California PATH
Annual Report 2005

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California PATH

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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.

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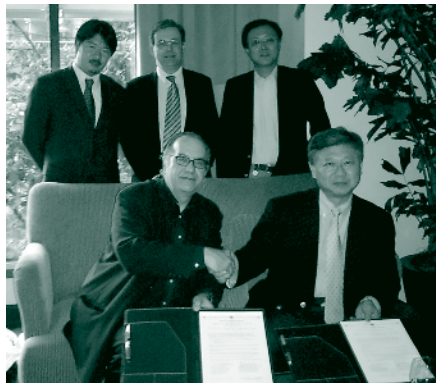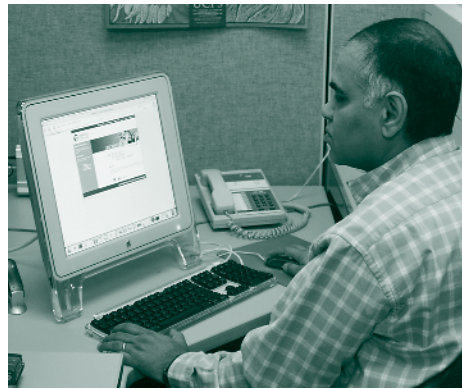
The California PATH Program is a collaboration between the California Department of Transportation (Caltrans) and the University of California. PATH's mission is to develop innovative Intelligent Transportation Systems (ITS) strategies and technologies to improve the safety, flexibility, mobility, stewardship,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

PATH's accomplishments are due to the work of an impressive group of researchers, faculty and students of the highest quality, dedication and enthusiasm. Since becoming PATH Director in the summer of 2005, I have had the privilege to work closely with them and I am thrilled with the opportunity to help shape PATH's future.

In this year's annual report, we highlight many of the ongoing projects and new research thrusts. Some developments in 2005 include:

- PATH researchers developed methodologies based on surveillance data for performance measurement, bottleneck identification and estimation of the congestion causes and impacts. Improved ramp metering strategies were developed and field tested. Work is in progress to develop improved traffic flow models as part of the Federal Highway Administration's NGSIM (Next Generation SIMulation) project.
- PATH researchers developed and successfully demonstrated an integrated collision warning system for transit vehicles. Ongoing work on bus rapid transit (BRT) developed and field tested advanced transit signal priority strategies. An arterial laboratory was established that receives real-time data from arterial surveillance systems, signal controllers, and onboard equipment from transit vehicles.
- PATH researchers are leading the research efforts in several vehicle-infrastructure integration (VII) related projects. They developed, tested and installed VII California, the first of its kind roadside deployment of VII, implemented with Dedicated Short Range Communication (DSRC) in a key traffic corridor in Northern California. PATH researchers successfully concluded the Intersection Decision Support project, which demonstrated operational concepts for active left-turn countermeasures for signalized intersections. Also, a new center, Vehicle Infrastructure Technology, Analysis and Science (VITAS) was established to provide focus to long-standing PATH research in vehicle-infrastructure cooperative systems.
- The Field Operational Test (FOT) of PATH's Smart Parking research project was successfully run through 2005, with planned demonstration completion in April 2006. In May 2005, this groundbreaking project was awarded the Intelligent Transportation Society of America's "Best in Research" award. Work is continuing to extend this concept to the field pilot phase at other transit stations in the Bay Area and California

2006 will be the 20th anniversary of the launch of the PATH program. We plan to celebrate "PATH at 20" by demonstrating the benefits of our current research through real-world testing, leading the way on the national ITS research efforts, and formulating new innovative research ideas.

Alexander Skabardonis
Director, California PATH

The Division of Research and Innovation (DRI), within the California Department of Transportation (Caltrans), is committed to providing strategic solutions to the transportation problems of California. DRI stimulates innovation in transportation by performing applied, customer-focused research that yields tangible products and process improvements to improve mobility across California. This has been a challenging and exciting year for DRI and its partners as we continue to develop new ways of doing business to better serve the people of California.

In November 2005, Caltrans hosted the ITS World Congress Event in San Francisco, drawing thousands of people from around the world to explore new and innovative ITS technologies. Caltrans played an important role at the World Congress, not only as host state, but also in partnering with UC Berkeley to host and sponsor a number of ITS demonstrations. These tours included the Innovative Mobility Showcase, which offered more than 30 demonstrations, allowing participants to experience a variety of ITS technologies in a controlled environment. Through Caltrans continued partnership with UC Berkeley, we had a major presence at this year ITS World Congress Event. "ITS Rocks."

DRI is in its third year of a comprehensive research process for identifying, selecting, monitoring and deploying research projects. As part of this effort, Caltrans research project selection process emphasizes customer participation, effective deployment and customer ownership of the research products. The DRI research program has been developed in partnership with Caltrans internal transportation experts and our external partners. The internal experts are represented on Research Program Steering Committees and on Technical Advisory Panels. Our external partners include academic research programs across California that conduct research for the Caltrans.

I am proud to be associated with colleagues at Caltrans, PATH, CCIT and many of the other university programs that are committed to the betterment of California's transportation system. I am confident that we will continue to build innovative partnerships, deploy worthwhile research and provide more choices for California's traveling public.

Laurence H. Orcutt

LAWRENCE H. ORCUTT
Chief
Division of Research and Innovation

A Word from Caltrans

California PATH Program

The California Partners for Advanced Transit and Highways (PATH) Program has been leading the way in ITS (Intelligent Transportation Systems) research since PATH's founding in 1986, before the term ITS or its predecessor IVHS (Intelligent Vehicle Highway Systems) had even been coined. PATH's purpose is to develop foundations for the widespread adoption of advanced technologies that will improve the operation of California's surface transportation systems. PATH's primary goals are to improve mobility and safety. By succeeding at these, we also expect to help reduce travel stress, pollution, and energy consumption, and contribute to better land-use management and strengthening of California's economy. We are also dedicated to improving transportation equity through our research on diverse populations and older drivers. Because PATH's goals and objectives coincide with national interest in solving transportation problems using advanced technologies, PATH played an important role in initiating ITS in the United States and the creation of the Intelligent Transportation Society of America.

The California Department of Transportation (Caltrans) provides the seed funding for PATH's core research, based on its goal of promoting the development of new knowledge and innovative technology that can improve the safety, flexibility, mobility, stewardship, delivery, and environmental impacts of California's surface transportation systems. As a California statewide ITS research program, PATH's mission is to develop solutions to the problems of California's surface transportation systems through cutting edge research. PATH also conducts research outside of California—both nationally and internationally. PATH develops these solutions by harnessing the knowledge of transportation researchers, working in conjunction with experts in the fields of information technology, electrical engineering, mechanical engineering, economics, 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
- applied technology and research and development
- system-level design and evaluation
- experimental verification of design predictions
- evaluations of existing technologies or equipment
- evaluations of costs and benefits
- technology assessments
- predictions of users' behavioral responses
- predictions of the impacts of 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, developing public/private/academic partnerships, and educating students as well as practitioners about ITS and alternative fuels.

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

PATH headquarters has about thirty full-time staff members, including a core group of research staff members, plus program leaders and administrators. The full-time research staff at PATH headquarters conducts a substantial body of research, but most PATH research work is done by faculty members and graduate students from various UC campuses and California universities that form the PATH partnership. This work is supplemented by subcontracts to private companies as needed, or by cooperative research agreements with a variety of public and private organizations, both domestic and international. The product-development-oriented work of private companies complements the more basic work of the academic researchers, so that each group can concentrate on what suits it best. Publication of PATH research work is coordinated at PATH headquarters.

Research Groups at PATH

Arterial Traffic and Transit Laboratory

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

Innovative Mobility Research (IMR) Group

Since September 2002, PATH headquarters has housed the Innovative Mobility Research (IMR) group. IMR is a group of policy and behavioral research projects focused on exploring innovative mobility technologies and services that could improve transportation options, while reducing their negative societal and environmental impacts. IMR's current research areas include: carsharing, ridesharing, smart parking, low-speed modes linked to transit, transit oriented development, demographic analysis of diverse traveling populations in California, older drivers, automated speed enforcement, virtual weigh-in motion, and the Innovative Corridors Initiative/2005 ITS World Congress.

Vehicle Infrastructure Technology, Analysis and Science (VITAS) Center

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

These projects are manifold, with current projects addressing VII, and in particular VII California, Cooperative Adaptive Cruise Control, car-to-car communications for vehicle safety, and building radio testbeds for DSRC. These projects are now organized in the cross-cutting VITAS Center within PATH. The VITAS Center now gives to PATH and its research sponsors:
- Focus on vehicle-infrastructure research at PATH
- Cross-fertilization of research ideas and researchers
- Housing of VITAS Center research assets in a common laboratory

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

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

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 13 academic departments on 16 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 State University San José, Ohio State University, San Diego State University, Texas Tech, Utah State University, University of Calgary, University of Florida, University of Minnesota and the University of Southern California.

PATH Activities in National ITS Programs

PATH has received substantial funding from the Federal Department of Transportation (USDOT), including support from the Federal Highway Administration and Federal Transit Administration. PATH participation in USDOT ITS programs during the past year includes:

- Understanding How Individuals Make Travel and Location Decisions: Implications for Public Transportation
- Older Mobility Research Focused on Minimizing Transit Barriers
- CICAS Urban and Suburban Assisted Left-turn (USUAL) System (FHWA)
- Onboard Monitoring for Commercial Vehicle Safety (FMCSA)
- Next Generation Simulation (NGSIM) Program: Improved Algorithms (FHWA)
- Development of performance specifications and interface requirements for Transit Lane Assist Systems (FTA)
- Integrated Transit Collision Warning Systems (FTA)
- Development of TSP Control Strategies and Modeling Tools (FTA)

Other Projects

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

- Development and evaluation of a variety of technologies and methodologies for Bus Rapid Transit
- Assessment of Bus Rapid Transit Opportunities in the San Francisco Bay Area
- EasyConnect: Improving BART Connectivity and Access with Low-Speed Modes
- Smart Parking for Transit Field Test
- Understanding How Individuals Make Travel and Location Decisions: Implications for Public Transportation
- Older Mobility Research Focused on Minimizing Transit Barriers and Maximizing Safe Driving Years
- Hydrogen Fuel Cell Vehicle Research

- Applying Safety Improvements to Fleet Vehicles
- San Joaquin Rail Corridor Crossing Survey
- Bicycle Detection and Operational Concept at Signalized Intersections
- Methods for Preventing Vehicle Backing Accidents
- Methods for Reducing Headlight Glare
- Quantifying Performance of Countermeasures for Collision Concentrations Related to Ramp / Freeway Mainline Junctions
- Safety of HOV Ingress / Egress along Limited Access Buffer-separated Facilities
- Evaluation of Wet Weather Accident Causation Criteria
- Animal Warning System Effectiveness
- Data Collection, Analysis and Evaluation Support in the Development of the Strategic Highway Safety Plan
- Cooperative Vehicle Safety
- VII California

Highlights

- PATH and Caltrans won in the Research Category of the ITS America 2005 "Best of ITS" awards for its Smart Parking at Transit research project in collaboration with the Bay Area Rapid Transit (BART) District, ParkingCarma, Quixote Systems, and other partners.

- PATH in partnership with Caltrans, U.S. Department of Transportation, the Metropolitan Transportation Commission (MTC) and several other governmental, industrial and academic institutions presented an Innovative Mobility Showcase of ITS technologies during the 12th World Congress on Intelligent Transport Systems (ITS) in San Francisco, November 2005. Some of the projects successfully demonstrated by PATH included Vehicle-Infrastructure Integration (VII) Technology, Integrated Collision Warning System, Automated Bus Rapid Transit Technology, and Smart Intersection. The VII California showcase demonstration – of which PATH was a significant part – is a finalist for ITSA's "Best of Research and Development".

- PATH signed a research cooperation agreement with the new Research Center for Advanced Mobility at the University of Tokyo during the 2005 ITS World Congress in November 2005. Under this agreement, researchers from two centers will collaborate on ongoing ITS research, and pursue funding opportunities for joint new projects.

- PATH continues our significant research relationships with various automobile manufacturers in areas of vehicle-vehicle cooperation and communication.

- On December 20th, 2005, representatives of DaimlerChrysler Corporation delivered a Mercedes-Benz "F-Cell" hydrogen fuel cell vehicle to PATH. Under the agreement with DaimlerChrysler, PATH researchers will provide "real-world" operational experience with the vehicle, and conduct various travel-behavior studies related to the use of the vehicle.

- DaimlerChrysler Corporation and Toyota Motor Company presented PATH with gift grants to support research on hydrogen and older mobility.

- Toyota Information Technology Center presented PATH with a gift grant to support research in driving behavior.

- PATH co-sponsored the Traffic Modeling Conference, organized by the Federal Highway Administration and the University of Arizona, in Sedona, Arizona, September 2005. PATH researchers presented ongoing research and discussed future directions in traffic modeling and simulation.

Policy and Behavioral Research
Susan Shaheen, Program Leader

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

Projects involve faculty, staff, and students from across the State. These include: innovative strategies to enhance transit services and increase ridership, such as carsharing (i.e., short-term vehicle access), low-speed modes (e.g., Segway Human Transporters and electric bikes), and spatial/temporal utility modeling; 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; measuring the impact of graduated licensing laws in California; and understanding travel behavior of diverse population groups.

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

- ***Measuring the Impact of Changes in Graduated Licensing Laws in California*** (TO 5100). In July 1998, California changed its graduated driver licensing laws (GDL) for new drivers under the age of 18 to include restrictions on hours of driving, carrying teen-age passengers, and requiring more adult supervised driving practice. With fatal and injury crash data from California's Statewide Integrated Traffic Records System, this study, sponsored by the California Department of Transportation, used standard regression analysis as well as the Bai-Perron stochastic multiple structural break model to determine the effect of the law on teen-age passengers and crash rates of 16 year-old drivers. Researchers found that in the four and one-half years following implementation of the new law, crashes caused by 16 year-old drivers decreased by 11 percent and the average number of teen-age passengers carried by 16 year-olds decreased by approximately 31 percent. The combination of these two decreases resulted in the saving of 29 lives and the prevention of 2,632 injuries. To test the specific effect of the restrictions on driving between midnight and 5 AM, regression analysis was performed on the quarterly percentage of curfew crashes for 16 year-old drivers. Quarterly data were used due to the relatively small number of curfew crashes. The percent of curfew crashes has been in a nearly significant long-term down trend since 1996. There was a small, non-significant lessening of the long-term downward trend at the time of the implementation of the new law. Thus, the new law does not appear to have had a material effect on the percentage of driving done by 16 year-olds during curfew hours. This percentage was in a downtrend prior to the law and continued after the law took effect.

Research

- ***Spatial and Temporal Utility Modeling to Increase Transit Ridership*** (TO 5102). The objective of this research was to develop a better understanding of the possible alternatives that a large employment center, like the University of California at Santa Barbara, can adopt to better use transit, mitigate traffic, and reduce demand for on-site parking. The techniques and approaches developed were designed to be equally applicable elsewhere. This project: 1) developed an understanding of commuting employees through the use of a survey, 2) identified spatially whether there exist areas in which transit service is competitive to the use of the single occupant vehicle (SOV), and 3) identified whether there are areas in which special express bus routes could provide competitive access to the University. The survey involved more than 2300 university students, faculty, and staff. It revealed a number of important points including that nearly 30 percent of the staff and faculty have never used transit, do not know where their nearest route or bus stop is, and have no knowledge of how to obtain such information. The survey also revealed that a sizable minority ride their bikes to the University. The project also focused on the provision of transit services by mapping access times in the journey to the University and home. Overall, access times are quite large, especially when comparing transit service times to that of using a personal vehicle. Map results tend to indicate that most of the south coast region is poorly served by transit when commuting directly to the University, where the public transit trip takes at least twice the time as compared to using a personal vehicle. There are, however, some areas that are served with good access to the University. Finally, a special routing model was developed that can be used to design express bus service routes. All of the tools developed as a part of this project were designed within the context of future application at other centers of large employment.

- ***Evaluating Innovative Strategies to Enhance Transit Services and Increase Ridership*** (TO 5103). Increases in congestion, transportation costs, and associated environmental impacts continue to promote the research, planning, and development of enhanced transit strategies. The transit oriented development (TOD) concept, often synonymous with "transit village," integrates transit, residential, retail and/or commercial entities into a compact, pedestrian-friendly community. The ultimate transportation objective relative to a TOD is to reduce private car use with an associated increase in transit ridership. Previous research indicates that residents living in developments near stations are five to six times more likely to commute via transit than other residents in a region. Additionally, a proportional relationship has been found between urban density and transit use. Relative to bus transit, ridership associated with buses can promote greater efficiencies through the implementation of bus rapid transit (BRT) strategies. One of the most promising areas of BRT enhancements is Bus Lanes with Intermittent Priorities (BLIPs). How to successfully move individuals from private vehicle use to transit ridership is a complex question involving an array of socio-economic variables. This study focused on two strategies, BLIPs and ITS implementation architectures within TODs, to promote the adoption of transit. These strategies can enhance transportation efficiency and effectiveness within a TOD. Additionally, implementation of BLIPs for BRT can greatly increase system efficiencies without compromising the level of service for other facility users. This study also identified technology bundles and architectures, such as carsharing, low-speed modes, and smart parking, that have the greatest potential for increasing mobility and promoting transit efficiency and convenience beyond levels currently observed.

- ***An Integrated Hydrogen/Intelligent Transportation Systems (ITS) Evaluation of the California Department of Transportation*** *(TO 5112).* This project investigated hydrogen activities in the State and around the U.S. that might impact the California Department of Transportation's (Caltrans) operations. The main theme underlying this study is the potential for synergies between two rapidly evolving areas of advanced transportation and energy technology: hydrogen energy systems and ITS. Researchers hypothesize that concepts and schemes that combine these two types of technologies can help to enable the potential use of hydrogen infrastructure by allowing communication and mapping/navigation technologies to optimize the access to and operation of initially sparse hydrogen refueling networks. Based on this initial investigation, researchers conclude that: 1) several states are competing with California to develop hydrogen plans and to attract the emerging hydrogen and fuel cell industry to their states, most notably New York and Florida; 2) DOTs in these states have for the most part been interested observers to this point but are beginning to be drawn into hydrogen activities in these states; 3) the U.S. DOT is conducting activities at a relatively modest but significant level, particularly with respect to codes and standards development and hydrogen transit buses; 4) hydrogen activities will be continued for FY 2005/2006 at the U.S. DOT under the newly-created Research and Innovation Technology Administration (RITA); 5) the *California Hydrogen Blueprint Plan* contains several references to Caltrans as a potential key partner in hydrogen projects, particularly related to partnering on hydrogen station siting and incorporating hydrogen-powered vehicles in its fleets; 6) many different ITS technologies are applicable to the potential introduction of new alternative fuel vehicle (AFV) types, particularly with respect to the challenges of developing new vehicle refueling networks for hydrogen-powered vehicles and to help enable potential vehicle to grid (V2G) power schemes; and 7) emerging technologies and concepts for the distributed generation of electrical power have potential technological/economic interactions with hydrogen vehicle and refueling systems and ITS. Finally, researchers developed a list of potential concepts to be considered for a field operational test, particularly a "smart hydrogen refueling" demonstration based on timing, technology availability, and potential interest for Caltrans, as well as significant national and global interest.

- ***The EasyConnect Low-Speed Modes Linked to Transit Planning Project*** (TO 5113). The integration of innovative technologies with traditional modal options in transit oriented developments (TODs) may be the key to providing the kind of high-quality transit service that can effectively compete with the automobile in suburban transit corridors. The EasyConnect project represents the integration of innovative strategies to enhance transit use during the development and construction of a suburban TOD at the Pleasant Hill Bay Area Rapid Transit (BART) District station in the East San Francisco Bay Area. This planning project brings together a unique partnership including small technology businesses, private developers, transportation agencies, city and county government, and academia. The project components include the introduction of shared-use low speed mode vehicles and electronic lockers at the proposed TOD. The evaluation of the EasyConnect field operational test (TO 6113—the next phase of this initiative) will provide insights into whether the introduction and integration of innovative technologies at TODs can significantly increase transit access/use and cost effectively provide a last mile solution.

Measuring the Impact of Changes in Graduated Licensing Laws in California: The Influence of Law, Urban-Rural Location, and Infrastructure, TO 5100, David Gillen, University of California, Berkeley and Wilfred Laurier University, Waterloo, Ontario, Canada. UCB-ITS-PRR-2005-25

Smart Parking Management Field Test Project: A Bay Area Rapid Transit (BART) District Parking Demonstration Expansion and Research Evaluation, TO 5101, Susan Shaheen, California PATH.

Spatial and Temporal Utility Modeling to Increase Transit Ridership, TO 5102, Richard Church and Michael Goodchild, University of California, Santa Barbara. UCB-ITS-PRR-2005-22

Evaluating Innovative Strategies to Enhance Transit Services and Increase Ridership, TO 5103, Carlos Daganzo, University of California, Berkeley and Matthew Barth, University of California, Riverside. UCB-ITS-PRR-2006- 2

A Case Study of California's Chassis: Long Beach and Los Angeles, TO 5104, Amelia Regan, University of California, Irvine.

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

California Trains Connected, TO 5106, Adib Kanafani, University of California, Berkeley.

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

Designing a Policy Framework for a Statewide Transit Smart Card System, TO 5108, Brian Taylor, University of California, Los Angeles UCB-ITS-PWP-2006-2,

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

A GIS-Based Tool for Forecasting the Travel Demands of Demographic Groups within California – An Optimal Resource Allocation Tool, TO 5110, Konstandinos Goulias, University of California, Santa Barbara.

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

An Integrated Hydrogen/Intelligent Transportation System (ITS) Evaluation for the California Department of Transportation, TO 5112, Timothy Lipman, University of California, Berkeley and Susan Shaheen, California PATH. UCB-ITS-PRR-2005-34

EasyConnect Low-Speed Modes Linked to Transit Planning Project, TO 5113, Susan Shaheen, California PATH.

Transportation Safety

Jim Misener, Program Leader

Transportation Safety research at PATH continues to extend traditional areas of competency at PATH, mainly in vehicle-highway cooperation and communication, and "science of driving" investigations on driving behavior, and in implementation of prototype vehicle-highway safety systems. In this past year, new areas of research have extended to efficient means to investigate crashes, rail-highway crossings, and importantly to Caltrans, means to understand high crash concentrations in order to embark on road safety improvements.

Specific project groupings include:
- Intersections and Cooperative Systems – crossing path vehicle crashes, safety aspects of cooperative driver-assist systems, Vehicle Infrastructure Integration (VII) with Expedited VII and VII California
- Driver behavior – modeling and applications for safety and countermeasure studies of car following and lane changes, at roadway intersections, at-grade crossings
- Employee Safety – work zone warning signals, snow removal equipment
- Emerging areas include speed enforcement, heavy truck safety, pedestrian safety and research with older driver safety.

In 2005, accomplishments include work on pedestrian detection and warning, and our human factors / vision science researchers are working on areas of work zone safety and driver modeling. We have also wrapped up a large a multidisciplinary project on intersection safety, Intersection Decision Support (IDS) and have defined along with Caltrans and US DOT a version of Cooperative Intersection Collision Avoidance Systems focused on left turn assistance.

Another significant milestone in PATH safety research was the 2005 ITS World Congress Innovative Mobility Showcase held in San Francisco in November. The IDS and VII California projects were demonstrated at the showcase, highlighting to appreciative attendees the Caltrans- and US DOT-sponsored work and demonstrating a harbinger to the future of PATH-developed safety systems.

Intersections and Cooperative Systems

Cooperative Collision Warning, Sponsor: General Motors Research and Development Center.

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

Integrated Roadway/Adaptive Cruise Control System: Safety, Performance, Environmental and Near Term Deployment Considerations, TO 5501, Petros Ioannou, University of Southern California.

Intersection Decision Support, TO 5600 and 5601, Samer Madanat, Jim Misener, California PATH. UCB-ITS-PWP-2005-1, UCB-ITS-PWP-2005-4,

Vehicle Lateral Control Under Fault in Front and/or Rear Sensors, TO 4204, Masayoshi Tomizuka, University of California, Berkeley. UCB-ITS-PRR-2003-26, UCB-ITS-PRR-2004-36

Driver Behavior

Improved Grade Crossing Safety with In-Pavement Warning Lights, TO 4138, Theodore Cohn, University of California, Berkeley. UCB-ITS-PRR-2005-10

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

The Naturalistic Driver Model: Development, Integration, and Verification of Lane Change Maneuver, Driver Emergency, and Impairment Modules, TO 5500, Delphine Cody, California PATH. UCB-ITS-PRR-2005-4

Employee Safety

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

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

Global Warning Signal Integration as a Tool for Workzone Safety and Efficiency, TO 5207, Theodore Cohn, University of California, Berkeley. UCB-ITS-PRR-2006-03

Emerging Areas

Experimental Vehicle Platform for Pedestrian Detection, TO 5200, Ching-Yao Chan, California PATH.

Automatic Steering for Conventional Truck Trailers: Development and Assessment of Operating Concepts for Improving Safety, Productivity and Pavement Durability, TO 5201, Jacob Tsao, San Jose State University.

Pedestrian/Bicycle Safety on a SMART Corridor, TO 5204, David Ragland, University of California, Berkeley.

Innovative Mobility Showcase at 2005 ITS World Congress

Traffic Operations
Alex Skabardonis, Program Leader

The PATH Traffic Operations Research Program focuses on advancing the state-of-the-art in traffic management and traveler information systems, and producing results that can be implemented in the field. The research is undertaken by a statewide research team of nineteen faculty and more than 50 graduate students and staff working closely with the program sponsors. Currently, there are more than thirty ongoing research projects that fall in five major categories: traffic surveillance, algorithms for data processing, analysis and performance measurement, development and application of modeling tools, and formulation and testing of advanced operational strategies.

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

- Methods have been developed to perform detector diagnostics, and use detector data for travel time estimation, incident detection and other ITS applications (TO 5302, TO 5303 and TO 5304). A new wireless MEMS sensor has been developed and tested in various environments (TO 5301 and TO 5328). The results show that it can replace loops and other conventional sensor systems. Under the FHWA sponsored Next Generation of Traffic Simulation Models (NGSIM) project, the machine vision algorithms for vehicle tracking from video data were enhanced and integrated into a software suite. The algorithms were used to produce detailed data of vehicle trajectories on two freeway sites for studying driver behavior and traffic dynamics on freeways.

- The freeway Performance Measurement System (PeMS) covers all the freeways of the State with surveillance systems; PeMS provides real-time and historical performance measures. Using the traffic and incident data in the PeMS database, empirical models are being developed to estimate the cause and impact of congestion (TO 5306 and TO 5321). A prototype implementation of PeMS on arterial streets (APeMS) has been developed to provide travel time estimates on arterial links from real-time detector and signal control data (RTA 20861).

- Work is underway to develop improved car-following and lane-changing algorithms as part of the NGSIM project (RTA 7214). Several enhancements to simulation tools were developed and tested, including Application Program Interfaces (APIs) to better model ramp metering and adaptive signal control (TO 5305, and TO 5311), procedures for simulating large networks (TO 5310), and interface of simulation and optimization tools (TO 5325). Improved analysis tools have been developed for calibration of microscopic simulation models (TO 5308).

- Improved ramp metering strategies have been developed and field tested on an isolated on-ramp (TO 5312). The results from the field experiments show that the proposed strategies are effective in alleviating bottlenecks at freeway merging areas. An improved algorithm for system-wide traffic responsive control has been developed for a congested freeway in Los Angeles (TO 5503). Advanced strategies for adaptive traffic signal control are been developed and will be field tested on a major arterial (TO 5322 and TO 5323).

- Work is in progress on developing a system that facilitates the coordination of operating agencies to minimize the response time to incidents along traffic corridors (TO 5313 and TO 5324). The system will be implemented in the Orange County ATMS testbed. PATH evaluation of the Bay Area Incident Management System (BAIRS) showed that BAIRS produced significant delay savings due to reduced incident response and clearance times (TO 5316).

Traffic Surveillance

Conventional Surveillance and Communications Technologies

Extracting More Information from the Existing Freeway Monitoring Infrastructure, TO 5302, Pravin Varaiya, University of California, Berkeley, Ben Coifman, Ohio State University.

Traffic Analysis to Enhance Detector and System Diagnostics/Berkeley Highway Laboratory Implementation at CCIT, TO 5303, Adolf May, University of California, Berkeley. UCB-ITS-PRR-2005-24

New Detector Technologies

Low-Cost Vehicle Detection and Communication Systems for Freeways, Intersections and Parking Lots, TO 5301, Pravin Varaiya, University of California, Berkeley. UCB-ITS-PWP-2004-6, UCB-ITS-PWP-2004-7

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

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

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

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

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

Data Processing/Analysis/ Performance Measurement

Traffic Flow

New Approach to Bottleneck Capacity Analysis, TO 5309 (6309), James Banks, San Diego State University.

A Hybrid Model of Traffic Flow, TO 5330, Carlos Daganzo, University of California, Berkeley

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

Performance Measurement

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

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

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

Highway Traffic Data Sensitivity Analysis, TO 5320; Xiao-yun Lu, PATH, University of California, Berkeley.

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

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

Modeling

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

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

Developing Optimal Planning and Management Strategies for a Robust Highway System, TO 5329; Samer Madanat, University of California, Berkeley. UCB-ITS-PRR-2005-35

Development and Application of Traffic Simulation Models

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

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

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

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

Development of an Integrated Microscopic Simulation and Optimization Tool, TO 5325; Wei-Bin Zhang, PATH, University of California, Berkeley.

Traffic Control, Management and Traveler Information Systems

Design, Field Implementation and Evaluation of Adaptive Ramp Metering Algorithms, TO 5503; Roberto Horowitz, Pravin Varaiya, Alexander Skabardonis, University of California Berkeley, Michael Zhang, University of California Davis. UCB-ITS-PRR-2004-44

On Ramp Metering Experiments to Increase Freeway Merge Capacity, TO 5312; Michael Cassidy, University of California, Berkeley UCB-ITS-PRR-2005-28

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

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

Evaluation of the Bay Area Incident Management System (BAIRS), TO 5316; Alexander Skabardonis, University of California, Berkeley. UCB-ITS-PRR-2006-1

Measure 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 Approach, TO 5323 (6323), Will Recker, University of California, Irvine.

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

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

Transit Operations
Wei-Bin Zhang, Program Leader

The transit research program emphasize new service concepts, methods and ITS technologies for innovating, enhancing and improving transit solutions with a goal that an enhanced public transit system will provide transportation choices that ultimately help to reduce traffic congestion. PATH researchers, including faculty, staff, and students from across the State, are working closely with transit agencies across and outside of California to address real world problems and bring in advanced yet practical solutions, dealing with a wide range of transit research, including planning and technological aspects of Bus Rapid Transit, Demand Schedule and Responsive Transit, Vehicle Assist and Automation, Transit Signal Priority, Interaction between transit rail and traffic, and rural transit ITS applications.

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

- *Factors Influencing Productivity and Operating Cost of Demand Responsive Transit **TO 5403***: The project team at University of Southern California has conducted a survey of transit agencies providing Demand Responsive Transit service in medium-sized and large urban centers throughout the United States. The team evaluated the impact of the implemented technologies and management practices for the 67 responding agencies on productivity and operating cost measures derived from the 1997-2002 National Transit Database. The analysis indicates that use of a Paratransit CAD system to group service requests into vehicle routes provides a productivity benefit of approximately 12,000 passenger miles per vehicle, and 1,100 trips per vehicle, annually. However, the practice of manually revising routes during the time of service produces a detrimental impact on productivity of approximately 1,800 trips per vehicle annually. Consequently, policy makers should insist on some form of computational assistance for dispatchers, so that system-wide impacts of route revisions can be evaluated correctly in real time. Furthermore, the use of financial penalties in contracts with service providers was found to have beneficial impacts on productivity and operating cost. This result is in conflict with the results of our previous study (UCB-ITS-PRR-2003-1). Note that there are few agencies in common between the responders to the two surveys and attribute this apparent flip-flop in results to an as yet unidentified distinction between the two survey groups.

- *Transit Integrated Collision Warning System **(RTA 20855)***: After successful testing of both frontal collision warning system (FCWS – Previously developed by PATH, Caltrans, and Samtrans) and side collision warning system (SCWS – previously developed by CMU, Pennsylvania Department of Transportation and Port Authority of Allegheny County (PAT)), FTA, with the advice of the transit IVI stakeholder group, decided to move forward with integrating the FCWS and SCWS into an Integrated Collision Warning System (ICWS). Two prototypes of the Integrated Collision Warning System (ICWS) were developed by PATH and CMU and were installed on a SamTrans and a PAT bus. The prototype systems were put in revenue service in the San Francisco Bay Area and in Pittsburgh. Detailed analysis of the test data revealed driver behavior changes, indicating that the introduction of the warning system appeared to lead to more consistency of driving behavior across the sample of operators. More significantly, these data show that drivers with somewhat more aggressive and inconsistent driving

behaviors before the introduction of the warning system changed their driving behaviors and became noticeably more consistent and less aggressive after the warning system was activated. These study results have indicated the feasibility and effectiveness of transit collision warning systems.

- ***Development of Performance Specifications and Interface Requirements for Transit Vehicle Assist and Automation System (RTA 20866)***: Vehicle Assist and Automation (VAA) systems offer the opportunity of providing high quality transit service within reduced lane widths. Transit operators are very interested in VAA in order to deliver rail-like service, an attractive feature to riders, at a fraction of the cost of rail. The primary technological barrier to VAA deployment is the fact that many of these VAA products are tied to a specific, specialized and costly vehicles and cannot be easily retrofitted onto the existing buses produced by North American bus manufacturers. In order to facilitate progress toward the development and deployment of VAA systems on transit buses in the U.S., the Federal Transit Administration (FTA) and Caltrans sponsored research to develop the requirements for the interface between VAA subsystems/elements and bus subsystems/elements. Under this research PATH developed a modular system architecture, based on which electrical, data communication, power supply and infrastructure interface requirements were established. These requirements were tested and validated using an advanced BRT vehicle previously developed by PATH under Caltrans sponsorship.

- ***Toward Deployment of Adaptive Transit Signal Priority (TO 5404):*** PATH has developed an Adaptive Transit Signal Priority (ATSP) system concept aimed at reduction of delays for buses at traffic signals, while minimizing the impact on the rest of the traffic and maintaining pedestrian safety. The ATSP concept uses real-time GPS position, bus movement information and historical bus travel behavior data to predict the bus arrival time at the intersection. The predicted bus arrival information provides a much longer lead time to allow the traffic controller to be "adaptive" to the bus arrival as well as to the traffic situation and makes it possible to distribute the impact over several signal control phases prior to the 'hit' phase. Many transit buses have already been instrumented with GPS-based advanced communication systems (ACS). The ATSP would allow all buses instrumented with GPS/ACS to become signal priority capable without additional equipment on the buses. It is therefore an integrated and cost-effective approach for deployment of bus signal priority. A prototype ATSP has been tested on SamTrans bus along El Camino Real in San Mateo County, CA, where results show that ATSP can potentially provide 2-3 times more bus travel time savings at intersection as compared with traditional TSP systems, while the impact on cross traffic is negligible.

- ***Development of Deployment Strategy for an Integrated BRT System (TO 5603)***: In contrast to rail transit, Bus Rapid Transit can adopt a variety of designs to meet a particular application, fit specific urban sittings and offer opportunities for incremental deployment. Previously PATH has conducted a number of BRT planning studies to investigate various planning, design, technology and operational options available for BRT and their cost -benefit implications. The findings from these studies were applied in BRT planning studies for the cities of Riverside and Chicago. Building upon these case studies, PATH further researched BRT/ITS architecture and developed a BRT deployment framework and strategies which define how to get from the present transit system to a future regionally integrated BRT system.

- ***Development of Bus Rapid Transit Information Clearinghouse (TO 5602)***: The primary objective of this project was to develop a single online address for well-organized information related to bus rapid transit (BRT) systems and to fill a gap in the availability of knowledge-based information to support intended users in the planning for and implementation of bus rapid transit systems. We developed a web-site, called the BRT Information Clearinghouse, located at *http://path.berkeley.edu/informationclearinghouse/*, which has three primary elements: 1) Planning Support Tool, 2) Publications Database, and 3) BRT Resources. The Planning Support Tool provides users directly with or pointers to information resources by walking users through the scope of a given BRT situation and the nature of the issues being addressed to arrive at a set of resources to provide the necessary support. The Planning Support Tool contains knowledge-based information about BRT including the planning and development process, institutional arrangements, economics and finance, major elements of BRT, system integration, land use, design specifications, and operations planning, together with case study findings. The Publications Database portion provides access to fully abstracted records of published and/or otherwise publicly available materials from professional journals, technical and trade magazines, academic publications, conference proceedings, technical reports, government documents, and links to related websites. Direct links to the documents (in PDF) are provided where available. The BRT Resources section of the Clearinghouse allows the user to access portals to BRT-related information including links for site-specific BRT systems around the world, BRT-focused websites, organizations, search engines and research databases, and technical information, assistance and training.

In 2005 the PATH transit program embraced the following research areas in the Task Order (TO) 5000 series, RTA's or outside funding sources:

Bus Rapid Transit

Toward Deployment of Adaptive Transit Signal Priority (ATSP) System TO 5404, Yafeng Yin, Wei-Bin Zhang, Kun Zhou and Meng Li, California PATH.

Development of Bus Rapid Transit (BRT) Information Clearinghouse TO 5602, Mark Miller, California PATH

Development of Deployment Strategy for an Integrated BRT System TO 5603, Mark Miller and Chinwoo Tan, California PATH

Transit Safety, Vehicle Assist and Automation

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

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

Development of Interface Requirements for Transit Lane Assist System, RTA 20866, Wei-Bin Zhang, California PATH.

Multimodal and Connectivity

Productivity and Cost Effectiveness of Demand Responsive Transit Systems TO 5401, Maged Dessouky, Fernando Ordonez, University of Southern California. UCB-ITS-PRR-2005-29

User Driven Scheduling Transit Service TO 5402, Mike Cassidy, University of California, Berkeley

Factors Influencing Productivity and Operating Cost of Demand Responsive Transit TO 5403, Kurt Palmer, Maged Dessouky, University of Southern California.

A Combined Quantitative and Qualitative Approach to Planning for Improved Intermodal Connectivity at California Airports TO 5406, Xiaoyun Lu, California PATH. UCB-ITS-PWP-2006-01

Relieve Congestion and Conflicts Between Railroad and Light Rail Grade-Crossing Intersections TO 5407, Wei-Bin Zhang, California PATH.

Improving Mobility through Enhanced Transit Services TO 5408, Mike Cassidy, University of California, Berkeley.

POLICY AND BEHAVIORAL

CONSIDERING RISK-TAKING BEHAVIOR IN TRAVEL TIME RELIABILITY

Will Recker, Younshik Chung, Jiyoung Park, Lesley Wang, Anthony Chen, Zhaowang Ji, Henry Liu, Matthew Horrocks, Jun-Seok Oh

In this report, the authors examine a number of questions related to travel time variability and how these questions can aid in designing and evaluating transportation planning and managing strategies. These questions look at: 1) quantifying travel time variability at both the section level and the route level; 2) the value of travel time and its reliability; 3) the contribution that travel time reliability makes to traveler's route choices; 4) the amount of variation present in traveler's preferences regarding the potential tradeoff between reliability and travel time; 5) incorporating travel time variability into the route choice models for transportation planning purposes; and, 6) incorporating the effects of travel time reliability in considering risk-taking behavior in route choice models.
UCB-ITS-PRR-2005-3
January 2005, 198 pp

SMART PARKING MANAGEMENT PILOT PROJECT: A BAY AREA RAPID TRANSIT (BART) DISTRICT PARKING DEMONSTRATION

Susan Shaheen, Caroline Rodier, Amanda M. Eaken

This report describes the research and feasibility analysis for the design and implementation of a smart parking management field test at the Rockridge BART station in the East San Francisco Bay Area. The study presented the opportunity to apply smart parking technologies with the objective of expanding effective parking capacity, transit ridership, and farebox revenues. The report consists of three primary sections: 1) a literature review evaluating the effectiveness of different types and applications of smart parking management systems; 2) a feasibility analysis comprised of focus groups, surveys, and observation-

al analyses guiding the development and initial evaluation of the smart parking field test; and, 3) a smart parking project description, including the applied demonstration design and technology.
UCB-ITS-PRR-2005-5
February 2005, 138 pp

SPATIAL AND TEMPORAL UTILITY MODELING TO INCREASE TRANSIT RIDERSHIP

Richard L. Church, Val Noronha, Ting Lei, Wils Corrigan, Shaunna Burbidge, Jim Marston

This research project was directed at developing a better understanding of the possible alternatives that a large employment center can adopt in order to better utilize transit, mitigate traffic, and reduce the demand for on-site parking. Using the University of California at Santa Barbara as a case study, researchers focused on three areas: 1) using a survey to understand commuting employees; 2) spatially identifying the possible existence of areas where transit service is competitive or nearly so the use of single occupant vehicles; and, 3) identifying areas in which special express bus routes could provide competitive access to the University.
UCB-ITS-PRR-2005-22
June 2005, 77 pp

LONG TERM IMPACTS OF CALIFORNIA'S GRADUATED LICENSING LAW OF 1998

Douglas Cooper, David Gillen, Frank Atkins

In July 1998 California changed its graduated driver licensing laws (GDL) for new drivers under the age of 18 to include restrictions on hours of driving, carrying teen-age passengers, and requiring more adult supervised driving practice. With fatal and injury crash data from California's Statewide Integrated Traffic Records System, this study, sponsored by Caltrans, used standard regression analysis as well as the Bai-Perron stochastic multiple structural break model to determine the effect of the law on teen-age passengers and crash rates of 16 year-old drivers. We found that in the four and one-half years following implementation of the new law, crashes caused by 16 year-old drivers decreased by 11% and the average number of teen-age passengers carried by 16 year-olds decreased by approximately 31%. The combination of these

two decreases resulted in the saving of 29 lives and the prevention of 2,632 injuries.

To test the specific effect of the restrictions on driving between midnight and 5 AM, regression analysis was performed on the quarterly percentage of curfew crashes for 16 year-old drivers. Quarterly data was used due to the relatively small number of curfew crashes. The percentage of curfew crashes have been in a nearly significant long term down trend since 1996. There was a small, non-significant lessening of the long-term downward trend at the time of the implementation of the new law. The new law does not appear to have had a material effect on the percentage of driving done by 16 year-olds during curfew hours. This percentage was in a downtrend prior to the law and continued after the law took effect. UCB-ITS-PRR-2005-25
July 2005, 45 pp

VIRTUAL COMMERCIAL VEHICLE CONTROL STATIONS FOR CALIFORNIA: A REVIEW OF LEGAL AND INSTITUTIONAL ISSUES

Caroline J. Rodier, Susan A. Shaheen, Ellen Cavanagh

In the past five years, commercial vehicle travel has increased 60 percent on California's highways, without a corresponding increase in compliance inspection station capacity or enforcement officers. Commercial vehicles that do not comply with regulations impose significant public costs including, for example, pavement and structure damage to roads and catastrophic crashes. In response to these problems, the California Department of Transportation is investigating the potential application of detection and communication technology in virtual compliance stations (VCS) to cost-effectively improve enforcement of commercial vehicle regulations. This study begins with a description of the fledgling VCS research programs in the U.S. as well as more advanced international VCS programs. Next, the results of expert interview with key officials involved in the early deployment stages of VCS programs in Kentucky, Florida, Indiana, and Saskatchewan are reported. This is followed by an analysis of institutional barriers to VCS screening and automated enforcement based on the relatively extensive body of literature on the commercial vehicle electronic pre-screening programs and red-light and speeding automated enforcement

programs. The paper concludes with some key recommendations to address legal and institutional barriers to VCS deployment in the U.S.
UCB-ITS-PRR-2005-33
November 2005, 21 pp

INTEGRATED HYDROGEN AND INTELLIGENT TRANSPORTATION SYSTEMS EVALUATION FOR THE CALIFORNIA DEPARTMENT OF TRANSPORTATION

Timothy E. Lipman, Susan Shaheen

This "Integrated Hydrogen/Intelligent Transportation Systems Evaluation for the California Department of Transportation" project was conceived to investigate hydrogen activities in the State and around the U.S. that might impact the California Department of Transportation's (Caltrans) operations. The project is intended to review these activities and to suggest potential interesting applications of combined hydrogen and intelligent transportation system (ITS) technologies. This project was conducted by researchers at the University of California, Berkeley under California Partners for Advanced Transportation and Highways (PATH) Task Order 5112.

The main theme underlying this study is the potential for synergies between two rapidly evolving areas of advanced transportation and energy technology: hydrogen energy systems and Intelligent Transportation Systems (ITS). We hypothesize that concepts and schemes that combine these two types of technologies can help to enable the potential use of hydrogen infrastructure by, first and foremost, allowing communication and mapping/navigation technologies to optimize the access to and operation of initially sparse hydrogen refueling networks. Additional benefits include helping to contend with the potentially limited driving range of initial hydrogen-powered vehicles and exposing consumers to new technologies in ways that do not require purchasing them, such as through fleet/motor pool, transit, and carsharing (i.e., short-term vehicle rentals) organization operations.
UCB-ITS-PRR-2005-34
November 2005, 63 pp

VIRTUAL WEIGH STATIONS IN CALIFORNIA: A PRELIMINARY COST-EFFECTIVENESS ANALYSIS

Nicholas Santero, William Nokes, John Harvey

A new technology known as Virtual Weigh Stations (VWS) is intended to transform datacollecting weigh-in-motion (WIM) sites to weight enforcement mechanisms. This study investigates the possible benefits to the highway pavements in California from potential use of VWS. The investigation proceeded in two steps: (1) determining the damage currently caused by overweight trucks and (2) modeling the potential pavement life saved with VWS. The data used for analysis is from the California Department of Transportation (Caltrans) WIM database.
UCB-ITS-PWP-2005-5
November 2005, 30 pp

TRANSPORTATION SAFETY

DEVELOPMENT OF A HEAVY-DUTY DIESEL MODAL EMISSIONS AND FUEL CONSUMPTION MODEL

Matthew Barth, Theodore Younglove, George Scora

This report first provides background material on Heavy Duty Diesel (HDD) vehicle fuel consumption and emissions. A description of the vehicle testing program then follows. The HDD vehicle model development is descried, along with the model validation process. The model is then integrated with a number of transportation simulation modeling tools in order to evaluate several automation scenarios. Focus is placed on the simulated truck platoon scenario, in which aerodynamic drafting effects can provide a noticeable benefit in terms of fuel and emissions savings. Besides the modeling, experimentation in real-world tests have been carried out, examining trucks traveling in tandem with close inter-vehicle spacing. Results of these tests are included.
UCB-ITS-PRR-2005-1
January 2005, 123 pp

THE NATURALISTIC DRIVER MODEL: A REVIEW OF DISTRACTION, IMPAIRMENT AND EMERGENCY FACTORS

J.K. Caird, M. Lees, C. Edwards

The purpose of this project is to review the literature on driver distraction, impairment and emergency response that supports the development of the Naturalistic Driver Model. Driver models that are based on high-quality empirical research are more likely to serve as a useful and valid tool to professionals and researchers.

Project Objectives:

1. Generate an extensive literature review that identifies the extent that driver distraction and impairment affects reaction time, lateral and longitudinal vehicle control and other variables.

2. Review emergency responses in a variety of situations and determine their implications for lane change, car following and merging.

3. Synthesize the results on reaction time so that a range of values can be incorporated into a driver model.
UCB-ITS-PRR-2005-4
February 2005, 91 pp

IMPROVED GRADE CROSSING SAFETY WITH IN-PAVEMENT WARNING LIGHTS

Theodore E. Cohn

The focus of this project is the modification of a commercially available in-pavement warning signal that was evolved from one originally designed to indicate the presence of pedestrians in a crosswalk. We have proposed use of a similar device to provide warning to vehicles approaching a railroad grade crossing, and we have tested a variety of illumination patterns in order to provide an optimal implementation of such a warning device. Our laboratory tests demonstrate an improvement in visual response, as evidenced by a lowered reaction time, to a pattern that incorporates alternating groups of spatially-separated flashed LEDs in order to stimulate perception of movement. We have also completed preparations, including installation, for a future field test to study vehicle behavior in the presence of embedded warning lights incorporating this modified firing pattern.
UCB-ITS-PRR-2005-10
March 2005, 60 pp

CALIFORNIA INTERSECTION DECISION SUPPORT: A SYSTEMS APPROACH TO ACHIEVE NATIONALLY INTEROPERABLE SOLUTIONS

Ching-Yao Chan, et al

The overall IDS research plan was constructed to realize, in slightly more than three years, the requirements, tradeoffs assessment, and technology investigations necessary to define an IDS. Toward the end of the project we will combine our understanding of the problem definition, IDS technologies and our integration experience with a standard Caltrans intersection (with advanced controller) and design a deployable IDS demonstration that can be field tested.
UCB-ITS-PRR-2005-11
April 2005, 218 pp

SAFETY PERFORMANCE AND ROBUSTNESS OF HEAVY VEHICLE AVCS

R. Jemonde Taylor, Paul Yih, J. Christen Gerdes

Dynamically, heavy trucks are inherently different than passenger cars. In addition to the increased rollover risk arising from an elevated center of gravity height, heavy trucks possess additional failure modes such as jackknifing and excessive trailer swing. As a response to these issues, significant research has been performed in the last three decades to establish safety metrics for heavy trucks based on dynamic testing. This research has had an impact on determining acceptable size and weight restrictions for heavy vehicles and on the actual design of heavy trucks for increased safety.
UCB-ITS-PRR-2005-15
April 2005, 30 pp

SAFETY ASSESSMENT OF ADVANCED VEHICLE CONTROL AND SAFETY SYSTEMS (AVCSS)

Ching-Yao Chan

With the advancement of technologies, a variety of vehicle control and safety products have become available in recent years. Based on this trend in AVCSS and the need to address its effects on safety, either on the fundamental level of driver acceptance and behaviors to the general level of overall transportation safety, we initiated this research project to look into one crucial issue of adopting and deploying advanced technologies into new vehicles or new

systems - the safety assessment of AVCSS. Once we developed the verification methods and the procedures for conducting safety assessment, we proposed to apply the methodology to a realistic system so that we can exercise our procedure to explore if there are other issues and problems that we have overlooked. For this purpose, we identified the planned Demonstration 2003 in San Diego, California as the case study for validating our approach. Our work in this project allowed us to form the tool sets needed for safety assessment, including hazard analysis, component evaluation, architecture definition, verification procedures. The availability of these tools and the familiarity of safety experts with the tools can enable the conduction of safety verification and assessment for future systems.
UCB-ITS-PRR-2005-19
April 2005, 106 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 presents a literature review on driver distraction, impairment and emergency reponse that supports the development of the Naturalistic Driver Model. The need for a driver model that integrates a wider range of natural driver activities is important for both the traffic engineering and human factors communities. The PADRIC naturalistic driver model is further developed by increasing the scope of simulation capabilities to lane-change maneuvers and emergency or impaired driving. Determining the structure and pattern of driving activities under emergency or impaired conditions is central to the extension of the naturalistic driver model.
UCB-ITS-PRR-2005-20
June 2005, 69 pp

Human Driver Model Development

Delphine Cody, Swekuang Tan, Aurelien Garcia

This report presents the continuation of the development of the PADRIC naturalistic driver model. The development consists of increasing the scope of simulation capabilities to lane change

maneuvers and the gathering of data for calibrating the car-following model that has already been implemented. The report first presents the development of the model architecture for integrating lane change maneuvers. It then focuses on the data collection methodology and its related shortcomings.
UCB-ITS-PRR-2005-21
June 2005, 88 pp

Demonstration of Automated Heavy-Duty Vehicles

Steven E. Shladover, Xiao-Yun Lu, Bongsob Song, Susan Dickey, Christopher Nowakowski, Adam Howell, Fanping Bu, David Marco, Han-Shue Tan, David Nelson

This report documents the development of experimental buses and trucks and their performance in testing the use of automation technologies. It first describes the host vehicle platforms chosen for automating buses and trucks. The report next describes the hardware and software modifications that were made to the production vehicles in order to give them automated driving capabilities. The performance that was achieved by the automation systems is then described, along with experimental data derived from testing the vehicles.
UCB-ITS-PRR-2005-23
June 2005, 459 pp

Fault Diagnosis and Safety Design of Automated Steering Controller and Electronic Control Unit (ECU) for Steering Actuator

Han-Shue Tan, Fanping Bu, Shiang-Lung Koo and Wei-Bin Zhang

BRT has demonstrated its effectiveness to be a portion of the 'backbone' of an integrated transit network. It has become an effective means for attracting non-traditional transit riders and therefore can help to reduce urban transportation needs and traffic congestion. Many California transit agencies are planning to deploy BRT and have considered the use of dedicated lanes for BRT to be a very attractive option as it is less affected by automobile traffic and therefore can provide raillike quality of service. In 1999, Caltrans generated a Caltrans Action Request (CAR) to request participation in the Bus Rapid Transit Project with VTA and other local transit providers. The future of BRT in California, as envisioned

by Caltrans, would include a system of coordinated transit infrastructure, equipment, and operations that will give preference to buses on local urban transportation systems and the High Occupancy Vehicles (HOVs) lanes at congested corridors. The goal of the BRT service is to attract riders from single-occupancy vehicles, which could result in congestion relief without major infrastructure expansion. In the long-term, the proposed project may integrate the currently separate local transportation systems and transit services (offered by multiple transit agencies in a region) to provide express transit services enabled by interconnectivity between local systems and the State highway HOV system. Under the Caltrans Action Request, a BRT research program is established. One of the elements of this program is "Development of Precision Docking Function for Bus Rapid transit (named 'Precision Docking' or BPD from hereon)".
UCB-ITS-PRR-2005-27
September 2005, 66 pp

Preparing the Way for Vehicle-Infrastructure Integration

Steven E. Shladover

Vehicle-Infrastructure Integration (VII) is one of the most important new national programs within the field of ITS, but until now it has been treated at the federal level as a deployment-oriented activity, without significant research elements. This report identifies some key research issues that need to be investigated in support of VII, in order to ensure that the VII concept and designs are as efficient and effective as possible and in order to produce the essential knowledge base that public agencies throughout the country can rely upon to make well-informed decisions about participating in the deployment of VII.
UCB-ITS-PRR-2005-31
November 2005, 25 pp

Investigation of Elderly Driver Safety and Comfort: In-Vehicle Intersection "Gap Acceptance Advisor" and Identifying Older Driver Needs

Benedicte Bougler et al.

Our work in Toyota GapAdvise is comprised of two interrelated elements: identify driving task challenges, and a pilot study on one

particular class of decision support system, an intersection gap advisor. From these elements, we have recommended countermeasures and potential design guidelines for the elderly driving population in the United States.

We performed our work in the following sequence of technical tasks, each corresponding to a section heading in this final report:

Determine Extent of Problem (Task 1). From crash databases and demographic data, we have determined the projected extent of the problem, extending from past work. From our synthesis and interpretation of data and publications, we have ranked causal factors.

Conduct Focus Group and Observational Analysis of Elderly Drivers (Task 2). Through focus groups and observing elderly drivers in their own vehicles, we have developed an understanding of the problems faced by elderly drivers.

Conduct Driving Experiments (Task 3). Using PATH instrumented vehicle and test intersection at the University of California, Berkeley's Richmond Field Station facility, we have performed in-vehicle experiments to characterize driver behaviors.

Recommend In-Vehicle Design (Task 4). From Tasks 1 - 3, we provide integrated recommendations, to include engineering constraints and design principles, from Tasks 1.
UCB-ITS-PRR-2005-36
November 2005, 197 pp

A Reliable Direct Drive for the Steering Wheel Column of Buses

Gabriel Eirea, Seth Sanders and Wei-Bin Zhang

The design of a direct drive actuation for the steering wheel in an automotive automatic steering application is considered here. The main goals of this design are: reliability and fault-tolerance, compact size and low weight, low cost, and adequate control performance.

The system proposed here consists of a permanent magnet (PM) motor whose rotor is attached to the steering wheel column (direct drive). The motor has 6 phases, arranged as two sets of 3-phase wye-connected windings. Each one of those sets is driven by an independent electronic inverter.

During normal operation, the 6 phases help to generate torque in a coordinated way. When a fault

is detected, the faulty set is disconnected, and the entire load is transferred to the other 3-phase set.

Some fault-detection and fault-isolation mechanisms are discussed, pondering their advantages and disadvantages.
UCB-ITS-PRR-2005-37
November 2005, 21 pp

EFFECTS OF TRAFFIC DENSITY ON COMMUNICATION REQUIREMENTS FOR COOPERATIVE INTERSECTION COLLISION AVOIDANCE SYSTEMS (CICAS)

Steven E. Shladover

Intersection collisions are difficult to mitigate or eliminate by use of ITS technologies for a variety of reasons. These include the complexity of the driving environment and of the driver decision making process at intersections, but also the difficulty of accurately detecting the movements of all potentially conflicting vehicles. Prior research by Calspan-Veridian Engineering (now part of General Dynamics) (1) showed the near impossibility of detecting the relevant information using vehicle-mounted sensor systems. Current research under the IDS program is revealing the challenges associated with detection using infrastructure-based sensor systems.

As our understanding of intersection crashes and the performance needs of intersection collision avoidance systems have been improving, so has the interest in cooperative system implementations. In these Cooperative Intersection Collision Avoidance Systems (CICAS), information detected by both vehicle- based and infrastructure-based sensors can be combined to produce better real-time knowledge of the dynamic "state map" of an intersection. Wireless communications between the vehicles and the infrastructure and among the vehicles makes it possible for each entity (every vehicle, as well as the intersection's traffic controller) to have complete intersection state map information, so that it can then use its own intelligence and threat assessment logic to determine whether to alert a driver to an impending hazardous condition.

In this report, Section 2 identifies the contents of the intersection state map, Section 3 sketches out the general architecture for information sharing among vehicles and the intersection infrastructure, and Section 4 defines the "worst case" traffic scenarios in which this information needs to be exchanged. This information is important in specifying the capacity of the wireless communication system that supports the information exchange. Although most operations will take place under much less demanding conditions, it is still important to ensure that the communication system can support operations under "worst case" conditions, so that intersection safety is not compromised then.
UCB-ITS-PWP-2005-1
March 2005, 12 pp

A MULTI-CHANNEL VANET PROVIDING CONCURRENT SAFETY AND COMMERCIAL SERVICES

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

One of the key goals of a vehicular ad-hoc network (VANET) is providing sufficient quality of service (QoS) for real-time safety applications while concurrently supporting commercial services. This paper proposes a multi-channel wireless communication architecture and protocol for the scenario where commercial services are provided by roadside infrastructure. This solution extends the IEEE 802.11 wireless LAN protocol to schedule periodic safety messages in a "safety channel". It explicitly supports concurrent non-time-critical communications in separate, non-safety "service channels". Further, it is shown that this arrangement maximizes service channel access time while maintaining the requisite QoS for safety applications. This paper concludes with simulations that confirm the attractive properties of this architecture and protocol.
UCB-ITS-PWP-2005-2
March 2005, 16 pp

REAL-TIME ESTIMATION OF A MARKOV PROCESS OVER A NOISY DIGITAL COMMUNICATION CHANNEL

Qing Xu, Raja Sengupta

We study the real-time estimation of a Markov process over a memoryless noisy digital communication channel. The goal of system design is to minimize the mean squared stimation error. We first show the optimal encoder and decoder can be memoryless in terms of the source symbols. We then prove the optimal encoder separates the real space with hyperplanes. In the case of the binary symmetric channel and scalar source, the optimal encoder can be a threshold. A recursive algorithm is given to jointly find a locally optimal encoder and decoder for the binary symmetric channel. For a memoryless Gaussian vector source and a binary symmetric channel, we show the optimal policy is to encode the principal component. We derive the minimum mean squared error as a function of the variance of source and the channel noise.
UCB-ITS-PWP-2005-3
November 2005, 26 pp

MEDIUM ACCESS CONTROL PROTOCOL DESIGN FOR VEHICLE-VEHICLE SAFETY MESSAGES

Qing Xu, Tony Mak, Jeff Ko, Raja Sengupta

We propose a Medium Access Control (MAC) protocol design for a vehicle to send safety messages to other vehicles. We develop a QoS model for safety messages consistent with the active safety systems literature. Each message has a range and useful lifetime. The QoS target is to have each message be received with high probability within its specified lifetime by each vehicle within its specified range. The protocol design is based on rapidly re-broadcasting each message multiple times within its lifetime in combination with the 802.11 DCF. This makes the design compatible with the emerging standards for DSRC. Six different design variations are proposed. We derive equations and develop a simulation tool to assess the performance of the designs. Using these we identify the best and most easily implemented of the designs. Design performance depends on the number of re-broadcasts, power, modulation, coding, and vehicular traffic volumes. We show that under certain assumptions on the loss probability tolerated by safety applications, the design is able to transport safety messages in vehicular ad-hoc networks.
UCB-ITS-PWP-2005-4
November 2005, 28 pp

TRAFFIC OPERATIONS

DESIGN, FIELD IMPLEMENTATION AND EVALUATION OF ADAPTIVE RAMP METERING ALGORITHMS

Roberto Horowitz, Adolf May, Alex Skabardonis, Pravin Varaiya, Michael Zhang, Gabriel Gomes, Laura Muñoz, Xiaotian Sun, Dengfeng Sun

The main objectives are (1) the design of improved freeway on-ramp metering strategies that make use of recent developments in traffic data collection, traffic simulation, and control theory, and (2) the testing of these methods on a 14-mile segment of Interstate 210 Westbound in southern California. To date, the major accomplishments of this project include (i) the development of a complete procedure for constructing and calibrating a microscopic freeway traffic model using the Vissim microsimulator, which was applied successfully to the full I-210 test site, (ii) a simulation study, using the calibrated Vissim I-210 model, comparing the fixed-rate, Percent Occupancy, and Alinea local ramp metering schemes, which showed that Alinea can improve freeway conditions when mainline occupancies are measured upstream of the on-ramp (as on I-210 and most California freeways), as well as when occupancy sensors are downstream of the on-ramp, (iii) development of computationally efficient macroscopic freeway traffic models, the Modified Cell Transmission Model (MCTM) and Switching-Mode Model (SMM), validation of these models on a 2-mile segment of I-210, and determination of observability and controllability properties of the SMM modes, (iv) design of a semi-automated method for calibrating the parameters of the MCTM and SMM, which, when applied to an MCTM representation of the full I-210 segment, was able to reproduce the approximate behavior of traffic congestion, yielding about 2% average error in the predicted Total Travel Time (TTT), and (v) development of a new technique for generating optimal coordinated ramp metering plans, which minimizes a TTT-like objective function. Simulation results for a macroscopic model

of the 14-mile I-210 segment have shown that the optimal plan predicts an 8.4% savings in TTT, with queue constraints, over the 5-hour peak period.

UCB-ITS-PRR-2005-2
January 2005, 183 pp

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

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

This report presents the results of Phase 2 of a multi-year research effort on "Field Investigation of Advanced Vehicle Reidentification Techniques and Detector Technologies." Phase I of this research was conducted under PATH MOU 3008. Phases I and II of this research extended previous PATH research by the authors on MOU 336 "Section-Related Measures of Traffic System Performance: Prototype Field Implementation." Phase II of this research continued development, field investigation and assessment of the latest technologies available for traffic detection and surveillance, for collecting more accurate traffic characteristics and traffic data necessary for Intelligent Transportation Systems (ITS) applications. The focus of Phase II of this research was to utilize fully instrumented freeway and signalized intersection sites in the California Advanced Transportation Management Systems Testbed in Southern California for field investigation of several emerging traffic sensor and detector technologies for vehicle reidentification (REID) purposes and real-time traffic performance measurement. As part of this project, a traffic detector and surveillance sub-testbed (TDS 2) on North I-405 in Irvine became operational in August 2002, and the ability to perform REID-based real-time traffic performance measurement in TDS 2, developed as part of this research, and including section travel times, traffic origins and destinations, and vehicle classification, was demonstrated on-line at the PATH Annual Meeting in October 2002. The very encouraging results obtained to date by developing and applying a vehicle reidentification approach for real-time traffic performance measurement suggest that further development, implementation and testing of this approach would clearly be of value.

UCB-ITS-PRR-2005-8
March 2005, 88 pp

Anonymous Vehicle Tracking for Real-Time Freeway and Arterial Street Performance Measurement

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

This research involved an important extension of existing field-implemented and tested PATH research by the authors on individual vehicle reidentification, to develop methods for assessing freeway and arterial (and transit) system performance for the Caltrans PeMS (Performance Measurement System). PeMS has been adopted by Caltrans as the standard tool for assessing freeway system performance, but lacks capabilities for assessing arterial and transit system performance, and strategies that combine freeways, arterials and/or transit and commercial vehicle fleets. It was shown that the research methodology of this project could directly address these limitations in PeMS. A systematic investigation was conducted of anonymous vehicle tracking using existing inductive loop detectors on both freeway and arterial street facilities combined with new, low-cost high-speed scanning detector cards (that were utilized by the authors in PATH TO 4122) to meet the needs of PeMS.

UCB-ITS-PRR-2005-9
March 2005, 78 pp

Development of the Capability-Enhanced PARAMICS Simulation Environment

Lianyu Chu, Henry Liu, Michael McNally, Will Recker

This report summarizes research work conducted under TO 4304 at the University of California, Irvine. Under this task order, the research team provided Caltrans with on-call direct support, technical guidance, and research related support. A series of Paramics plug-ins were developed and have been released to Caltrans. These plug-ins include actuated signal, multiple actuated signal timing plan, actuated signal coordination, detector data aggregator, ramp metering control, on-ramp queue override control, ALINEA ramp metering control, BOTTLENECK ramp metering control, SWARM Ramp metering control, and Freeway MOE. They complement the current Paramics simulation model and enhance its functionalities.

This report describes how we developed these plug-ins and the step-by-step procedure to use them. It can be used as user manuals.

UCB-ITS-PRR-2005-12
April 2005, 114 pp

Dynamic Path-Based Equilibrium Assignment With Microscopic Traffic Simulation

Henry Liu, Lianyu Chu, Will Recker

This report summarizes research work conducted under TO4158 at the California ATMS Testbed of the Institute of Transportation Studies at the University of California, Irvine. The specific research project conducted under this task order is to develop a path-based equilibrium assignment model with micro-simulator Paramics. Since off-the-shelf Paramics can only do the link-based assignment, no path information during the traffic assignment process is stored nor provided. This will bring difficulties in the ATMS evaluation particularly related to the route diversion because partial or full path information is needed to conduct this type of evaluation with Paramics. To overcome this difficulty, a path-based assignment model is developed using Paramics Application Programming Interfaces (API) functions. The model comprises the advantages of the analytical traffic assignment model and the good properties of the simulation tools, which can represent the real world more properly. Some key techniques, route choice plug-in, turn penalty consideration and methods of successive average, and etc., were applied in the model. The Paramics V4 was selected as the demonstration simulation tool. A real grid network in Tucson, Arizona, was designed to test the performance of the model, and the results showed that the model converged with the user equilibrium as expected.

UCB-ITS-PRR-2005-13
April 2005, 17 pp

Estimating and Validating Models of Microscopic Driver Behavior with Video Data

Alex Skabardonis

This report describes the enhancements to the video data collection of the Berkeley Highway Laboratory (BHL), a unique surveillance system on a section of I-80 freeway in the city of Emeryville. We also present the development of advanced machine vision algorithms to process the video data to generate vehicle trajectories. A pilot application of the BHL system produced trajectories of over 4700 vehicles. This is the largest dataset of vehicle trajectories on extended freeway segments. In addition, algorithms and software were developed for data analysis and visualization.

UCB-ITS-PRR-2005-14
April 2005, 43 pp

Mobile Traffic Management System Test Deployment

Jeffrey Brian Gerfen

The Mobile TMC and various field elements were developed for Caltrans Division of Research and Innovation (DRI) between 1994 and 2002. These systems were all designed to operate independent of one another to provide on-site traffic data collection, video surveillance, and traffic management functions to support Caltrans TMC operations. Cal Poly researchers integrated these systems and an off-the-shelf changeable message sign into a Mobile Transportation Management System (MTMS). This new and integrated system is capable of operation untethered from a fixed-site Transportation Management Center (TMC).

Two field tests were designed to test the field deployment capabilities of the new traffic management system. The first test utilized the new MTMS to support event management while the second test focused on supporting freeway operations. Both tests were conducted, each with different levels of technical success. The primary lesson learned from these tests regarding the operation of the Mobile TMC and deployable field elements in general is that simplicity of system setup and operation is paramount. ITS elements designed for quick field deployment must be extremely reliable, require minimal setup, and be simple to operate. Systems that do not have these attributes will frustrate operators and not meet the expectations of traffic managers.

UCB-ITS-PRR-2005-16
April 2005, 31 pp

Freeway Analysis Manual: Parts 1 and 2

Dolf May, Lannon Leiman

This Freeway Analysis Manual is intended for those who are responsible for understanding, analyzing, and evaluating the operations of freeways for planning, design, and operational improvements of such facilities. Freeway

analysis requires a creative person, knowledgeable in freeway analysis fundamentals, having good traffic data, and selecting appropriate analytical tools. The first part of this Manual attempts to cover the fundamentals of freeway analysis using a demand-supply analytical framework. Special attention is given to estimating capacity and origin-destination demands. A detailed example application of the demand-supply analytical framework is provided for a typical freeway situation. This part of the Manual concludes with a description of special situations that may be encountered and ways in which they can be analyzed. The second part of this Manual attempts to cover the study design and required traffic data for analyzing a freeway. This portion of the Manual begins with guidelines for establishing spatial and temporal limits of the freeway study area, the selection of appropriate analytical tool(s), and the identification of critical issues to be considered. Specific data requirements for freeway analysis are identified and described which include supply, demand, control, and performance data.
UCB-ITS-PRR-2005-17
April 2005, 70 pp

BERKELEY HIGHWAY LABORATORY PROJECT: FINAL REPORT

Dolf May, Randall Cayford, Lannon Leiman, Greg Merritt

This document serves as the final report for a project whose primary objectives have been to operate, maintain, enhance, and conduct research on the Berkeley Highway Laboratory (BHL) detector system. The project focused on five major areas of research: 1) Macroscopic freeway traffic performance measures; 2) Assessment and improvements of detector diagnostics; 3) Installation and testing of new BHL system at the California Center for Innovative Transportation (CCIT); 4) Maintaining and operating the BHL detector system; and, 5) Preliminary design of portable detector diagnostic tool.
UCB-ITS-PRR-2005-24
June 2005, 303 pp

ON-RAMP METERING EXPERIMENTS TO INCREASE FREEWAY MERGE CAPACITY

Michael J. Cassidy, Jittichai Rudjanakanoknad

In this report, the authors present observations of two freeway/on-ramp merges that indicate the mechanism that causes their ca-pacities to diminish when queues form just upstream. Using data from field experiments at one of the sites, the authors demonstrate that by responding to occupancies measured near the merge, ramp meter can effectively reverse this mechanism, or at least postpone its occurrence, thus generating higher merge capacities. Observations from the second site indicate that higher merge capacities can also be achieved using traffic control schemes that regulate inflows to the merge from the freeway shoulder lane.
UCB-ITS-PRR-2005-28
September 2005, 24 pp

A TOOL FOR THE INCORPORATION OF NON-RECURRENT CONGESTION COSTS OF FREEWAY ACCIDENTS IN PERFORMANCE MANAGEMENT

Will Recker, Younshik Chung, Tom Golob

In this research, we develop and apply an analytic procedure that estimates the amount of traffic congestion (vehicle hours of delay) that is caused by different types of accidents that occur on urban freeways in California. A key feature of this research is the development of a method to separate the non-recurrent delay from any recurrent delay that is present on the road at the time and place of a reported accident, in order to estimate the contribution of non-recurrent delay caused by the specific accident. Our analysis involves a case study of accidents that occurred on freeways in Orange County in 2001. The non-recurrent delay caused by the case study accidents is estimated based on inferred link speeds derived from loop data and a binary integer programming formulation to identify the temporal and spatial region affected by the accident. Computations of non-recurrent delay were successfully performed for 870 accidents that occurred on weekdays throughout the period of March through December 2001 on the six major Orange County non-toll freeways. A statistical model was estimated that describes non-recurrent delay as a function of day of week, time of day, weather, and the observable (e.g., from emergency calls and/or aerial or on-scene observation) characteristics of the accident.
UCB-ITS-PRR-2005-30
November 2005, 49 pp

DEVELOPING OPTIMAL PLANNING AND MANAGEMENT STRATEGIES FOR A ROBUST HIGHWAY SYSTEM

Yafeng Yin, Samer Madanat

The report attempts to deliver a proof of concept that optimal planning and management strategies can be formulated through applying robust optimization methodology such that limited resources could be allocated more rationally, and reliability of a highway network improved more efficiently.

The report focuses on two applications: the network design problem under demand uncertainty, and fleet allocation for freeway services patrols. Their corresponding decision-makings are formulated as several optimization models. By solving these models robust optimal strategies can be obtained. Numerical examples and simulation tests are presented to demonstrate the validity and usefulness of the proposed models.

The report has proved that through applying robust optimization methodology, robust optimal improvement strategies can be obtained to improve substantially the capacity of a highway system against high-consequence scenarios incurred by fluctuations in travel demand or irregular incidents.
UCB-ITS-PRR-2005-35
November 2005, 69 pp

TRANSIT OPERATIONS

ADVANCED BUS STOPS FOR BUS RAPID TRANSIT

Joy Dahlgren, Betsy Morris

This research had as its objective to determine what improvements at the Santa Clara Valley Transportation Authority's (VTA's) planned bus rapid transit (BRT) stops would be most valued by passengers. A second objective was to provide helpful information to other transit agencies that might wish to improve their bus stops. The study focused on determining passengers' and VTA staff perceptions and values, investigating potential improvements to bus stops, and matching VTA needs to potential improvements. The study found that the continual provision of accurate schedule information, cleaning, repair, and patrolling can perhaps better meet passen-gers' needs at bus stops than the utilization of latest technologies or the provision of stylish shelters.
UCB-ITS-PRR-2005-6
February 2005, 88 pp

TRANSIT SERVICE INTEGRATION PRACTICES: AN ASSESSMENT OF U.S. EXPERIENCES

Mark A. Miller, Larry S. Englisher, Rick Halvorsen, Bruce Kaplan

This report presents the results of its assessment of transit service integration practices in the United States. Initially, a review of the literature was performed that identified the various types of service integration policies that have been and are being implemented including infrastructure, schedule, information, fare payment and special events/emergency service integration. The review also revealed how the introduction of service integration policies are part of overall changes in transit properties' way of conducting business. The research then made use of a two-stage survey of transit agencies which have implemented specific practices. The initial survey cast a wide net to identify service integration practices across the country by about 100 agencies. The subsequent survey targeted specific examples of each type of practice and addressed the objectives of the practices, the agency responsible for promoting integration, the effectiveness of the practices, the measures of effectiveness, the barriers overcome and the lessons learned. Transit agencies that have implemented integration practices have been able to overcome barriers to coordination and integration and have made a number of trailblazing efforts. While there has been little formal evaluation of these practices by transit agencies, the predominant view is that transit integration supports the overall goals of the transit agency and provides substantial benefits to the customers. Data to support impact evaluation is limited; however several case studies were also conducted quantitatively and qualitatively as part of this project. Lessons learned and guiding principles are also provided.
UCB-ITS-PRR-2005-7
March 2005, 223 pp

HIGH COVERAGE POINT TO POINT TRANSIT (HCPPT): A NEW DESIGN CONCEPT AND SIMULATION - EVALUATION OF OPERATIONAL SCHEMES

R. Jayakrishnan, Cristian E. Cortes, Laia Pages, Riju Lavanya, Amelia C. Regan

This research proposes the development and evaluation of a new concept for high-coverage point-to-point transit systems (HCPPT). Overall, three major contributions can be identified as the core of this initial stage of the research: the proposed scheme design, the development of sophisticated routing rules that can be updated in real-time to implement and optimize the operation of such a design, and the implementation of a multi-purpose simulation platform in order to simulate and evaluate such a design under real network conditions. The design is based on Shuttle-style operations with a large number of deployed vehicles under a coordinated transit system that uses advanced information supply schemes with fast routing and optimization schemes. The system design is rather innovative and ensures that no more than one transfer is needed for the travelers, by using transfer hubs as well as reroutable and nonreroutable portions in the vehicles' travel plans. It yields flexibility for demand-side benefits from options such as price incentives for time-bound "passenger-pooling" at the stops without destination constraints, by the users. A strict optimization formulation and solution for such a problem is computationally prohibitive in real-time. The design proposed here is effectively geared towards a decomposed solution using detailed rules for achieving vehicle selection and route planning. If real-time update of probabilities based upon modeling the future dispatch decisions is included, then this scheme can be considered as a form of quasi-optimal predictive-adaptive control problem. Finally, a multi-purpose simulation platform is developed as part of this research in order to evaluate the performance of the system. The final simulations of HCPPT required point-to-point vehicle simulation, which is not possible with off-the-shelf simulators. The simulation framework uses a well-known microscopic traffic simulator that was significantly modified for demand-responsive vehicle movements and passenger tracking. A simulated case study in Orange County showed that with enough deployed vehicles, the system can be substantially better, even competitive with personal auto travel, compared to the often-unsuccessful traditional DRT systems and the existing fixed route public transit. Furthermore, HCPPT can be incrementally implemented by contracting out services to existing private operators.

UCB-ITS-PRR-2005-18
April 2005, 280 pp

SMARTBRT: A TOOL FOR SIMULATING, VISUALIZING, AND EVALUATING BUS RAPID TRANSIT SYSTEMS

Joel VanderWerf

This document presents an overview of the goals and achievements of the SmartBRT project. SmartBRT is a tool for modeling, simulating, and evaluating hypothetical traditional transit systems, and in particular, those one that are using bus rapid transit (BRT) technologies and policies. The document also contains links to the detailed documents and software produced by the SmartBRT project.

UCB-ITS-PRR-2005-26
August 2005, 150 pp

FAULT DIAGNOSIS AND SAFETY DESIGN OF AUTOMATED STEERING CONTROLLER AND ELECTRONIC CONTROL UNIT (ECU) FOR STEERING ACTUATOR

Han-Shue Tan, Fanping Bu, Shiang-Lung Koo and Wei-Bin Zhang

BRT has demonstrated its effectiveness to be a portion of the 'backbone' of an integrated transit network. It has become an effective means for attracting non-traditional transit riders and therefore can help to reduce urban transportation needs and traffic congestion. Many California transit agencies are planning to deploy BRT and have considered the use of dedicated lanes for BRT to be a very attractive option as it is less affected by automobile traffic and therefore can provide rail-like quality of service. In 1999, Caltrans generated a Caltrans Action Request (CAR) to request participation in the Bus Rapid Transit Project with VTA and other local transit providers. The future of BRT in California, as envisioned by Caltrans, would include a system of coordinated transit infrastructure, equipment, and operations that will give preference to buses on local urban transportation systems and the High Occupancy Vehicles (HOVs) lanes at congested corridors. The goal of the BRT service is to attract riders from single-occupancy vehicles, which could result in congestion relief without major infrastructure expansion. In the long-term, the proposed project may integrate the currently separate local transportation systems and transit services (offered by multiple transit agencies in a region) to provide express transit services enabled by interconnectivity between local systems and the State highway HOV system. Under the Caltrans Action Request, a BRT research program is established. One of the elements of this program is "Development of Precision Docking Function for Bus Rapid transit (named 'Precision Docking' or BPD from hereon)".

UCB-ITS-PRR-2005-27
September 2005, 66 pp

PRODUCTIVITY AND COST-EFFECTIVENESS OF DEMAND RESPONSIVE TRANSIT SYSTEMS

Maged M. Dessouky, Fernando Ordóñez, Luca Quadrifoglio

This research studies the impact on productivity and costs of two specific operating practices currently in used by demand responsive transit (DRT) systems. The first is the "time-window setting" in which the time range that the provider must pick up the customers is specified. The second practice is "zoning", a concept in which a number of DRT agencies divide their service area into regions, contracting the service in each of them to a different provider to simplify the management of the service. Historical demand data of a representative large-scale agency is analyzed. A simulation model used to represent the Los Angeles County DRT system is described. The analysis can be used by transit managers to understand and quantify the impact of changing either their zoning strategy or time window settings. The model is also considered to be applicable as a source for simulations on other DRT system environments.

UCB-ITS-PRR-2005-29
September 2005, 51 pp

AN ASSESSMENT OF OPPORTUNITIES FOR BUS RAPID TRANSIT IN THE SAN FRANCISCO BAY AREA

Mark A. Miller

This report presents the findings from an investigation of opportunities to implement bus rapid transit systems in the San Francisco Bay Area with a focus on bus transit routes that travel on the state's highway system. A primary component of this project has been the consideration of inter-connectivity and regional aspects of bus rapid transit systems deployment in the Bay Area. We examined approximately 200 bus transit routes in the Bay Area that lie on the state highway system from which five routes were identified as likely candidates for bus rapid transit implementation. Two of the five routes–VTA's Line 22 and SamTrans' Lines 390/391–were selected for follow-up case study analysis because they involve bus routes on the same roadway, SR 82, which includes not only multi-jurisdictional issues by including two counties and numerous local cities, but also two transit properties making this selection uniquely qualified to consider inter-connectivity and regional aspects of bus rapid transit systems deployment in the Bay Area. .

Bus rapid transit activities are underway along the SR 82 corridor in the context of two distinct enterprises corresponding to VTA's plans for the new route 522 in Santa Clara County and SamTrans' plans for enhancement to transit service for its Route 390 in San Mateo County. These two systems' primary connection point is the Palo Alto Transit Center for which enhancements are being planned. From a macroscopic perspective, the level of cross-county travel, both current and forecasted, does not now warrant development of a single and integrated BRT corridor between Santa Clara and San Mateo counties and into San Francisco County. Nonetheless, whether a single integrated corridor or two-system solution is eventually selected to satisfy levels of service needs, institutional cooperation and coordination is a continuing essential component to the transportation system along the peninsula of the Bay Area. We recommend that the two-system solution be maintained together with continued development of the Palo Alto Intermodal Transit Center while simultaneously initiating a comprehensive data collection effort together with an evaluation to fully understand the tradeoffs

between these two alternatives coupled with more accurately determining the level of inter-county demand.

A RELIABLE DIRECT DRIVE FOR THE STEERING WHEEL COLUMN OF BUSES

Gabriel Eirea, Seth Sanders and Wei-Bin Zhang

The design of a direct drive actuation for the steering wheel in an automotive automatic steering application is considered here. The main goals of this design are: reliability and fault-tolerance, compact size and low weight, low cost, and adequate control performance.

The system proposed here consists of a permanent magnet (PM) motor whose rotor is attached to the steering wheel column (direct drive). The motor has 6 phases, arranged as two sets of 3-phase wye-connected windings. Each one of those sets is driven by an independent electronic inverter.

During normal operation, the 6 phases help to generate torque in a coordinated way. When a fault is detected, the faulty set is disconnected, and the entire load is transferred to the other 3-phase set.

Some fault-detection and fault-isolation mechanisms are discussed, pondering their advantages and disadvantages.

POWER SYSTEM RELIABILITY FOR PRECISION DOCKING AND ELECTRONIC GUIDANCE SYSTEMS

Carsten Nesgaard, Seth Sanders and Wei-Bin Zhang

The power system is one of the most critical parts of almost any system. Due to the severe consequences of a guidance system failure in the application at hand it is of vital importance to ensure a stable and continuous output voltage to the subsequent systems. This report contributes to an identification of critical parts of the power system as well as to a classification of techniques for increasing the overall power system reliability.

To comply with the general guidelines of the UpTime Institute the input power has to come from at least two different and independent sources. This is a rather stringent requirement that limits its implementation to systems comprised of multiple power sources. In systems with only a single power source these guidelines are not applicable for which reason such systems cannot be classified as fault tolerant. However, even if the system cannot be classified as fault tolerant from a system point of view does not prevent it from being fault tolerant at a subsystem level. Furthermore, even though true fault tolerance might not be obtainable, improvements to the overall system reliability is still possible by means of different techniques.

In this particular application the failure rate of the battery is very low - meaning that the challenge in terms of reliability is the voltage conversions to the interconnected subsystems.

This report will provide an examination of the power system with intend to optimize reliability as well as overall system performance. The foundation of the analysis is a Functional Failure Modes Effects and Criticality Analysis (FFMECA) followed by a description of hardware redundancy implementations. The FFMECA is performed at a block level and indicates a prioritized criticality evaluation of each block.

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