase, (4) specifications needed for purchase of biodiesel by Caltrans, (5) regional issues e.g., air quality, weather, etc., impacting the use of biodiesel by Caltrans, (6) optimum biodiesel blend ratio, (7) miscibility with other diesel fuels, (8) emissions and petroleum reduction calculations, and (9) regulations as well as other legal considerations that may have bearing on the use of biodiesel in California.

EasyConnect II: Integrating Transportation, Information, and Energy Technologies at the Pleasant Hill BART Transit Oriented Development (TO 6104): This research capitalizes on the seamless integration of innovative technological strategies



to enhance transit during the development and construction of a suburban Transit Oriented Development (TOD) at the Pleasant Hill BART station. This project would entail a phased integration and evaluation approach that seamlessly links with the existing EasyConnect project: (1) “eLockers”, and (2) a smart parking services. The initial EasyConnect project consists of a field test of low-speed mode vehicles, linked to transit, at the Pleasant Hill BART station. Other innovations to be explored for this site include carsharing, stationary fuel cell technology, hydrogen fuel cell vehicles, and real-time transit information.



Compliance & Commercial Vehicle Operators: A Systems Evaluation of the Problem & Virtual Solutions (TO 6105):

Despite the dramatic increase in truck travel, there has been no concurrent increase in the capacity of truck compliance inspection stations or officers assigned to truck enforcement. If a substantial number of trucks need to be inspected, then queues form at weigh stations, causing operational and safety problems. Recognizing these problems, compliance inspection station operators allow trucks to bypass overcrowded stations. This research looks into the potential of field testing and evaluation of Virtual Compliance Stations (VCS) for commercial vehicles.

Smart Parking at Transit: Phase Two Field Test (TO 6109): This study evaluated the first transit-based smart parking project in the U.S. conducted at the Rockridge BART station in Oakland, California. The study final report first presents a literature review on smart parking, followed by a description of the smart parking field test, including the capital, operational, and maintenance costs involved. The report next presents the results of the participant survey analysis. It concludes with a discussion of lessons learned from institutional, user, and operational perspectives.

A GIS-based Tool for Forecasting the Travel Demands of Demographic Groups within California (TO 6110): This project developed an optimal resource allocation tool for the entire state of California using Geographic Information Systems and widely available data sources. As this tool evolves it will be used to make investment decisions in transportation infrastructure while accounting for their spatial and social distribution of impacts.

Understanding Travel Behavior for Diverse Population Groups in California (TO 6111): The objective of this study is to provide Caltrans and other transportation agencies in the state with an essential foundation for the design and targeted marketing of transportation systems and services, including those that involve advanced technologies (e.g., telecommuting, carsharing), to produce better outcomes for the diverse and dynamic population of California. With a better understanding of the factors influencing travel choices, planners can develop a transportation system that effectively and efficiently produces better outcomes for the diverse demographic groups of California.

Seamless Travel: The Importance of Class I Bike Routes in Journey-to-Work Trips, and Research to Support the California Blueprint for Bicycling and Walking (TO 6117)



This multi-year project will (a) evaluate existing bicycle and pedestrian data sources and collection methods, (b) conduct comprehensive counts and surveys of bicyclists and pedestrians, (c) conduct counts and surveys using San Diego County as a model community, (d) analyze how bicycle and pedestrian activity levels relate to facility quality, factors such as land use and demographics, (e) identify factors that are highly correlated with increased bicycling and walking, (f) provide methods for quantifying usage and demand that will enhance research on benefits and exposure, and (g) evaluate how the transit-linkage can be improved.



Exploratory Field Test of Early Fleet Niches for Hydrogen fuel Cell Vehicles and fueling Infrastructure (TO 6114): This study is a field test of three recent placements of hydrogen-powered “F-Cell” vehicles by DaimlerChrysler. It is a collaborative effort among Caltrans, PATH, CCIT, DaimlerChrysler Research & Technology North America, Inc., and the BART District.

Seamless Door-to-Door Travel: Smart Transit Parking Pilot Project in Conjunction with the San Diego Association of Governments (SANDAG) and the Bay Area Rapid Transit (BART) District (TO 6115): This project identifies the advantages and disadvantages of smart parking - the use of advanced technologies to improve the efficiency and speed of locating, reserving, and paying for parking. This pilot program uses concepts and resources from the existing smart parking field operational test (FOT) at the Rockridge BART station for the San Diego COASTER commuter

rail system. Ideas include CMS alongside highways approaching COASTER stations to alert drivers of traffic conditions ahead and available parking spots at each station, smart cards or vehicle-based transponders to expedite payment transaction time for parking, and a shuttle service between privately or publicly-owned parking structures around COASTER stations.

A Proposed RFID Field Integration with Smart Parking (TO 6116): This project designed and field tested a smart parking solution using Parking Carma wireless parking guidance services and RFID (Radio Frequency Identification) technology.

Evaluation of the Consequences and Effectiveness of Using Highway Changeable Message Signs for Safety Campaigns (TO 6119): Changeable message signs (CMS) on highways are now commonly used to alert motorists to downstream accidents and guide them to alternate routes as well as for Amber Alerts. More recently, in California and throughout the nation, CMS have been used as part of public campaigns to promote roadway safety by posting messages that encourage motorists to use seat belts, not drink and drive, and not speed. The results of this study will provide a clear and comprehensive understanding of the consequences and effectiveness of using CMS for public safety campaigns.

Commercial Vehicle Parking in California: Exploratory Evaluation of the Problem and Possible Technology-Based Solutions (TO 6120): Because of lack of private and public parking for commercial vehicles, more trucks are parking illegally on ramps and shoulders and truck driver fatigue is increasing. Both are causing more safety hazards and crashes. The first part of the study conducts a problem evaluation with expert interviews, literature review, and data analysis of the commercial vehicle parking problem. The second part identifies federal funding opportunities for Caltrans to leverage for this problem for the final report. The third part of this study conducts extensive shareholder outreach program intended to understand the institutional barriers to implementing commercial vehicle parking solutions in California.

Sustainable Transportation Energy Pathways Program (TO 6121): This is a multi-year research and outreach program to address the technical, operational, and logistical issues related to the transition to an alternative fuel-based economy. This project focuses on the utilization, demands, and transition to an alternative fuel-based transportation system. It will develop the theory, tools, and methods that allow for self-consistent and transparent comparison of promising alternative energy and vehicle pathways, and will apply these tools in comparative assessments of four general transportation energy pathways - hydrogen, biofuels, electricity and fossil fuels.

Liability, Regulation, and Autonomous Vehicle Technologies (TO 6122): This project will provide preliminary research on liability and regulatory regimes and their effect on the adoption of autonomous vehicle technology. The research team will evaluate how the existing liability regime would likely assign responsibility in crashes involving autonomous vehicle technology, and investigate the role of safety and performance standards for autonomous vehicle technology and offer some proposed examples of the proper role of safety standards.

Integrating Wildlife Movement and Transportation System Networks (TO 6123): This project will investigate appropriate scientific methods for predicting and modeling wildlife movement and critical habitat connectivity from the point of view of transportation planning and circulation modeling. The project team's approach will be to investigate methods for an analytical and predictive modeling system that can integrate transportation and wildlife movement assessment and models. The project team will conceptually pilot this approach in the North Coast, which includes urban to wildland gradients.

Evaluation of Open Road Electronic Toll Collection for California Applications (TO 6330): This project will identify appropriate technologies and conditions to implement open road electronic toll collection (ORETC) systems in the form of public-private partnerships on California's highway system. In addition to technological considerations, we will evaluate institutional issues that may arise in the planning and implementation of such systems, paying particular attention to issues surrounding public-private partnerships in open road electronic toll collection systems.





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

Caroline J. Rodier, Susan A. Shaheen, Charlene Kemmerer

This report presents an evaluation of the first transit-based smart parking project in the U.S. conducted at the Rockridge Bay Area Rapid Transit (BART) District station in Oakland, California. A literature review on smart parking is first presented. This is followed by a description of the smart parking field test, including the capital, operational, and maintenance costs involved. The report next presents the results of the participant survey analysis. It concludes with a discussion of lessons learned from institutional, user, and operational perspectives.

UCB-ITS-PRR-2008-5

June 2008, 46 pp.

INTERIM REPORT: COMPLIANCE AND COMMERCIAL VEHICLE OPERATORS – A SYSTEMS EVALUATION OF THE PROBLEM AND VIRTUAL SOLUTIONS

California PATH, School of Policy, Planning and Development, USC

This report presents a literature review of commercial motor vehicle inspection and compliance stations and its relationship with the growth of truck travel over the next 25 years, as well as the lack of concurrent capacity increases in staffing at such stations. Focus is on the problem of commercial vehicle non-compliance with regulations as they relate to pavement damage, safety, security, and air quality. In addition, the report addresses issues of capacity and performance related to California's weigh-in-motion technologies, as well as a broader assessment of available WIM technologies and their real world applications.

UCB-ITS-PRR-2008-16

August 2008, 240 pp.

EASYCONNECT: LOW-SPEED MODES LINKED TO TRANSIT PLANNING PROJECT

Susan A. Shaheen, Caroline J. Rodier

This report presents the final report on the EasyConnect project, operating from August 2005 to December 2006, which introduced shared-use electric bicycles, non-motorized bicycles, and Segway Human Transporters (HTs) to employment centers in and around the Pleasant Hill BART District station located in the eastern part of the San Francisco Bay Area. The goals of the field test were to test and evaluate the potential for a shared-use low-speed mode vehicle service that would bridge the "last mile" from a public transit station to the workplace. This report first describes the field test and its operation, as well as providing background information on other similar programs internationally. This is followed by a description of the evaluation methods and a discussion of the evaluation results. The report concludes with a summary of major findings.

UCB-ITS-PRR-2008-17

October 2008, 72 pp.

A STATEWIDE OPTIMAL RESOURCE ALLOCATION TOOL USING GEOGRAPHIC INFORMATION SYSTEMS, SPATIAL ANALYSIS, AND REGRESSION METHODS

Konstadinos G. Goulias, Thomas F. Golob, Seo Youn Yoon

The overall objective of this project is to develop an optimal resource allocation tool for the entire state of California using Geographic Information Systems and widely available data sources. As this tool evolves it will be used to make investment decisions in transportation infrastructure while accounting for their spatial and social distribution of impacts. Tools of this type do not exist due to lack of suitable planning support tools, lack of efforts in assembling data and information from a variety of sources, and lack of coordination in assembling the data. Suitable planning support tools can be created with analytical experimentation to identify the best methods and the first steps are taken in this project. Assembly of widely available data is also demonstrated in this project. Coordination of frag-

mented jurisdictions remains an elusive task that is left outside the project. When this project begun we confronted some of these issues and embarked in a path of feasibility demonstration in the form of a pilot project that gave us very encouraging results. In spite of this pilot nature aiming at demonstration of technical feasibility, substantive conclusions and findings are also extracted from each analytical step.

UCB-ITS-PRR-2008-27

November 2008, 121 pp.

EVALUATING WIRELESS BROADBAND AND SYSTEM AT CALIFORNIA SAFETY ROADSIDE REST AREAS

Rachel S. Finson, Jeffrey Lidicker, Cynthia Phan, Caroline Rodier

To meet the demand for Internet access by the traveling public, the California Department of Transportation (Caltrans) launched a field operational test of wireless Internet access (WiFi) at two Safety Roadside Rest Areas (SRRAs), Phillip S. Raine and Enoch Christoffersen, along State Route (SR) 99 in July 2007. In this report, researchers evaluate the potential of WiFi at California's SRRAs in order to make recommendations for future public agency participation in SRRA WiFi partnerships. A number of methods were used to gain insight into the potential of WiFi at SRRAs including (1) expert interviews with public agency representatives and private WiFi service providers to identify the range of possible business models and lessons learned to date; (2) focus groups conducted throughout California to understand the traveling public's need for WiFi services at SRRAs; (3) analysis of data that recorded the actual use of WiFi service at the pilot demonstration; and (4) a survey of the users of the WiFi pilot demonstration

UCB-ITS-PRR-2008-34

December 2008, 126 pp.

SMART CARDS, SLOW DEPLOYMENT: FINDINGS FROM INTERVIEWS WITH U.S. TRANSIT AGENCIES

Hiroyuki Iseki, Brian D. Taylor, Allison Yoh

This report presents a summary of findings from interviews with transit officials at seven transit

agencies in North America regarding smart card evaluations, expectations, and implementation. The interviews focused on the decision-making and collaboration processes involved in adopting interoperable smart card systems, as well as the barriers to multi-agency implementation. The report first describes interview methods, followed by summaries and highlights of each of the seven smart card projects currently being evaluated or implemented. The case studies include projects in Los Angeles County, the San Francisco Bay Area, Ventura County, Orange County, Santa Barbara County, the Washington Metropolitan Area, and South-eastern Pennsylvania. The report concludes with a summary of issues common to the seven cases as well as some strategies used in implementing interoperable smart card systems.

UCB-ITS-PWP-2008-1

January 2008, 56 pp.



EMPIRICAL OBSERVATIONS OF RED LIGHT RUNNING AT ARTERIAL SIGNALIZED INTERSECTION

Liping Zhang, Kun Zhou, Wei-bin Zhang and James A. Misener

Red Light Running (RLR) has become an increasingly national safety issue at signalized intersections. Significant efforts have been made to understand the RLR related driver behaviors and develop countermeasures to reduce RLR and its related crashes. At high speed intersections, it has been well shown that drivers caught in dilemma zone is an important reason of RLR. While at arterial intersections, there are still needs to further investigate RLR related driver behaviors. We carried out our research at a well-designed arterial intersection (speed limit 35 mph to 30 mph, approach dependent) and collected data using multiple discrete point sensors at different distances-to-intersection from multiple approaches. Empirical data showed that for over 90% of the RLRs, the drivers were not trapped in dilemma zone at yellow onset. Instead, they could

have stopped safely and comfortably. Further analysis of the empirical data showed that over 60% of the RLR were with a headway less than 3 seconds, or belonged to a platoon. The average headway of RLR vehicles were 10% less than that of vehicles going through yellow. The findings were used in the development of an all-red interval extension system for intersection collision avoidance.

Tech Note 2008-1

December 2008, 20 pp.

**CALIFORNIA INTERSECTION
DECISION SUPPORT: A DRIVER-
CENTERED APPROACH TO
LEFT-TURN COLLISION AVOIDANCE
SYSTEM DESIGN**

*Bénédicte Bougler,
Delphine Cody, Christopher
Nowakowski*

This report focuses on two human factors studies which used an instrumented research vehicle to study driver behavior while making left turns. The first study focused on observing drivers' intersection approaches and left-turn maneuvers in a mostly naturalistic setting. The instrumented vehicle recorded driver actions, such as approach speed, brake activation, steering inputs, and limited estimates of oncoming vehicle gap (and lag) acceptance. The second study examined left-turn gap (or lag) acceptance in an environment where gaps could be more accurately measured and tightly controlled. It also introduced drivers to the concept of a left-turn Driver Infrastructure Interface (DII), a dynamic, no-left-turn sign, warning sign. The vehicle approaches were timed to test the effects of different DII settings such as warning threshold onset timing on gap (lag) acceptance.

UCB-ITS-PRR-2008-1

January 2008, 111 pp.

**MIDDLEWARE FOR COOPERATIVE
VEHICLE-INFRASTRUCTURE SYSTEMS**

*Christian Manasseh, Raja
Sengupta*

Middleware has emerged as an important architectural component in supporting distributed applications. The role of middleware is to present a unified programming model to application writers and to mask out problems of heterogeneity and distribution. Mobile sensors fall into the

space of distributed systems that suffer from isolated data sources, heterogeneous communication infrastructure and varying application requirements. In this report, we provide a middleware architecture that addresses the needs of a distributed system made of mobile sensors in general and discuss the implementation of this middleware architecture in a mobile sensor network comprised of vehicles and intersections producing traffic related data for traffic safety and operations. We conclude our report with some performance measures that relate to the cost of overhead incurred from using the middleware which prove it efficient for traffic management applications.

UCB-ITS-PRR-2008-2

January 2008, 35 pp.

**WORKZONE SAFETY
IMPROVEMENTS THROUGH
ENHANCED WARNING SIGNAL
DEVICES**

*Kent Christianson, Daniel
Greenhouse, Theodore Cohn,
Roy Young Kim, Christina
Chow*

The high incidence of accidents associated with work zones suggests that current warning lights and signals have been in need of improvement. In this project we have developed and tested an improved emergency warning light intended specifically for Caltrans work zone vehicles, and an enhanced rear warning light for shadow trucks, both intended to improve visibility and conspicuity, and to reduce reaction times for drivers approaching the work zone.

UCB-ITS-PRR-2008-3

January 2008, 118 pp.

**SAN JOAQUIN RAIL CORRIDOR
CROSSING SURVEY**

*Daniel Greenhouse, Kent
Christianson, Scott Johnston,
Zu Kim*

This report describes three goals that were accomplished in this project. The authors first describe the merging of two existing databases in order to create a single database of all San Jose Rail Corridor (SJRC) railroad crossings and their physical properties. The authors next describe the feasibility of creating a database of crossing violations (termed as "near-misses") by using a digi-

tal video data gathering system, known as the Locomotive Video Data Acquisition System (LVDAS) and mounted in an Amtrak locomotive. This would allow crossings that are particularly susceptible to violations, and considered precursors to collisions, to be identified. Finally, the authors describe the demonstration of a new in-pavement crossing signal based that is based upon LED technology and is designed to increase safety at crossings.

UCB-ITS-PRR-2008-6

June 2008, 31 pp.

**HIGH COLLISION CONCENTRATION
LOCATION: TABLE C EVALUATION
AND RECOMMENDATIONS**

*David Ragland, Ching-Yao
Chan*

This report describes the research that was conducted to improve the effectiveness and consistency of methods for identifying High-Concentration Collision Locations (HHCL) within the California State Highway System. These are locations that have collision frequencies significantly higher than expected when compared to other locations. Table C is a list of high concentration collision locations and is regularly published by the California Department of Transportation. The research involved literature reviews and surveys, as well as interactions with a out-of-state agencies and experts in order to gather the latest information and techniques regarding HCCL. Included in the report are the findings and conclusions, along with recommendations for potentially addressing and improving the process of identifying HCCL.

UCB-ITS-PRR-2008-11

June 2008, 107 pp.

**DRIVER/PEDESTRIAN
UNDERSTANDING AND BEHAVIOR
AT MARKED AND UNMARKED
CROSSWALKS**

*David R. Ragland, Meghan
Fehlig Mitman*

This reports presents the results of a study examining pedestrian and driver knowledge of right-of-way laws. Input for the study came from a series of focus groups and surveys, in addition to observations of pedestrian and driver behavior at a sample of unsignalized, high volume, three- and

four-lane intersections in the San Francisco Bay Area. Focus of the study was to identify potential human factors explanations for the crosswalk dilemma. Results of the study reveal that pedestrians and drivers have significantly different knowledge of right-of-way laws and crossing/yielding behaviors in marked versus unmarked crosswalk. Additionally, the study found that pedestrians and drivers exhibit different behaviors in marked versus unmarked crosswalks on multi-lane, higher volume roads. The study concludes with recommendations and analyses of countermeasures for improving pedestrian crosswalk safety.

UCB-ITS-PRR-2008-13

July 2008, 234 pp.

**ONBOARD MONITORING AND
REPORTING FOR COMMERCIAL
VEHICLE SAFETY (OBMS) PHASE
II: FIELD OPERATIONAL TEST**

*Jim Misener, Christopher
Nowakowski, Jessica
O'Connell, John Murray*

Truck driver error plays a major role in truck-related crashes. Onboard monitoring has been examined as a promising method for recognizing and providing the necessary feedback to correct self-induced hazardous driving situations. This report details a field operational test (FOT) that was conceived to determine the technical and operational effectiveness of a n Onboard Monitoring System (OBMS). The OBMS involves a hardware suite that allows for the online measurement of a set of driving characteristics that are indicators of unsafe driving behavior. The OBMS would provide the driver with real time feedback, offline to the carrier, and then back to the driver. The report also describes the original statement of work for the project.

UCB-ITS-PRR-2008-18

October 2008, 57 pp.

**PEDESTRIAN AND BICYCLE SAFETY
EVALUATION IN A SMART
CORRIDOR**

*David R. Ragland, Terri
O'Connor*

The San Pablo/I-80 corridor is a "SMART" transportation corridor that extends about 20 miles along the eastern shore of the San Francisco Bay. The corridor uses Intelligent Transportation System

(ITS) technologies to increase and enhance transportation mobility.

The goal of the SMART Corridor Plan was to improve vehicle mobility throughout the corridor. Since the plan focused almost exclusively on vehicular traffic, achieving these goals has the potential to raise the risk of injury to pedestrians and bicyclists without thorough analysis of the overall effects of the SMART corridor implementation.

This study identifies and describes multiple factors that may affect the behavior of pedestrians, bicyclists and drivers along the corridor. This report focuses on findings for the Berkeley sector.

The evaluation utilized multiple types of data collection including vehicle counts, field observations, field inspections, and collision data. Researchers inspected the physical elements of each intersection and observed driver, pedestrian, and bicyclist behavior. Analysis of these data led to a typology, used to assign context-specific safety interventions, many of which involve engineering and enforcement.

The main goal is to ensure that motorists as well as pedestrians and bicyclists should have a sense that all have an equal right to travel in the area. This can be accomplished through clear and consistent signage, a distinctive crosswalk treatment, consistent lighting and other enhancements.

Implementation of the recommended countermeasures and follow up analysis are not part of this baseline study. A detailed traffic engineering analysis would be required to produce estimates of costs and benefits, and to determine priorities.

UCB-ITS-PRR-2008-25

October 2008, 79 pp.

METHODS FOR IDENTIFYING HIGH COLLISION CONCENTRATION LOCATIONS FOR POTENTIAL SAFETY IMPROVEMENTS

Judy Geyer, Elena Lankina, Ching-Yao Chan, David Ragland, Trinh Pham, Ashkan Sharafsaleh

The California Department of Transportation (Caltrans) uses Table C and related documents to identify and to investigate locations within the state highway system where a relatively large number of collisions occur. In earlier years, a task force evaluated

the process of generating and using these reports and found that there was much room for improvements. A list of recommendations was made. The efforts undertaken within this project is part of the effort to make the process of safety investigations and improvements more efficient and productive. This report summarizes the work carried out in the first phase of Task Order 5215 and it provides guidelines for the second phase of the project.

UCB-ITS-PRR-2008-35

December 2008, 59 pp.

THE NATURALISTIC DRIVER MODEL: DEVELOPMENT, INTEGRATION, AND VERIFICATION OF LANE CHANGE MANEUVER, DRIVER EMERGENCY AND IMPAIRMENT MODULES

Delphine Cody, Swekuang Tan, Jeff K. Caird, M. Lees, C. Edwards

This report documents work conducted in order to support the development of a driver model. This work consisted of (i) a review of driver models for identifying the possibility to add some functionalities to the current model based on existing models and (ii) the data collection and analysis in order to describe the mechanism of distraction and potentially offer some quantification of its effect on drivers' behavior and performance

UCB-ITS-PWP-2008-8

December 2008, 58 pp.



DEVELOPING CALIBRATION TOOLS FOR MICROSCOPIC TRAFFIC SIMULATION FINAL REPORT PART II: CALIBRATION FRAMEWORK AND CALIBRATION OF LOCAL/ GLOBAL DRIVING BEHAVIOR AND DEPARTURE/ROUTE CHOICE MODEL PARAMETERS

Michael Zhang, Jingtao Ma, Hu Dong

This report describes the development of a calibration framework for micro simulation projects that separates the calibration process into five components: 1) project scoping and error checking, 2) global parameter calibration,

3) local parameter calibration, 4) departure/route (D-R) choice parameter calibration, and 5) global calibration. The report describes the development of genetic algorithm (GA)-based calibration tools for local and global parameters, as well as D-R choice parameters. The report then describes how the developed tools were integrated into one user-friendly graphical interface and how the developed methods and tools were tested on synthetic and real networks. Using working examples, it is shown that the developed tools can help achieve satisfactory calibration results with significantly less human intervention as found in traditional trial-and-error calibration procedures.

UCB-ITS-PRR-2008-7

June 2008, 90 pp.

DEVELOPING CALIBRATION TOOLS FOR MICROSCOPIC TRAFFIC SIMULATION FINAL REPORT PART III: GLOBAL CALIBRATION - O-D ESTIMATION, TRAFFIC SIGNAL ENHANCEMENTS AND A CASE STUDY

Michael Zhang, Jingtao Ma, Shailendra P. Singh, Lianyu Chu

This report is part of a study that focused on developing a systematic framework and support tools to ease, streamline and speed up the calibration of micro simulation projects. In this specific report, the authors first describe the implementation of a faster heuristic optimization technique, referred to as simultaneous perturbation stochastic approximation (SPSA), and compare its performance with other heuristic optimization methods. The authors next describe the development of a faster origin-destination (O-D) estimation tool for obtaining an initial time-dependent O-D trip table. They also describe the enhancement of the vehicle actuated signal control application program interfaces (APIs) in Paramics. A set of guidelines, developed to help micro simulation users to set up and check signal settings in a micro simulation project, are also described. Finally, the authors discuss how they developed summary statistics tools to track, diagnose and report on the calibration, as well as how they carried out a case study using the SR-41 network in Fresno. The case study

was designed to demonstrate the use of the developed tools, identify potential problems and summarize calibration experiences with large scale networks

UCB-ITS-PRR-2008-8

June 2008, 102 pp.

INTEGRATED CONSTRUCTION ZONE TRAFFIC MANAGEMENT

Michael Zhang, Wei Shen, Yu Nie, Jingtao Ma

This report describes the development of a work zone impact assessment procedure using a series of state-of-the-art dynamic network analysis tools as building blocks. The procedure was implemented into a work zone traffic impact assessment software package known as NetZone. This software package is used to estimate time-dependent travel demand based on link counts, estimate demand diversion in response to work zone delay and various traffic management measures, show traffic congestion level in the network over time, and provide network wide traffic performance measures with and without traffic congestion mitigation measures. Results from a preliminary case study showed that NetZone can be used to study a reasonably large network in a fraction of time that a micro-simulation package would take for the same network

UCB-ITS-PRR-2008-9

June 2008, 105 pp.

DEVELOPMENT OF A PATH FLOW ESTIMATOR FOR INFERRING STEADY-STATE AND TIME-DEPENDENT ORIGIN-DESTINATION TRIP MATRICES

Michael Zhang, Yu Nie, Wei Shen, Ming S. Lee, Sarawut Jansuwan, Piya Chootinan, Surachet Pravinovongvuth, Anthony Chen, Will W. Recker

This report describes how a previously proposed logit path flow estimator (LPFE) has been further developed in order to improve the reliability and efficiency of origin-destination (O-D) trip table estimates. The report describes how both steady-state and time-dependent LPFE are implemented in an object-oriented programming (OOP) framework. The performance of the LPFE is tested using synthetic data and the accuracy and reliability of its O-D trip table estimates are quantified. The report also describes the de-

velopment of Visual PFE and Visual PFE-TD, which are the graphic user interfaces (GUI) for both static and time-dependent LPFE.

UCB-ITS-PRR-2008-10

June 2008, 247 pp.

EVALUATION OF PORTABLE AUTOMATED DATA COLLECTION TECHNOLOGIES: FINAL REPORT

James H. Banks

This report describes a project which evaluated portable automated traffic data collection systems. Using a series of field demonstrations, the systems that were evaluated included: 1) temporarily mounted microwave radar sensors intended to provide volume, speed, and/or length classification data for traffic census or various traffic studies; 2) similar sensors mounted on a semi-permanent basis and intended to serve as substitutes for loop detectors in traffic surveillance systems; and, 3) low-mounted infrared sensors used for axle counting. Focus of the field demonstrations was on the issues of sensor accuracy for all systems and the reliability of wireless transmission systems for semi-permanent installations.

UCB-ITS-PRR-2008-15

August 2008, 74 pp.

VIDEO VEHICLE DETECTOR VERIFICATION SYSTEM (V2DVS)

Art MacCarley, John Slonaker

This report describes a project which involved the development of an automated vehicle detector verification system designed to verify all individual detection results. The project was prompted by the need to assess the accuracy and attributes of the various types of roadway sensors and detectors currently in use. A traffic detector test bed was constructed on I-405 in Southern California by the California Department of Transportation. Because of the number of different types of detectors being tested, an automated testing process was designed. The design is based on the fusion of data from each of the detectors under test with data from a reference image processing system, in order to create a reliable composite ground truth record. The performance of the individual detectors was assessed by comparing it with the verified dataset. In addition, the report discusses the data acquisition architecture, data

fusion methodology, computer vision detection methods, and automated data reduction and reporting methods.

UCB-ITS-PRR-2008-21

October 2008, 68 pp.

DEVELOPMENT OF AN ADAPTIVE CORRIDOR TRAFFIC CONTROL MODEL

Will Recker

This report describes a study whose objective was to develop and implement a real-time adaptive control system for corridor management. The proposed control strategy is based on a mathematical representation describing the behavior of traffic flow in corridor networks and actuated controller operation. In formulating the optimal control problem, the report notes that focus is only on controlling those parameters commonly found in modern actuated controllers.

UCB-ITS-PRR-2008-22

October 2008, 32 pp.

CORRIDOR DEPLOYMENT AND INVESTIGATION OF ANONYMOUS VEHICLE TRACKING FOR REAL- TIME TRAFFIC PERFORMANCE MEASUREMENT

Stephen G. Ritchie, Shin-Ting (Cindy) Jeng, Yeow Chern (Andre) Tok, Seri Park

This report describes a project which focused on the development of a real-time section-based traffic performance measurement system using inductive vehicle signatures. The signatures were obtained from single conventional loop sensors along a six-mile freeway corridor in Irvine, California. The real-time performance measurement system (RTPMS) is based on a new vehicle re-identification algorithm known as RTRE-ID-2 and a vehicle classification model. The report also discusses a separate research effort which investigated the potential of a new type of inductive sensor known as the Blade™ for application in commercial vehicle surveillance at the San Onofre Truck Weigh and Inspection Facility in Southern California. In this project, a new commercial vehicle classification model was developed for profiling commercial vehicles by their body type and axle configuration. A new commercial vehicle vector classification framework is then in-

troduced for describing the depth of information available from this developed model.

UCB-ITS-PRR-2008-23

October 2008, 182 pp.

EVALUATION OF INCORPORATING HYBRID VEHICLE USE OF HOV LANES

David Brownstone, Lianyu Chu, Tom Golob, K.S. Nesamani, Will Recker

This report presents a method to investigate the operational and environmental effects of the policy of allowing qualified single-occupancy hybrid vehicles to use dedicated High-Occupancy Vehicle (HOV)/carpool lanes in California. The method combines the traditional planning method with microscopic simulation modeling. The planning method is used for demand estimation and analysis and the microscopic traffic simulation modeling method is used for accurate measures of the system. The study employs a microscopic traffic simulation model that is capable of evaluating the HOV/hybrid system and providing detailed outputs that are not available in conventional static models. The study also includes detailed emissions modeling in order to estimate accurate emissions by integrating emission models into microscopic simulation models. An important aspect of the study involves predicting future hybrid vehicle demand; hybrid demand models are developed based on consumers' automobile choice behavior analysis. This is modeled both with standard network calculations employing network assignments sensitive to time savings from HOV lane use as well as using estimates of the locations of households owning hybrid vehicles and the O-D matrices for the hybrid drivers. We use these results to modify existing models to enhance their accuracy for hybrid vehicles. The updated models are then applied to data from the recent Caltrans 2000-2001 Statewide Household Travel Survey and the 2001 National Household Travel Survey (NHTS). These survey data allow us to locate the households and trip destinations of likely hybrid vehicle owners. Results from previous studies of demand for toll lanes have established monetary values of saved travel time that can be applied to estimated

time savings from network simulations to forecast incentives for purchase of hybrid vehicles. We also develop a supply-side model to estimate availability and prices of hybrid vehicles by body type and manufacturer and price in order to forecast penetration of hybrid vehicles. A total of four different scenarios were constructed. With the assumption that the total demand for all scenarios remains the same and the hybrid-HOV policy results in some solo drivers switching to hybrid vehicle drivers, these four scenarios are evaluated in terms of a set of operational performance measures and air quality measures. The key findings from this study are summarized as follows:

- o The initial wave of single occupant hybrid vehicles entering the HOV lanes do not have a substantial negative impact on HOV lane operations.

- o A hybrid demand exceeding 50 thousand statewide will have significant impact on the HOV lane operations in OC.

- o From the air quality perspective, a high share of hybrid vehicles will cause fewer emissions.

UCB-ITS-PRR-2008-26

October 2008, 67 pp.

DEVELOPMENT AND FIELD TESTING OF LASER PHOTODIODE ARRAY- BASED VEHICLE DETECTION SYSTEM

Harry H. Cheng, Ben Shaw, Joe Palen, Hong Duan, Stephen S. Netinger, Bo Chen, Ping Feng

Over the past year we have enhanced the performance of the Laser-photodiode Based vehicle Detection System (LBDS) which is sponsored and funded by the California Department of Transportation (Caltrans) through the PATH Program. This project incorporates the development a vehicle detection system for highway use that can implement correct, reliable, and accurate vehicle detection and has the ability to provide high quality traffic information such as traffic density and vehicle speed, length and profile to the traffic management center for surveillance. After several years of research, the performance of the LBDS has been enhanced and is almost ready for use in practical applications. In the last year, the focus of our research has been on the reliability, accuracy and

anti-disturbance capabilities of the LBDS.

UCB-ITS-PRR-2008-28

November 2008, 80 pp.

DEVELOPMENT OF HARDWARE IN THE LOOP SIMULATION AND PARAMICS/VIS-PLUS INTEGRATION

Susan Dickey, et al.

The report describes three research efforts carried out under a project titled "Development of Hardware-in-the-Loop (HiL) Simulation and Paramics/VIS-PLUS Integration" sponsored by the California Department of Transportation (Caltrans) under Task Order 5311. The first effort developed and evaluated traffic signal optimization with Hardware-in-the-Loop Simulation (HiLS), using the NI-ATT Controller Interface Device (CID) manufactured by McCain Traffic Supply to provide real-time linkage between the Paramics microscopic simulation and a NEMA TS1 controller. An adaptive control system incorporated the traffic flow prediction model to predict the traffic flows from the surrounding intersections, and an online signal optimization model was used to obtain the signal timing plan for the subsequent cycle, based on the traffic flows predicted in the previous cycle. The performance of the proposed adaptive control system was evaluated through a case study in which HiLS is applied to a small urban network in Logan, Utah. The second effort developed a Paramics plug-in that worked over a serial port connection to a specially modified 170 for HiL operation. After this initial development, the NIATT/McCain CID was configured to work as a Paramics plug-in with both 170 and 2070 controllers, and experiments were carried out to compare the performance of Paramics simulations with the UC Irvine Paramics signal controller plug-in with HiLS. In the third effort, investigation and evaluation of integrated Paramics/VIS-PLUS software was carried out, resulting in a user's guide for use of the integrated Paramics/VIS-PLUS simulation software.

UCB-ITS-PRR-2008-29

November 2008, 153 pp.

CAUSES OF FREEWAY PRODUCTIVITY DECLINE AND THE OPPORTUNITIES FOR GAIN: A QUANTITATIVE STUDY,

Pravin Varaiya

Work done under TO 5306 led to three accomplishments. First, a measure of freeway productivity was proposed. Second, the causes of productivity decline led to the notion of "congestion pie." Both productivity loss and congestion pie are available as PeMS applications. Third, the study entitled "An Empirical Assessment Of Traffic Operations" [1] provides a detailed empirical account of congestion.

UCB-ITS-PRR-2008-31

November 2008, 48 pp.

A LOW-COST WIRELESS MEMS SYSTEM FOR MEASURING DYNAMIC PAVEMENT LOADS

Pravin Varaiya

Work done under this "Innovative Proposal" may be summarized as follows. A closed-form series solution is provided for the displacement of a pavement loaded by a truck modeled as an Euler beam with elastic foundation under a moving load. A method is developed to estimate the load based on accelerometer measurements. Lastly, it was found that the measurement system that we built was not suited for the problem at hand because the accelerometer bandwidth was too high and the system could not isolate the accelerometer from ambient noise. This led to a new measurement system design. However, that design could not be built because of the limited resources available.

UCB-ITS-PRR-2008-36

December 2008, 31 pp.

DEVELOPING CALIBRATION TOOLS FOR MICROSCOPIC TRAFFIC SIMULATION FINAL REPORT PART 1: OVERVIEW METHODS AND GUIDELINES ON PROJECT SCOPING AND DATA COLLECTION

Michael Zhang, Jingtao Ma

This report summarizes the calibration experiences documented in the literature on microscopic simulation projects. The authors first categorize the successful microsimulation applications. Guidelines are next provided on calibration aspects including

project planning, network coding, data collection, and processing and traffic demand estimation. The authors describe the calibration steps and a few calibration methods that will be deployed in the study. Finally, a brief summary points out the gaps in the current calibration practices that will be addressed in future work. These include: the lack of a systematic calibration procedure, the lack of automated calibration tools, and the lack of reliable origin-destination trip demands.

UCB-ITS-PWP-2008-3

January 2008, 70 pp.

TOOLS FOR OPERATIONS PLANNING (TOPL1)

Pravin Varaiya

Tools for Operations Planning (TOPL) is a suite of software tools used to specify freeway operational improvement strategies, such as ramp metering, demand and incident management, auxiliary lanes, and traveler information. TOPL is also used for quickly estimating the benefits of these types of improvements. TOPL is based on the macroscopic cell transmission model (CTM). Version 1, TOPL1, provides preliminary software packages and a calibrated model of Interstate 880 North (I-880 N) in the San Francisco Bay Area. Included in the report is a paper that summarizes the theory of the cell transmission model and describes the procedure to carry out a TOPL application.

UCB-ITS-PWP-2008-4

June 2008, 22 pp.



TRANSIT SIGNAL PRIORITY RESEARCH TOOLS

Yue Li, Peter Koonce, Meng Li, Kun Zhou, Yuwei Li, Scott Beaird, Wei-Bin Zhang, Larry Hegen, Kang Hu, Alex Skabardonis, and Z. Sonja Sun

This report presents the results of a research project that addresses Transit Signal Priority (TSP) deployment issues. The report reviews National Transportation Communications for ITS Protocol (NTCIP) 1211 Signal Control and Prioritization (SCP) standards, defines five SCP scenarios, and describes how the SCP scenarios

can be applied differently based on TSP priority and operating policies. The report provides an overview of a number of TSP systems, including centralized TSP, two discrete TSP systems based on loop detection and Global Positioning System (GPS) technologies, and an Adaptive Transit Signal Priority (ATSP) system. A comparison of the different TSP deployments, and guidance on the necessary infrastructure required to implement these TSP systems, are provided. The report also discusses TSP evaluation methodologies, including recommended measures of effectiveness (MOE's) and data required for performing a quantitative assessment. Evaluations of a number of TSP deployment sites are documented to demonstrate how the benefits of TSP to transit and the impacts of TSP to traffic operations are assessed using the recommended approaches. Finally, the report provides guidance on TSP planning and analysis methods, such as simulation and regional modeling tools.

UCB-ITS-PRR-2008-4

June 2008, 191 pp.

DEVELOPMENT OF PERFORMANCE-BASED SPECIFICATIONS FOR EFFICIENT DEPLOYMENT OF ADVANCED PUBLIC TRANSPORTATION SYSTEMS (EDAPTS)

Jeff Gerfen, Neil Hockaday Xudong Jia

This report presents the results of research designed to develop performance-based specifications for the Efficient Deployment of Advanced Public Transportation Systems (EDAPTS) Smart Transit System. The primary goal of the EDAPTS project was to provide small, medium, and rural transit proprietries with access to low cost Intelligent Transportation Systems (ITS) technologies. The specifications are intended to facilitate industry adoption and widespread deployment of the EDAPTS transit management system. The EDAPTS Performance Specification was developed through a review of industry performance specification best practices. It also included identifying all unique EDAPTS elements and determining appropriate performance metrics for each element. The EDAPTS elements and performance metrics were then imported into a database for

analysis purposes as well as generating automated performance specification reports. An EDAPTS data-formatting standard, developed in conjunction with performance specification development efforts, is required to ensure that various parts of EDAPTS will be available, and with ensured interoperability, in the future. The EDAPTS performance specification is non-proprietary, and along with its supporting database program, is available to transit operators, service providers, and transit management system providers.

UCB-ITS-PRR-2008-12

June 2008, 250 pp.

EVALUATING THE COSTS AND BENEFITS OF TRANSIT SMART CARDS

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

This study focuses on the costs and benefits of smart card systems and offers a framework for conducting a proper transit smart card cost benefit analysis. Using the proposed framework, the authors found that individual transit operators and multiple agencies bear the majority of the deployment costs, while transit users and individual operators reap most of the smart card benefits. Case studies are presented on how transportation agencies in three metropolitan areas evaluated smart card systems: the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area, the Los Angeles County Metropolitan Transportation Authority (LA Metro) in Los Angeles, and the Southeastern Pennsylvania Transportation Authority (SEPTA) in the greater Philadelphia area.

UCB-ITS-PRR-2008-14

August 2008, 53 pp.

EDAPTS BENEFIT/COST EVALUATION

Xudong Jia, Edward Sullivan, Cornelius Nuworsoo, Neil Hockaday

This report presents a summary of a benefit/cost evaluation of the San Luis Obispo (SLO) Transit Efficient Deployment of Advanced Public Transportation Systems (EDAPTS) Intelligent Transportation Systems (ITS) system. It provides a detailed description of the methodologies and procedures used, in addition to the research

findings resulting from the evaluation. Various benefits and costs of the SLO Transit EDAPTS system were collected and estimated using passenger questionnaires, boarding time surveys and interviews with SLO Transit drivers and administrators. A benefit/cost (B/C) ratio analysis on the EDAPTS system was then conducted. In addition, the research team performed a sensitivity analysis of B/C ratios to different discount rates and service lives of the EDAPTS system. It was found that the ratios of annual benefits to annual costs were at least 3.9:1 for the SLO Transit EDAPTS system, thus indicating the economic viability of the EDAPTS ITS technologies.

UCB-ITS-PRR-2008-19

October 2008, 111 pp.

FACTORS INFLUENCING PRODUCTIVITY AND OPERATING COST OF DEMAND RESPONSIVE TRANSIT

Kurt Palmer, Maged Dessouky, Zhiqiang Zhou

This report presents the results of a study involving 67 large transit agencies in the U.S. providing Demand Responsive Transit (DRT). The study evaluates the impact of implemented technologies and management practices upon productivity and operating cost measures derived from information available in the 1997-2002 National Transit Database (NTD). Recommendations regarding Paratransit CAD systems and route revisions are presented.

UCB-ITS-PRR-2008-20

October 2008, 95 pp.

TOWARD DEPLOYMENT OF ADAPTIVE TRANSIT SIGNAL PRIORITY SYSTEMS

Meng Li, et al.

This report describes efforts conducted by the California Partners for Advanced Transit and Highways (PATH) Program on developing and implementing an Adaptive Transit Signal Priority (ATSP) system. Three distinguished features are associated with the ATSP system: 1) providing priority to transit vehicles while making a tradeoff between bus delay savings and the impacts on the rest of the traffic; 2) using existing automatic vehicle location (AVL)/communication systems already instrumented

on buses for continuously monitoring bus locations and predicting bus arrival times to intersections and requesting signal priority; and, 3) building upon closed-loop signal control systems with 170E controllers. These features would allow the ATSP to have potential for wide-scale implementation. This report describes the development of ATSP algorithms, the field test results of the prototype ATSP system, and the feasibility analysis for using existing transit communication for ATSP.

UCB-ITS-PRR-2008-24

October 2008, 174 pp.

STUDY OF INTEGRATED CORRIDOR MANAGEMENT FOR SAN FRANCISCO BAY AREA I-880 CORRIDOR

Wei-Bin Zhang, et al.

This document summarizes the efforts by the San Francisco Bay Area ICM team to develop the concept of operation, data needs and performance requirements for an Integrated Corridor management System for I-880 Corridor. Although the transportation management systems at the Bay Area are consistent with the regional ITS plans, these management systems are less integrated. It is believed that higher level of integration among freeway and arterial systems, transit systems with considerations of all transportation needs and demands in the region will greatly enhance and improve the efficiency and productivity of all individual systems. ICM benefits include, to name a few, enhanced ability of the partner agencies to provide true integration of multiple operational components of the corridor, better management of nonrecurrent congestion caused by major incidents, unexpected weather events, unexpectedly high travel demand, and major construction and maintenance activities by allowing the full capacity of the corridor to be utilized through improved integration, and improved capabilities to manage daily recurrent congestion in the corridor.

UCB-ITS-PRR-2008-30

November 2008, 56 pp.

ESTABLISHING INFRASTRUCTURE REQUIREMENTS FOR BUS RAPID TRANSPORTATION OPERATIONS IN DEDICATED BUS LANES

Carl L. Monismith, Shmuel L. Weissman, Lorina Popescu, Nicholas J. Santero

Bus Rapid Transit (BRT) has the potential to improve mass transit service and contribute to reduced traffic congestion in urban areas. To achieve this improvement in service BRT will require the use of dedicated bus lanes together with lane assist and precision docking (LA/PD) to accelerate the passenger boarding process. Using this approach, BRT lanes can be reduced somewhat in width. However, such a reduction will result in increased channelization of traffic which in turn can lead to a more rapid development of pavement distress. With today's improved pavement engineering technology, it is possible to design and construct pavement infrastructure which can result in long term and cost effective pavement performance (both in terms of pavement deterioration and equipment wear and tear). At the same time the system can be environmentally friendly with reduced traffic noise and increased passenger comfort from a smoother ride.

UCB-ITS-PRR-2008-32

November 2008, 60 pp.

SAN DIEGO I-15 INTEGRATED CORRIDOR MANAGEMENT (ICM) SYSTEM: PHASE I

Mark Miller, Linda Novick, Yuwei Li, Alex Skabardonis

This report describes the Stage One work of the US Department of Transportation's (DOT) federally-sponsored Integrated Corridor Management (ICM) Program for the I-15 Corridor in San Diego County, California, between State Route 52 in the city of San Diego and State Route 78 in the city of Escondido. The development work is based on the systems engineering process whereby this work focused specifically on the concept of operations and the system requirements specifications. The development of the concept of operations consists of the following elements: vision, goals and objectives for the I-15 corridor; operational concept description, approaches, and strategies; cor-

ridor user needs; implementation issues; institutional framework; and operational scenarios. The development of the system requirements specification primarily depends on the set of user needs developed in concept of operations. Seventeen user needs were transformed into 17 corresponding functional areas for the I-15 ICMS system, which formed the core of the development of the system requirements. The report also includes a description of the data available for the next Phase of I-15 ICM effort (analysis, modeling and simulation).

UCB-ITS-PRR-2008-33

December 2008, 65 pp.

LITERATURE REVIEW REPORT ON BENEFIT/COST STUDIES AND EVALUATIONS OF TRANSIT MANAGEMENT SYSTEMS,

Xudong Jia, Edward Sullivan

In this study, the authors examine the benefits and costs of Advanced Public Transportation Systems (APTS) applications in small and medium sized transit agencies. The research test implementation of a small transit oriented Intelligent Transportation System (ITS) on San Luis Obispo (SLO) Transit is used as a case study. The Smart Transit System at San Luis Obispo makes use of the Efficient Development of Advanced Public Transportation Systems (EDAPTS) framework concept. The authors hypothesize that small transit properties will be encouraged to deploy the EDAPTS ITS framework concept if the San Luis Obispo Smart Transit System can show a viable benefit cost ratio. The authors document the literature review conducted in order to summarize past work on evaluation of similar APTS applications and to identify and assess the analytic methods and tools available for the complete benefit cost evaluation of SLO Transit Smart Transit System.

UCB-ITS-PWP-2008-2

January 2008, 15 pp.

A COST-EFFECTIVE TRAFFIC DATA COLLECTION SYSTEM BASED ON THE iDEN MOBILE TELECOMMUNICATION NETWORK

Liping Zhang, Meng Li, Peter Lau, Wei-Bin Zhang, Kai Leung

This report describes a cost-effective data collection system for the California Department of Transportation (Caltrans) 170 traffic signal controller. The system is based on TCP/IP communications over existing low-cost mobile communication networks and Motorola Integrated Digital Enhanced Network (iDEN) mobile handsets. Continuous reliable communication over unstable wireless links is ensured by an adaptive wireless flow control protocol. Results from laboratory tests indicate that with the adaptive flow control protocol, individual handsets can deliver data fetched from signal controllers at a period of 200ms continuously over 95% of the time. The cost for one set of data collection devices is less than \$100 and the monthly cost can be as little as \$10.

UCB-ITS-PWP-2008-5

October 2008, 39 pp.

LITERATURE REVIEW REPORT ON BENEFIT/COST STUDIES AND EVALUATIONS OF TRANSIT MANAGEMENT SYSTEMS

Xudong Jia, Edward Sullivan, Cornelius Nuworsoo, Neil Hockaday

This literature review is a part of a study addressing the benefits and costs of Advanced Public Transportation Systems (APTS) applications in small and medium sized transit agencies. The study makes use of the research test implementation of a small transit-oriented Intelligent Transportation System (ITS) and uses San Luis Obispo Transit as a case study. The literature review summarizes past work on evaluating APTS applications. In addition, the study identifies and assesses analytic methods and tools available for a benefit-cost evaluation of San Luis Obispo's Transit Smart Transit System.

UCB-ITS-PWP-2008-6

October 2008, 15 pp.

FIELD EVALUATION OF SAN PABLO CORRIDOR TRANSIT SIGNAL PRIORITY (TSP) SYSTEM,

Kun Zhou et al.

This document reports the results of the evaluation of the Transit Signal Priority currently under operation at AC Transit. The paper discusses about the Measure of Effectiveness and a quantitative evaluation method for TSP. It reports the data collected and analysis conducted of the concerned TSP system and presented the evaluation results.

UCB-ITS-PWP-2008-7

October 2008, 24 pp.