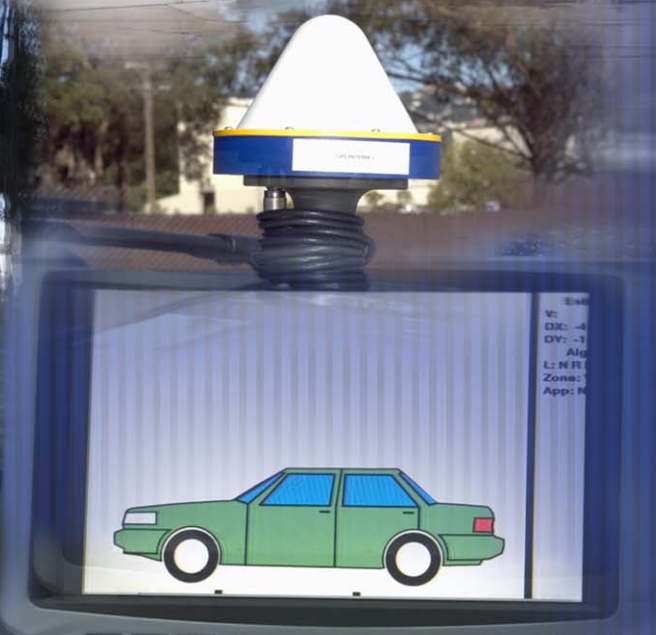


California PATH Annual Report 2004



California PATH

2004

Annual Report



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

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

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Director's Introduction

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

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

PATH is organized along four research programs:

- Traffic Operations
- Transit Operations
- Transportation Safety
- Policy and Behavior

In this year's annual report, we highlight many of the ongoing projects and new research thrusts in our four programs. Some developments in 2004 include:

- The Berkeley Highway Laboratory (developed by PATH and administered by the California Center for Innovative Transportation, CCIT) was selected as the preferred site for providing data to the Federal Highway Administration's NGSIM (Next Generation SIMulation) project, a national effort aimed at developing state of the art traffic simulators. PATH researchers, working with UC Berkeley faculty, are developing traffic models underlying these simulators.
- PATH researchers have made significant advances in the development and evaluation of Bus Rapid Transit Systems (BRT). The Federal Transit Administration recently awarded PATH a major research project for the development of Transit Signal Priority strategies for BRT applications.
- PATH researchers, working closely with UC Berkeley faculty and students, have demonstrated new concepts for Collision Avoidance through Wireless Communication between vehicles; this project was funded by a major automobile company, and promises to make significant improvements to Active Traffic Safety.
- A Field Operational Test (FOT) of PATH's Smart Parking research project was launched at the Rockridge BART station in Oakland. The results of this FOT will pave the way for possibly extending Smart Parking Technologies to other BART stations or other rail transit systems in the U.S.

Since becoming PATH Director in the summer of 2003, I have worked closely with many of its research and development staff, and have been tremendously impressed by the quality of their work. I am thrilled to be part of PATH and to have the opportunity to help shape its future.

Samer Madanat
California PATH Director

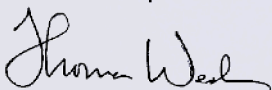
This has been an exciting year for the California Department of Transportation (Caltrans) and its research partners as we continue to develop new ways of doing business to better serve the people of California. Caltrans and its research partners have undergone dramatic changes to better meet the needs of our customers, and we are now beginning to see the dividends of that change. In my estimation, the level of positive engagement in research activities across Caltrans has never been greater, and examples of innovative projects, programs, and partnerships abound.

Working in partnership with the California Center for Innovation and the Partners for Advanced Transit and Highways (PATH), Caltrans sponsored the Call For Submissions (CFS) initiative and the Innovative Corridor Initiative. Both efforts are aimed at improving partnership with researchers and industry to accelerate the implementation of intelligent transportation products and services to improve transportation. This effort is a unique and innovative way of doing business to improve both the research and its successful implementation. While this is a long-term effort, a short-term milestone will be the launch of many new transportation innovations during the 2005 ITS World Congress in San Francisco. This international event will attract more than 10,000 professional from all over the world.

Caltrans is working with PATH on several projects that have direct impact on our transportation infrastructure. In a project that combines efforts at UC Berkeley, UC Irvine, and UC Davis, we are investigating the use of Virtual Weigh in Motion and ultimately Virtual Weigh in Compliance Stations to encourage compliance with existing weight and related regulations. This will have two primary goals, 1) reducing the number of overweight vehicles thus reducing damage to the infrastructure and 2) encouraging commercial vehicle operators to maintain safe and legal speeds thereby reducing the number and severity of accidents involving commercial vehicles. As a small part of this effort, Caltrans is partnering with PATH and several existing and potential vendors to demonstrate the state of the technology of Weigh in Motion at the 2005 ITS World Congress in San Francisco.

Caltrans, in conjunction with the UC Berkeley ITS Technology Transfer group, has been partnering with the Federal Highway Administration (FHWA) to conduct ITS training classes throughout California by targeting both Caltrans and local government partner employees. Caltrans has already presented classes covering Fundamentals of Systems Engineering for ITS Projects, Developing and Maintaining Your Regional ITS Architecture, and Using Your Regional ITS Architecture. Future planned classes include Development of a Concept of Operations, Requirements Management, and Configuration Management. The Fundamentals of Systems Engineering class is currently being updated to harmonize with the recently completed and published Systems Engineering Guidebook for ITS Projects, sponsored by Caltrans and the FHWA. Caltrans and PATH are actively working to incorporate the full Systems Engineering Process into many research projects.

These few examples exemplify the great work that results from our strong partnership. I am confident that together we will continue to build innovative partnerships, deploy exceptional research, and provide even greater choices for California's traveling public.



Thomas West
Acting Division Chief
Division of Research and Innovation



A Word from Caltrans

California PATH Program

Overview

The California Partners for Advanced Transit and Highways (PATH) Program has been leading the way in ITS (Intelligent Transportation Systems) research since PATH's founding in 1986, before the term ITS or its predecessor IVHS (Intelligent Vehicle Highway Systems) had even been coined. PATH's purpose is to develop foundations for the widespread adoption of advanced technologies that will improve the operation of California's surface transportation systems. PATH'S primary goals are to reduce traffic congestion and improve traffic safety. By succeeding at these, we also expect to help reduce travel stress, pollution, and energy consumption, and contribute to enhancing the strength of California's economy.

Caltrans provides the seed funding for PATH's core research, based on its goal of promoting the development of new knowledge and new technology that can improve the productivity, safety, and environmental impacts of California's surface transportation systems.

PATH's charter includes the missions of conducting leading-edge research, evaluating and conducting field operational tests, developing public/private/academic partnerships, and educating students as well as practitioners about ITS.

PATH's mission is to develop solutions to the problems of California's surface transportation systems through cutting edge research. PATH develops these solutions by harnessing the knowledge of transportation researchers, working in conjunctions with experts in the fields of information technology, electrical engineering, mechanical engineering, economics, transportation policy and behavioral studies. The PATH charter includes conducting leading research, planning and evaluating field operational tests, developing partnerships between academia, the public sector and private companies, and educating both students and practitioners. Research and development done under PATH auspices include:

- identification of problems and needs
- basic research on enabling technologies
- applied technology research and development
- system-level design and evaluation
- experimental verification of design predictions
- evaluations of existing technologies or equipment
- evaluations of costs and benefits
- technology assessments
- predictions of users' behavioral responses
- predictions of the impacts of technologies' use
- evaluations of legal and institutional issues.

PATH is managed by the Institute of Transportation Studies of the University of California at Berkeley, which established the PATH Program Headquarters Office at the University's Richmond Field Station in 1986.

Policy issues are addressed by the PATH Executive Committee, composed of representatives of the primary participating universities, and by the Caltrans-PATH Joint Management Team, composed of program managers from both Caltrans and the University. PATH's day-to-day operations are managed by the headquarters staff.

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



State-Funded Core Program of ITS Research

The core of the PATH program is its collection of research projects funded by Caltrans' Division of Research and Innovation. Currently there are about 60 such projects, selected on the basis of an annual Request for Proposals (RFP) and proposals submitted from throughout California. These involve the work of about 35 professors, representing 12 academic departments on 14 different university campuses, supervising the research of more than 90 graduate students and post-doctoral researchers. Projects are currently being conducted at: UC Berkeley, UC Davis, UC Irvine, UC Riverside, UC Santa Barbara, UC San Francisco, California Polytechnic State University at San Luis Obispo, California State University San José, Ohio State University, San Diego State University, Stanford University, University of Texas, Texas Tech, Utah State University and the University of Southern California.

PATH Activities in National ITS Programs

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

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

Other projects

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

- A simulation and visualization model for evaluation of Bus Rapid Transit Systems (SmartBRT), under the joint sponsorship of the Federal Transit Administration and Caltrans.
- Development and evaluation of a variety of technologies for Bus Rapid Transit, under Caltrans sponsorship.
- New technology approaches for railroad crossing warnings at uncontrolled crossings in the San Joaquin Valley, under sponsorship of the Caltrans Division of Rail.
- A precision automatic steering control system for a Caltrans rotary snow blower, under the sponsorship of Caltrans' Advanced Highway Maintenance and Construction Technology program (AHMCT).
- Testing Base Flap on Class 1 Tractor Trailer
- Integrated Multichannel Vehicle-Vehicle and Vehicle-Roadside Communications for ITS.
- Cooperative Collision Warning: Enabling Crashless Cars with Wireless Technology.
- Prototype Data Collection and Model Development: Next Generation Simulation.
- Radio Frequency ID Tags to Enhance Safety.
- Assessment of Bus Rapid Transit Opportunities in the San Francisco Bay Area.
- Improving BART Connectivity and Access with the Segway Human Transporter.

Policy and Behavioral Research

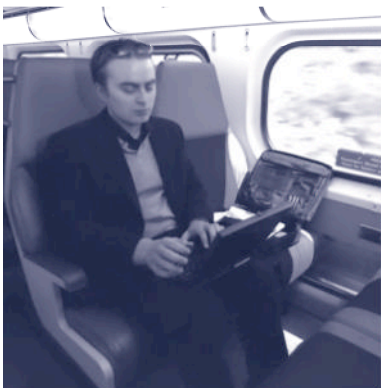
Susan Shaheen, Program Leader

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: hydrogen transportation applications for the State and Caltrans, wireless Internet access on trains, ITS solutions to goods movement, innovative strategies to enhance transit services and increase ridership, smart parking, measuring the impact of graduated licensing laws in California, planning for Caltrans' Innovative Corridors Initiative, and assessment of Caltrans' communication needs and solutions.

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

- ***Innovative Corridors Initiative/2005 ITS World Congress*** (TO 4151). California's Innovative Corridors Initiative (ICI) is developing a unique partnership between government and private industry that is designed to break through some of the challenges to ITS deployment. The collaboration among Caltrans, the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area, and the Los Angeles Metropolitan Transportation Authority (MTA), and the California Center for Innovative Transportation (CCIT) offers a new ventures model to public and private partners. Early lessons learned include: 1) concurrence on the vision and goals at the highest levels within the public agencies is critical; 2) early partnership building and key player involvement in projects is important for successful collaboration; 3) allowing adequate time for public outreach and for questions and answers is essential for gaining participant involvement; 4) it is important to define project proposer and public agency responsibilities early, as it is difficult to anticipate what expertise will be necessary; 5) the nature of the ICI project is unique from standard requests for proposal projects, which requires new processes to support a new relationship with industry; 6) the call for submittals (CFS) process as part of the ICI has been successful in identifying numerous ITS innovations that could benefit the traveling public; and 7) the CFS appears to have opened a process of creating stronger linkages between government and industry that should allow the exchange of information and sharing of resources and expertise in a manner that will improve transportation management.
- ***Assistance to Caltrans for Assessment of Communication Needs and Solutions*** (TO 4133) focused on identifying optimal software solutions to Caltrans' practical problems, using state-of-the-art network and communication technologies.
- Key findings from the ***Institutional Approaches for Interjurisdictional System Management*** project (TO 4155) include: project leadership and communication represent two key needs for ITS project success; however, these typically can only



be controlled in forming the project team rather than crafting an interjurisdictional agreement. The interjurisdictional agreement's primary purpose is to clearly specify the roles of different participants. Memoranda of Understanding are the most common form of agreement, but at different stages they may no longer be the best choice for the interjurisdictional agreement.

- **Smart Parking Field Operational Test Planning** (TO 4305). As part of this study, researchers implemented a survey and conducted focus groups. It was found that a potential market exists for a daily paid parking information service among current and new riders with relatively high incomes, high auto availability, and variable work locations and schedules. Further, the current Bay Area Rapid Transit (BART) District monthly reserved paid parking service may have increased the frequency of BART use among subscribers, but it had not reduced net auto travel because of diversions to BART from carpool, bus, and bike modes for their main commute and increased drive alone access to the BART station. A smart parking field test (including reservations, in-ground parking sensors, and changeable message signs) at the Rockridge BART station was planned and launched on December 8, 2004, based on the feasibility results of this study.

Assistance to Caltrans for Assessment of Communication Needs and Solutions, TO 4133, C. Arthur MacCarley, California Polytechnic University, San Luis Obispo.

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.

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

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

Institutional Approaches for Interjurisdictional System Management, TO 4155, Michael McNally, University of California, Irvine and Stephen Mattingly, University of Texas, Arlington.

ITS Solutions to I-710 Corridor Challenges, TO 5105, Amelia Regan, University of California, Irvine.

Smart Parking Field Operational Test Planning, TO 4305, Susan Shaheen, California PATH.

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

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.

Clean Hydrogen for Transportation Applications, TO 5107, Daniel Sperling, University of California, Davis.

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.

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.

Spatial and Temporal Utility Modeling to Increase Transit Ridership, TO 5102, Richard Church and Michael Goodchild, University of California, Santa Barbara.



Transportation Safety

Jim Misener, Program Leader

Transportation Safety research at PATH stems from 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 (to include design, hardware/software development and integration, human-machine interface, then test and evaluation).

Specific project groupings are:

- Intersections and Cooperative Systems – crossing path vehicle crashes, safety aspects of cooperative driver-assist systems, emergent AASHTO and US DOT Vehicle Infrastructure Integration (VII) program
- 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 2004, a wide range of PATH transportation safety research accomplishments were realized. First and foremost, we have continued to transform the technical skills and research interest of research staff and affiliated faculty and students to problems of interest to Caltrans and other sponsors. Hence, our vehicle-oriented researchers are investigating snow removal equipment safety or performing research sponsored by vehicle manufacturers, some of our device-oriented researchers are working on pedestrian detection and warning, and our human factors / vision science researchers are working on areas of work zone safety and driver modeling. Finally, we continue a large multidisciplinary project on intersection safety, Intersection Decision Support, which will transform into a nation project entitled Cooperative Intersection Collision Avoidance Systems.

Specific accomplishments this past year include:

- Control of automated snowblower centimeters from the guard rail
- Significant observational studies to characterize driver behavior at intersections, and a subsequent effort in developing an intersection alert algorithm
- Demonstration of intersection safety with transit buses, showing synergism between two PATH research programs



Intersections and Cooperative Systems Employee Safety

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.

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

Driver Behavior

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

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.

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.

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.



Traffic Operations

Alex Skabardonis, Program Leader

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

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

A new wireless MEMS has been developed and being tested that potentially replaces loop detectors and other conventional sensor systems (TO 5301). Under FHWA sponsorship, the machine vision algorithms for vehicle tracking from video data collection were enhanced and applied to produce the most detailed data set of vehicle trajectories for studying driver behavior and traffic dynamics on freeways. This data set is available worldwide as part of the Next Generation of Traffic Simulation Models (NGSIM) project.

Work continues on the Performance Measurement System (PeMS), which has been deployed statewide and covers all the areas of the State with surveillance systems. New analytical capabilities include algorithms for bottleneck identification, lane closure planning, and estimation of congestion causes and impacts (TO 5306). A pilot implementation of PeMS on arterial streets (APeMS) is also underway in cooperation with the Los Angeles DOT to provide estimates of delays and travel times from real-time detector and signal control data (RTA 20861).

Several enhancements to microscopic simulation models were developed and tested in real-world environments. These enhancements include Application Program Interfaces (APIs) to widely used microsimulation models such as PARAMICS to better model ramp metering and adaptive signal control (TO 5305, 5311), and modeling frameworks for simulating large networks (TO 5310). Work is in progress to develop guidelines and analysis tools for calibration of microscopic simulation models (TO 5308).

Improved ramp metering strategies have been developed and field tested (TO 5312). The results from the field experiments show that the proposed strategies are effective in alleviating bottlenecks at freeway merging areas. Work is in progress on developing a system that facilitates the coordination of operating agencies to minimize the response time to incidents (TO 5313).



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.

New Detector Technologies

Low-Cost Vehicle Detection and Communication Systems for Freeways, Intersections and Parking Lots, TO 5301, Pravin Varaiya, University of California, Berkeley.

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; Chao Chen, University of California, Berkeley.

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, James Banks, San Diego State University.

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.

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.

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, R. Jayakrishnan, University of California, Irvine.

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

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.

On Ramp Metering Experiments to Increase Freeway Merge Capacity, TO 5312, Michael Cassidy, University of California, Berkeley.

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.

Transit Operations

Wei-Bin Zhang, Program Leader

We emphasize new service concepts, methods and ITS technologies for innovating, enhancing and improving transit solutions with a goal that an enhanced public transit system will provide transportation choices that ultimately help to reduce traffic congestion. PATH researchers are working closely with transit agencies across and outside of California to address real world problems and bring in advanced yet practical solutions. In 2004 the PATH transit program embraced the following research areas in the Task Order (TO) 4000 series, RTA's or outside funding sources:

- We continues devote significant efforts in the area of Bus Rapid Transit (BRT) investigating issues related to enabling technologies, evaluation and deployment planning. Based on knowledge gained through a number of BRT planning projects, PATH is studying issues related to integrated BRT deployment planning issue and is developing a BRT information clearinghouse. Following the initial concept development of adaptive signal priority system (ATSP), PATH has conducted field testing of ATSP demonstrating the ability to enable buses to gain priority at the intersection while minimizing the disturbance to other traffic. PATH is currently investigating deployment aspects of ATSP.
- Multimodal and connection service is the key for transit service with other traffic. but have been less cost effective for the transit agencies to operate. PATH studies address factors influencing productivity and operating cost of DRT and develop approaches for improving cost effectiveness.
- Demand Responsive Transit (DRT) and Paratransit provide critical links for transit dependent riders to gain mobility, but have been less cost effective for the transit agencies to operate. PATH studies address factors influencing productivity and operating cost of DRT and develop approaches for improving cost effectiveness.
- Transit safety is continuous an initiative by the US Department of Transportation to improve transit safety. Under the sponsorship of Federal Transit Administration, PATH is working with transit agencies, Caltrans and bus manufacturer and suppliers to develop requirement specifications for a frontal collision warning system.



Bus Rapid Transit

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, Steven Shladover and Mark Miller, California PATH.

Transit Safety, Vehicle Assist and Automation

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

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

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

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

Multimodal and Connectivity

A Combined Quantitative and Qualitative Approach to Planning for Improved Intermodal Connectivity at California Airports, TO 5406, Xiaoyun Lu, California PATH.

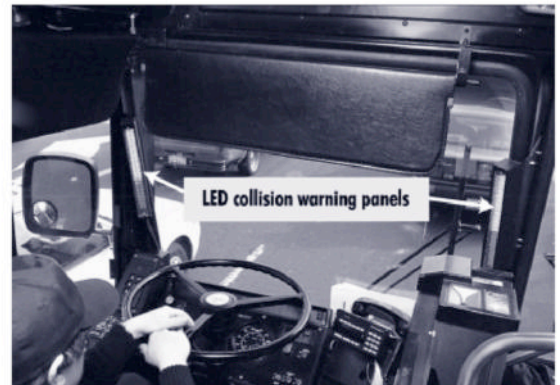
Improving Mobility through Enhanced Transit Services TO 5408, Mike Cassidy, University of California, Berkeley.

Productivity and Cost Effectiveness of Demand Responsive Transit Systems, TO 5401, Maged Dessouky, Fernando Ordonez, University of Southern California.

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.

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



Micro-simulation Modeling Approach to Applications of On-line Simulation and Data Fusion

Lianyu Chu, Will Recker

This report focuses on how microscopic simulation, such as PARAMICS, can be used as a tool for on-line simulation and data fusion studies under a traffic system with various Intelligent Transportation Systems (ITS) components. The report describes the development of the capability-enhanced PARAMICS simulation environment through API programming. A general approach for calibrating and validating microscopic simulation models is proposed. An example calibration study under PARAMICS environment is provided. The report explains how the capabilities of PARAMICS is enhanced in order to make it fit the needs of on-line simulation. The report concludes with a discussion regarding the development of a data fusion algorithm that can provide a better estimation of section travel time.

UCB-ITS-PRR-2004-1
January 2004, 72 pp

A Mobile Platform for Roadway Incident Documentation

Ray J. Su, Ching-Yao Chan

In this report, the authors describe the development process of an application tool intended for use by law enforcement officers, and targeted for information gathering at traffic accident scenes. The concept involves a portable computer with an architecture encompassing a collection of mobile platforms, with versatile software, wireless communications, and database functionality. Potential benefits from using this tool include: reduction in incident documentation time, faster scene restoration and traffic resumption, and reduced congestion caused by roadway incidents or collisions.

UCB-ITS-PRR-2004-2
January 2004, 52 pp

Analysis and Documentation of Roadway Incident Using Software and Photogrammetric Techniques

Ray J. Su, Ching-Yao Chan

In this report, the authors describe the investigation and development of a compute software application using photogrammetric techniques for facilitating the measurement of roadway incident scenes. The software allows the user to take one or a few photographs and extract all needed measurements in the convenience of an office, thus alleviating the burdens of on-site measurements. The method is advantageous in that it is non-contact, allowing the incident scene to be undisturbed.

UCB-ITS-PRR-2004-3
January 2004, 27 pp

Calibration of VISSIM for a Congested Freeway

Gabriel Gomes, Adolf May, Roberto Horowitz

A procedure for constructing and calibrating a detailed model of a freeway using VISSIM is presented and applied to a 15-mile stretch of I-210 West in Pasadena, California. This test site provides several challenges for microscopic modeling: an HOV lane with an intermittent barrier, a heavy freeway connector, 20 metered onramps with and without HOV bypass lanes, and three interacting bottlenecks. Field data used as input to the model was compiled from two separate sources: loop-detectors on the onramps and mainline (PeMS), and a manual survey of onramps and offramps. Gaps in both sources made it necessary to use a composite data set, constructed from several typical days. FREQ was used as an intermediate tool to generate a set of OD matrices from the assembled boundary flows. The model construction procedure consisted of: 1) identification of important geometric features, 2) collection and processing of traffic data, 3) analysis of the mainline data to identify recurring bottlenecks, 4) VISSIM coding, and 5) calibration based on observations from 3). A qualitative set of goals was established for the calibration. These were met with relatively few modifications to VISSIM's driver behavior parameters (CC-parameters).

UCB-ITS-PRR-2004-4
March 2004, 46 pp.

Travel Times on Changeable Message Signs: Pilot Project

Chao Chen

We describe a system to display real time travel times on Changeable Message Signs (CMS) in California. CMS's show dynamic information and allow the Traffic Management Center (TMC) to communicate to drivers information about traffic diversion, incidents, and delays. This type of service is deployed in other parts of the country and world and has been shown to be useful for this project, we implemented a system that uses existing algorithms for travel time estimation and prediction.

UCB-ITS-PRR-2004-5
March 2004, 41 pp

Fault Tolerant Lateral Control for Transit Buses and Trucks

Shashikanth Suryanarayanan, Tesheng Hsiao, Masayoshi Tomizuka

In this report, we develop procedures for the design of vehicle lateral control systems for automated vehicles that are insensitive to "hard" failures of magnetometers. The design methods may apply to various types of candidate vehicles for automated highway applications such as passenger vehicles, transit buses and trucks. First, the

problem of design of failure tolerant controllers is formulated as a simultaneous stability problem, i.e. given a finite number of LTI systems which respectively represent the vehicle under consideration operating in the normal and faulty conditions, design a controller such that the controller can stabilize all these given LTI systems while a performance criterion related to the normal operation is minimized. We reduce this problem to a standard H_{∞} control problem with Linear Matrix Inequality (LMI). It however suffers from the limitation of being conservative because it is based on only sufficient conditions for simultaneous stability. Next, we consider the problem of accommodating a specific type of failure in one of two sensors used for controlling a two-output system. We propose a dedicated observer-based fault tolerant control system which is built on a Fault Detection and Identification (FDI) mechanism. This control strategy is less conservative; however it is argued that the limitation of the dedicated observer based scheme is its heavy dependence on the model used to describe the system. The strategies developed above are tested on the test vehicles used by the Partners for Advanced Transit on Highways (PATH). Experimental results demonstrating failure tolerant control action are documented.

UCB-ITS-PRR-2004-6
April 2004, 64 pp

Detection and Avoidance of Collisions: the REACT Model

Craig Sauer, George J. Andersen, Asad Saidpour

An important perceptual task during driving is the ability to detect and avoid collisions. Failure to accurately perform this task can have serious consequences for the driver and passengers. The present research developed and tested a model of car following by human drivers, as part of a general model under development of a human driver. Unlike other car following models that are based on 3D parameters (e.g., range or distance) the present model is based on the visual information available to the driver. The model uses visual angle and change in visual angle to regulate speed during car following. Human factors experiments in a driving simulator examined performance in car following to speed variations defined by sine wave oscillations in speed, sum of sine wave oscillations, and ramp function. In addition, using real world driving data the model was applied to 6 driving events. The model provided a good fit to car following performance in the driving simulation studies as well as the real-world driving data, accounting for up to 96% of the variability in speed for the real world driving events.

UCB-ITS-PRR-2004-7
April 2004, 27 pp

Assessment of MeMS Sensors in an Urban Traffic Environment

Pravin Varaiya

The objective of this “innovative new research topics” proposal was to investigate the potential of a vehicle detection system that combines an acoustic or magnetic sensor, a micro-processor, a radio, and a battery. If such a system is feasible, it would be a low-cost, flexible alternative to loop detection systems. The wireless sensor system could be installed in a few minutes, without the expensive loop installation that requires cutting the pavement, power and loop cabling, and extended traffic disruption. Four tasks were proposed: (1) detecting a stationary vehicle, (2) detecting a moving vehicle, (3) detecting a string of vehicles, and (4) developing a networking protocol. Successful completion of these tasks would constitute evidence that the concept is worthy of further research and development effort. All four tasks have been completed with results that exceed our prior expectations. Indeed the work done has been carried much further.

UCB-ITS-PRR-2004-8
April 2004, 19 pp

Freeway Performance Measurement System (PeMS), Version 3 Phase II

Pravin Varaiya

Task 1, developed and implemented an algorithm that quantifies potential travel time reduction. The algorithm takes historical travel demand data from PeMS. It simulates the resulting traffic flow, based on an idealized ramp-metering algorithm, and calculates the resulting travel times on the freeway and waiting time at the ramps. Task 2, developed an algorithm for travel time predictions for Los Angeles, and made it available on the PeMS website. Users could select any two points on the freeway network, and state a departure (or desired arrival) time. The algorithm finds the 15 shortest alternative travel routes and estimates a travel time for each. The user could select any of these routes. Task 3, preparation and presentation of PeMS training material. Task 4 developed a clearly defined maintenance procedure and a very stable system.

UCB-ITS-PRR-2004-9
April 2004, 67 pp

Cooperative Multiple-Sensor Fusion for Automated Vehicle Control

J. K. Hedrick, J. Jang, A. Potier

The number and quality of sensors available for both on-board vehicle and infrastructure-based sensing is increasing while the cost of these sensors is rapidly decreasing. On-board vehicle

sensors can be utilized for both individual vehicle safety as well as automated vehicle control. It is becoming imperative that “fusion” techniques be developed, i.e., methods to combine the wide variety of sensors available so that reliable and accurate information can be obtained even though individual sensors may fail or become extremely noisy. The process of sensor fusion combines multiple sensor measurements in order to provide an accurate and coherent view of the vehicle and its environment. The objective of this project was to investigate sensor fusion methods for automated vehicle control. The focus of the first year was to complete the development and implementation of a modular sensor fusion architecture for longitudinal vehicle control in platoon formation. The sensor models, closed-loop vehicle models, and mathematical framework were then programmed and simulated with the use of MATLAB/Simulink in order to analyze the performance of the proposed system. Longitudinal control of vehicles in leader-follower mode is simple to implement and requires small computational resources. Lateral control, however, is more difficult to achieve due to the non-linear equations of motion governed by the vehicle dynamics. The PDA method can then be applied to the expanded, three-dimensional vehicle model to obtain fused estimates for the lateral and angular states. Additional sensors, such as magnetic road markers embedded in certain freeways, DGPS, and accelerometers, can also be used to achieve lateral control. Sensor fault diagnostic systems are discussed for future investigation. To increase accuracy of target tracking, IMM algorithm was applied to three cases, i.e. longitudinally moving target tracking under no measurement noise, longitudinally moving target tracking under measurement noise, and longitudinal / lateral moving target tracking under measurement noise. The IMM algorithm reduces the RMS position error by more than 65 % as well as indicates the current mode of a target with probability. The final estimate which is fused using the measurements from three sensors, two radars and one lidar, reduces the RMS position error by 80%. Even though the degree of error reduction depends on the choice of the process noise matrix that is determined by the maximum acceleration of the vehicle, the IMM algorithm and sensor fusion technique would improve the target tracking performance.

UCB-ITS-PRR-2004-10
April 2004, 66 pp

Assessing the Value of TMCs and Methods to Evaluate the Long Term Effects of ITS Implementation: A General Equilibrium Approach

David Gillen

The important contributions of this work are not only providing methods for calculating benefits and costs but also an empirical assessment of the set of projects that have been implemented. In all of this work, as well as most other project evaluation studies, two strong assumptions are made. First, the project is implemented successfully and second the impact of the transportation project is felt wholly within the transportation choice sets of consumers and producers. In the first of these assumptions, a project could potentially be declared unsuccessful when the technology may in fact be quite appropriate and potentially provide significant benefits, but the way it was implemented may have lessened some of the potential benefits. The study of implementation is one of understanding processes and how people integrate with new methods and technologies.

UCB-ITS-PRR-2004-11
April 2004, 17 pp

Personalized Demand-Responsive Transit Service

Randall Cayford, Y.B. Youngbin Yim

Providing easy access to the public transit service is the goal of the California transit agencies. Many travelers cannot take an express transit because they often cannot park and ride. Smart DRT (demand responsive transit) Feeder is a system that collects transit riders from neighborhoods and takes them to transit stations. This system will use APTS (Advanced Public Transit System) technologies to make the feeder service convenient and reliable. The concept is very simple. When demand is high, Smart Feeder will use the fixed-route fixed schedule service. When demand is low, it will use the on-demand service. For the on-demand service, customers will use an automated dial-a-ride system or the Internet for making a reservation or receiving a confirmation. Feeder vehicles will be equipped with Automated Vehicle Location (AVL) and on-board wireless computer devices. The first part of this paper describes the results of a user survey on the demand for and on the desired characteristics of a Smart Feeder system for the city of Millbrae. The second part of the paper describes the resulting design and implementation of the automated dial-a-ride system that will be used for the demand responsive transit service. The system uses an automated phone-in system for reservations, computerized dispatching over a wireless communication channel to the bus driver, and an automated callback system for cus-

tomers notifications. User requests for pickup are collected and a computerized scheduling system acts as a broker between the multiple user requests and the transit agency to determine the optimal departure time and route that minimizes customer wait time and maximizes the number of passengers per trip. The system requires no dispatchers and operates in real time without requiring advance reservations.

UCB-ITS-PRR-2004-12
April 2004, 34 pp

Automatic Diagnostics of Loop Detectors and the Data Collection System in the Berkeley Highway Lab

Adolf May, Benjamin Coifman, Randall Cayford, Greg Merritt

This document is the final report for the 2003 Berkeley Highway Laboratory (BHL) project that is part of the University of California's PATH program and supported by the California Department of Transportation (Caltrans). The primary objectives of this project have been to maintain, improve, and conduct research on the BHL detector system. This report contains seven chapters that describe the work undertaken and the results of each task of the project. The first chapter introduces the project, provides a project background, and a site description. The next five chapters describe the various tasks of the project including task objective, process followed, and results. The last chapter contains a summary of major accomplishments and identifies future research directions.

UCB-ITS-PRR-2004-13
April 2004, 60 pp

Development of Requirement Specifications for Transit Frontal Collision Warning System

Xiqin Wang, Joanne Chang, Ching-Yao Chan, Scott Johnston, Kun Zhou, Aaron Steinfeld, Matt Hanson, Wei-Bin Zhang

Bus transit systems need to use all the tools at their disposal to enhance the public perception of the desirability of their service, including its safety. Although bus transit is already a very safe mode of travel, more can be done to help bus drivers avoid crashes and the near-misses that may require them to brake suddenly. This project has explored how ITS technologies can be used to help avoid frontal collisions (collisions with other vehicles or objects located ahead of the bus). The project has followed a system engineering approach, beginning with a definition of the problem, preliminary identification of the requirements, preliminary design, testing and evaluation, and then several iterations of redesign and re-evaluation to refine the system and to lead toward the definition of a system specification. The safety chal-

allenges posed by frontal crashes have been defined first, based on a literature review, analysis of the safety records of a group of California transit properties, and then an extensive program of data collection on buses serving San Mateo County, CA. Based on the knowledge gained from this information, three generations of frontal collision warning systems have been developed and tested in daily use by bus drivers, with refinements to the designs incorporated at each generation based on the reactions of the drivers. Finally, the results of this work led to the definition of a preliminary specification for a frontal collision warning system to be field tested in wider use.
UCB-ITS-PRR-2004-14
May 2004, 182 pp

Control of Heavy-Duty Trucks: Environmental and Fuel Economy Considerations

Jianlong Zhang, Petros Ioannou

In this project we investigate the effect of heavy-duty trucks, equipped with different Adaptive Cruise Control (ACC) systems, on the environment and traffic flow characteristics. The sluggish dynamics of trucks whether manual or ACC that is due to their limited acceleration capabilities filter speed disturbances caused by leading vehicles and lead to beneficial effects on the environment and traffic flow characteristics. This response however may lead to higher travel times in certain situations as well as invite cut-ins from neighboring lanes causing additional disturbances. A new ACC design that is developed and experimentally tested reduces some of the negative effects of trucks in mixed traffic.
UCB-ITS-PRR-2004-15
May 2004, 101 pp

An Efficient Lane Change Maneuver for Platoons of Vehicles in an Automated Highway System

Roberto Horowitz, Chin-Woo Tan, Xiaotian Sun

The current lane change maneuver for vehicles in a platoon under the California PATH automated highway system (AHS) architecture is inefficient, because the follower has to split from the rest of the platoon before making a lane change. In this report, we propose to add a lane change within platoons maneuver that allows a follower to change lanes and be inserted into another platoon directly without splitting either platoon. This maneuver is performed by aligning and locking the longitudinal positions of the two platoons in adjacent lanes. The estimated improvement in the AHS utilization, in term of the space-time, is approximately 4342 m-s. The longitudinal controller for the lane changing follower is designed and proved to maintain the string stability of the platoons. The

leader law is modified for the common leader of the two locked platoons. An intra-platoon spacing adjustment procedure is also designed for the purpose of the proposed maneuver.
UCB-ITS-PRR-2004-16
May 2004, 21 pp

Magnetometer/GPS/INS Demo 2002 Support and Mitigation of GPS Signal Blockage Research

Jay Farrell

This project is concerned with accurately and reliably determining the state of a vehicle relative to a specified trajectory (e.g., a lane centerline). We are utilizing inertial navigation methods based on inexpensive solid state inertial sensors aided by external sensors such as carrier phase differential GPS, magnetometers, and roadway height. Due to this integration of sensors, reliability is increased relative to a single sensor approach and the changes required to the roadway infrastructure may be significantly decreased. This projects objectives included preparation for and participation in DEMO 2002, research into INS aided GPS tracking of satellites, and research into methods to use auxiliary sensors (roadway height or magnetometers) to aid the integer resolution process. This project has been very interesting and successful. Although Demo 2002 was ultimately cancelled our preparations for it were fruitful and we did participate in a smaller project demonstration with PATH at Crows Landing.
UCB-ITS-PRR-2004-17
May 2004, 39 pp

Automated-Manual Transitions: Human Capabilities and Adaptive Cruise Control

Joseph E. Barton, Theodore E. Cohn, Khoi M. Nguyen, Tieuvi Nguyen, Natsuko Toyofuku

ITS innovations in California are likely to include automated systems for vehicle guidance. Such systems will supplant manual controls during certain types of vehicle operation. However, the alternative manual control must remain intact in the vehicle. Thus, epochs of automated-manual transition (A-MT) are inevitable. The problem is how to characterize a given transition type and then how to optimize it. In this study we examined one of the several predictable transitions that use of the Adaptive Cruise Control (ACC) will lead to. This predictable A-MT is the event that would ensue when a lead vehicle (LV) suddenly brakes maximally and a following vehicle (FV) under the control of ACC must react appropriately (hereafter referred to as the LV Braking Scenario). Such an event is neither unlikely nor is it benign. It can be shown that within the current design of ACC, this event will lead to a collision. Collision avoidance is possi-

ble but only if the human operator (HO) of the FV assumes manual control in a timely way. In TO 4221 the conditions required for a graceful A-MT in this scenario were investigated. We focused attention on two features of the HO, those visual capabilities required by the HO to determine the need to assume manual control and also those features of an invehicle warning signal (initiated by either vehicle) that could reliably prompt appropriate HO action.
UCB-ITS-PRR-2004-18
June 2004, 35 pp

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

Roberto Horowitz

In this report, we describe the research carried out under PATH Task Order 4208. The objective of this project was to bridge the gap between the Automated Highway System (AHS) simulators SmartAHS and SmartCAP, by implementing an integrated AHS micro-meso simulation environment for analyzing a large-scale AHS network. In fulfillment of this goal, a meso-microscale traffic simulator was developed that allows a stationary region of microsimulation to be defined within a larger, mesosimulated AHS. This simulator permits analysis of traffic behavior in situations where both vehicle-level (microscopic) and aggregate flow (mesoscopic) effects are important, while avoiding the prohibitive computational cost of microsimulating a large-scale AHS. The accomplishments of this project, including the development of the meso-micro batch compiler, user interface, and a manual traffic extension to SmartCAP, are detailed in this report.
UCB-ITS-PRR-2004-19
June 2004, 75 pp

Fuel Saving Achieved in the Field Test of Two Tandem Trucks

Fred Browand, John McArthur, Charles Radovich

The fuel consumption of two tandem trucks is recorded for truck spacings of 3, 4, 6, 8, and 10 meters. The trucks are linked by means of an electronic control system, and are operated on an unused runway at Crows Landing, California. Fuel consumption data is averaged while traveling in both directions over the same central strip of runway to cancel the effect of runway slope and to partially cancel the effect of wind. The average fuel consumption saving to be achieved by tandem operation varies from about 11% at 3-4 meters spacing to about 8% at 8-10 meters spacing.
UCB-ITS-PRR-2004-20
June 2004, 29 pp

Moving Slot Concept for Automated Highway Control

Chi-nan Chin, Randolph Hall

The objective of this report is to optimize performance of Automated Highway Systems through management of space accounting for interaction between entrance and exit processes. To accomplish this objective, we develop a comprehensive framework, including a new integrated highway model called the moving slot model, and operational strategies, called slot/lane assignment rules. The model manages highway space to maximize capacity accounting for safety and vehicle maneuvers. Operational strategies minimize space requirements by forming vehicles into specific patterns of destinations through entry and lane-change control such that vehicles can exit successfully. This research aims to expedite the application of Automated Highway Systems without significantly altering system configurations while optimizing performance in terms of capacity and travel time. In the moving slot model, an operational unit, called a slot in a one-lane highway and a stack in a multi-lane highway, contains the minimal space for accommodating vehicles and supporting necessary maneuvers without affecting other units. This design provides independence among operational units and can vary with system parameters such as number of vehicles in a platoon. This not only reduces the complexity of system control but also makes the framework adaptable to various system requirements. We provide both theoretical and simulation results for system performance of a simplified highway under the framework as well as simulation results for varied system configurations.
UCB-ITS-PRR-2004-21
JULY 2004, 179 pp

Conceptual Development and Performance Assessment for the Deployment Staging of Advanced Vehicle Control and Safety Systems

Joel VanderWerf, Steven Shladover, Mark A. Miller

This report documents work for Task Order 4230 that was follow-on work to prior research performed at PATH under Task Order 366. The current work continued to expand our understanding of the issues involved with time-staging the deployment of advanced vehicle control and safety systems (AVCSS) to help lead toward future automated highway systems. The time-staging challenge has long been identified as one of the most significant impediments to deployment, particularly because of the "chicken and egg" problem associated with vehicle and infrastructure technology implementation. These "chicken and egg" deployment challenges are also

being investigated on an international scale. As part of this project we also conducted a detailed review of the international status of AVCSS development and deployment, in collaboration with the European Commission's STARDUST project and provides a comprehensive picture of the status of these technologies not only in the U.S., but also in Japan and Europe. In terms of the time-staging aspects of AVCSS deployment, heavy vehicle opportunities are likely to develop earliest, however, the largest potential benefits are still likely when the technologies are applied to the much larger population of passenger cars.

UCB-ITS-PRR-2004-22
August 2004, 118 pp

Carlink II: A Commuter Carsharing Pilot Program Final Report

Susan Shaheen, Kamill Wiprywski, Caroline Rodier, Linda Novick, Molly Anne Meyn, John Wright

Shared-use vehicle services provide members access to a fleet of vehicles for use throughout the day, without the hassles and costs of individual auto ownership. From June 2001 to July 2002, the authors surveyed 17 U.S. shared-use vehicle service organizations on a range of topics, including organizational size, strategic partnerships, pricing strategies, insurance costs, and technology applications. While survey findings demonstrate a decline in the number of organizational starts in the last year, the rate of operational launches into new cities, membership, and fleet size continue to increase. Several growth-oriented organizations in the U.S. are responsible for the majority of this expansion. The authors explore several factors that challenge shared-use vehicle growth, such as high capital investment (or start-up costs), dramatic hikes in insurance rates, and scarcity of cost-effective technologies. The authors conclude that while early niche market findings are encouraging, the ability of this emerging sector to actualize its total environmental, economic, and social goals may be limited without the collective support of private industry (e.g., automakers, insurance providers, technology producers), public agents (e.g., transit and governmental agencies), and shared-use vehicle programs. Indeed, public-private partnerships and cooperation among shared-use vehicle providers may play a key role in addressing insurance and technology costs and assuring the long-term viability of this market.

UCB-ITS-PRR-2004-23
August 2004, 186 pp

Fault Tolerant Autonomous Lateral Control for Heavy Vehicles

Craig Matthew Talbot, Iakovos Papadimitriou, Masayoshi Tomizuka

This report is concerned with the problem of fault-tolerant lateral control of heavy vehicles operating on highways. First, the lateral dynamics of two-unit vehicles are presented with the assumptions of negligible pitch, yaw and vertical motion. The complex nonlinear model, which is derived, is then simplified to a linear time invariant system. For single-unit vehicles, the derivation of the equations of motion follows intuitively from the two-unit vehicle dynamics. Next, the problem of lateral autonomous following within a platoon of vehicles is considered. It is shown that the use of sensors that monitor the preceding vehicle's relative lateral position is enough to achieve lateral control for a pair of vehicles, provided that certain limitations are taken into account. For a platoon of multiple vehicles, the lateral error propagation is a serious issue that can be solved if performance is compromised. The use of inter-vehicle communication is proposed in order to recover platoon stability and satisfactory performance. The communication delay is taken into account and it is shown that, under certain circumstances, the communicated data essentially eliminates the interconnection among the vehicles. Simulations for both passenger and tractor-semi-trailer vehicles illustrate the analytical results. Finally, the experimental setup for automated platooning is presented and several implementation issues are examined. Experimental results are also discussed.

UCB-ITS-PRR-2004-24
August 2004, 69 pp

Evaluation of Truck and Bus Automation Scenarios: Operations and Cost Analysis

Jan Botha, Jennifer E. Day, Nagabhargavi Adibhatla

Automated bus and truck systems hold the potential to improve road safety by eliminating some human error, increase the vehicle throughput by allowing vehicle convoying to shorten headways, and reduce costs associated with infrastructure, user time, and drivers. In this study, an automated bus system (ABUS) was compared with more-conventional light rail and bus-on-dedicated-lane (BDL) alternatives. A cost comparison (excluding accident costs) was also made among an automated freight trucking system (AHS-Truck), a no-build base condition, and configurations involving the addition of a conventional lane or a dedicated truck lane to the existing roadway. In both the ABUS and the Truck-AHS cases, the buses and trucks were assumed to operate in convoys. The benefits

and costs were assessed from a societal perspective. Another comparison, based on shipping rates, was made among the AHS-truck, conventional trucking, and intermodal rail. The study concludes that the proposed bus alternatives could have substantially-lower costs than a functionally-equivalent light rail system for relatively low passenger volumes, but that there is no significant difference between the ABUS and BDL options at these volumes. At intermediate and high passenger volumes, ABUS and light rail may be the preferred alternatives, respectively. With regards to the freight systems, the analysis presented here indicates that the AHS lane performed better than the other two alternatives, primarily because of the lower vehicle operating and user costs. Additional research is recommended that addresses safety, demand change, and other impacts of the systems considered in this study.

UCB-ITS-PRR-2004-25
August 2004, 433 pp

Assessment of the Applicability of Cooperative Vehicle-Highway Automation Systems to Bus Transit and Intermodal Freight: Case Study Feasibility Analyses in the Metropolitan Chicago Region

Steven Shaladover et al.

This report presents the results of its performance assessment of the feasibility of applying cooperative vehicle-highway automation systems (CVHAS) to bus transit and freight movements in the metropolitan Chicago area. Cooperative vehicle-highway automation systems are systems that provide driving control assistance or fully automated driving and are based on information about the vehicle's driving environment that can be received by communication from other vehicles or from the infrastructure, as well as from their own on-board sensors. Preliminary case studies have shown potentially significant benefits from use of CVHAS technologies to help solve specific problems for bus and truck transportation in the Chicago region. Although the case study examples are specific to Chicago, they indicate the potential that these technologies should have for use in other major metropolitan areas as well. Within the Chicago context, they should also stimulate follow-on studies to explore the design and deployment issues in more depth so that progress can be made toward the start of implementation.

UCB-ITS-PRR-2004-26
August 2004, 209 pp

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

Caroline J. Rodier, Susan A. Shaheen, Linda Novick

This report documents the results of the first phase of a two-part project: (1) research and feasibility analysis and (2) the field operational test and research of a shared-use Segway HT, electric bicycle, and bicycle rental model linked to a Bay Area Rapid Transit (BART) District station and surrounding employment centers. The feasibility analysis identified the Pleasant Hill BART station and surrounding community, in the East San Francisco Bay Area, as a viable field test location for the introduction of low-speed modes. The location met all criteria established by Partners for Advanced Transit and Highways (PATH) researchers and project partners (i.e., BART, Segway LLC, Giant Bikes, and All Aboard), including: (1) favorable location physical attributes (i.e., employment density and distribution, available pedestrian/bicycle infrastructure, and the absence of significant transit feeder service); (2) community support, in particular, the ability of the field test design to address the safety concerns of the elderly, disabled, and pedestrian advocates; (3) evidence of a large pool of employers who could benefit from the service; (4) a transit station vendor to distribute the devices; and (5) a multijurisdictional location to enhance the transferability of the results.

UCB-ITS-PRR-2004-27
August 2004, 77 pp

Analyses of the Response of Pavements Containing Ceramic Plugs for Vehicle Guidance

Carl L. Monismith

The purpose of this investigation has been to examine the influence of the sensor on pavement performance, specifically cracking, considering both the effects of traffic loading and temperature changes. A major effort of the study has been devoted to a series of simulations considering both the effects of a range in traffic loading conditions and temperature changes on representative pavement structures containing the type of sensor currently in use in California. To assess the reasonableness of the simulations, a limited traffic loading study was conducted on an asphalt pavement containing the sensors using the Heavy Vehicle Simulator (HVS) operated by the Pavement Research Center (PRC). The AC pavement section was subjected to more than 300,000 repetitions of a dual tire truck configuration representative of one-half of a legally loaded standard single axle.

UCB-ITS-PRR-2004-28
August 2004, 106 pp

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

Anthony Chen, Piya Chootinan, Will Recker, H. Michael Zhang

The origin-destination (O-D) trip table is a key input required for traffic assignment and simulation models utilized to analyze a wide variety of transportation applications. The main goal of this research is to develop an economical and quick method for estimating O-D trip tables from traffic counts. Path flow estimator (PFE), originally developed by Bell and Shield (1995), has been further developed to improve the reliability and efficiency of O-D trip table estimates. The research reported herein includes only the development of the steady-state O-D estimator. In this study, the original PFE model was carefully examined in several aspects to gain more insight for further improvements. Currently, the PFE has been successfully applied to estimate the steady-state O-D trip tables for the Irvine Testbed network in Orange County, California as well as some other real networks. The primary results demonstrate that PFE has the capability to correctly estimate the total and individual O-D demands when proper information is provided. They also indicate that the number and locations of traffic counts significantly influence the quality of O-D estimates as each observation contributes different amount and quality of information. The most difficult task observed thus far is the estimation of spatial pattern of O-D demands even when traffic counts were collected on all network links. These issues and the development of time-dependent PFE will be investigated in the second phase under Task Order 5502

UCB-ITS-PRR-2004-29
September 2004, 116 pp

An Assessment of Loop Detector and RTMS Performance

Benjamin Coifman

Traffic detectors support most traffic management applications, so it is important that a detector performs as expected. This study evaluates the performance of four loop sensor models and the Remote Traffic Microwave Sensor (RTMS), adding to the body of sensor performance knowledge through the use of new analytical techniques. The study collected contact closure data from all five of the detectors and concurrent video data. Each loop sensor was deployed following Caltrans guidelines for at least 24 hours across dual loop detectors in each lane of I-80, north of Oakland, CA.

UCB-ITS-PRR-2004-30
September 2004, 134 pp

Freeway Performance Measurement System (PeMS) Version 4

Pravin Varaiya

PeMS 4 is the latest of four task orders devoted to research, development, and maintenance of the PeMS system. PeMS collects, processes, stores, and makes available online data from the six Caltrans districts (D3, 4, 7, 8, 11, 12), which include the major urban areas in California. The data are obtained from 23,237 loops, grouped into 7,359 vehicle detector stations (VDS). These loops cover 2,812 out of 30,726 miles of interstate and state highways in California. The product of the research activity is reported in professional meetings and journals and in algorithms, and summarized in this report. The algorithms are incorporated into PeMS applications code as part of the development activity. The maintenance activity is concerned with database management, network troubleshooting, and providing PeMS access to users.

UCB-ITS-PRR-2004-31
September 2004, 37 pp

Integrated Roadway/Adaptive Cruise Control System: Safety, Performance, Environmental and Near Term Deployment Considerations

Jianlong Zhang, Petros Ioannou

In this project, we design two new Adaptive Cruise Control (ACC) systems based on driver comfort, safety, vehicle following performance, environmental and traffic flow characteristics considerations. A new variable time headway rule is proposed and used to meet these considerations. Analysis and simulations are used to evaluate and compare the two designs. The first ACC system (referred to as ACC01) incorporates two controllers: one for speed tracking and one for vehicle following. The second ACC system (referred to as ACC02) treats the vehicle following task as a special speed tracking task and incorporates more intelligence in dealing with disturbance rejection, smooth response and safe vehicle following without affecting travel time. It provides better transient performance than ACC01, and can attenuate oscillations in the speed response of the preceding vehicle. It has also been shown that ACC02 provides better fuel economy and emission results than ACC01. The ACC02 design will be used for subsequent studies in a continuation project.

UCB-ITS-PRR-2004-32
September 2004, 78 pp

Experimental Verification of Discretely Variable Compression Braking Control for Heavy Duty Vehicles: Final Report

Ardalan Vahidi, Anna G. Stefanopoulou, Xiaoyong Wang, Tsu Chin Tsao

In the first two chapters of this report, the development of discrete compression brake and transmission models is explained. In the third chapter, a recursive least square scheme with multiple forgetting factors is proposed for on-line estimation of road grade and vehicle mass. The estimated mass and grade can be used to robustify many automatic controllers in conventional or automated heavy-duty vehicles. In the final part of this work, an adaptive model predictive control scheme is designed for speed control of heavy vehicles. The controller coordinates use of compression brakes and service brakes on downhill slopes. The advantage of model predictive control (MPC) scheme over PI design is its ability to explicitly handle the constraints on service brake diagram and compression command.

UCB-ITS-PRR-2004-33
September 2004, 76 pp

Ad-hoc Medium Access Control Protocol Design and Analysis for Vehicle Safety Communications

Raja Sengupta, Qing Xu, Tony Mak, Jeff Ko

This paper studies the design of ad-hoc Medium Access Control (MAC) protocols for a vehicle or the roadside to send safety messages to other vehicles. Such a protocol is needed by Advanced Vehicle Safety Systems (AVSS) and the national Dedicated Short Range Communications (DSRC) architecture. The problem is formulated to meet the communication requirements of vehicle safety applications and the DSRC multi-channel operation model. We propose several ad-hoc protocols, all based on the principles of repetition coding. Analytical bounds of the protocols' performance are derived. Simulations are conducted to compare the performance of the protocols in terms of probability of reception success and channel busy time. The best among the proposed protocols is shown to significantly outperform IEEE 802.11 MAC protocol in vehicle safety communication environment. We obtain the optimal relation between the performance and protocol design, in particular that of data rate and transmission power. The sensitivity of the protocol performance is tested under various communication conditions as well as vehicle traffic conditions. Feasible combinations of the communication and highway traffic parameters are found to meet specific performance requirements on communication.

UCB-ITS-PRR-2004-34
September 2004, 71 pp

Coordination Layer Control Design for Automated Trucks and Buses

Xiao-Yun Lu, Sungmoon Joo, J. Karl Hedrick

This paper is a preliminary study of the coordination layer and decision making for automated trucks and buses. The most challenging issues for maneuverability of trucks and buses are: a) The overall system model for longitudinal control is highly nonlinear; b) Large time delays in power-train and actuators, particularly, control command to torque production delay, engine torque to wheel torque production delay, braking system (air brake, transmission retarder and Jake brake) delay; c) Their acceleration capability is severely limited, which is due to the low mass/power ratio compared to other vehicles; d) large internal/external disturbances from gear shifting, wind (aerodynamic dragging), road unevenness and road grade. Maneuver design and coordination algorithms need to take these factors into consideration.

UCB-ITS-PRR-2004-35
September 2004, 105 pp

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

Guang Lu, Jihua Huang, Masayoshi Tomizuka

The research goal is to develop vehicle lateral control strategies under faulty operation of the magnetometers. The main objectives of the project are: (1) to design controllers that use the output from only one set of magnetometers, and (2) to develop an autonomous lateral control scheme that uses no magnetometers. Two methods are employed in the degraded mode controller design using only one set of magnetometers. In the first method, H_{∞} control with gain scheduling combines the robust performance range of several H_{∞} controllers to achieve stronger robustness to the variation of vehicle velocity. The second method combines feedback linearization, which provides a simple and effective way of gain scheduling, with mismatched observer, which prevents undesired zeros of the vehicle lateral dynamics from being contained in the internal dynamics. To ensure the success of the fault management system, transition behavior between the normal mode control and the degraded mode control is also investigated.

UCB-ITS-PRR-2004-36
September 2004, 109 pp

Assessing the Value of TMCs and

Methods to Evaluate the Long Term Effects of ITS: Measuring Congestion, Productivity and Benefit Flow from Implementation

David Gillen, Douglas Cooper

The study carries out an evaluation of TMCs (traffic management centers) using three methodologies; case studies, performance based regressions and time series analysis. The study is an extension of previous work that assessed the contribution of different types of intelligent transportation investments and initiatives. However, this research sought to distinguish the separate contributions of the ITS investments from the synergies of integration under a traffic management center. Secondly, the research investigated the time dimension of benefits where we investigated if there was an 'S' curve effect in which a change in the network due to an ITS investment or the introduction of a TMC lead to benefits distributed over time. The distribution was important to evaluating ITS investments. If one measured the impact of the investment too soon, in the disequilibrium period, it would underestimate the true contribution of the investment or change in process or management strategy.

UCB-ITS-PRR-2004-37
September 2004, 74 pp

Development and Field Testing of Laser Photodiode Array-Based Vehicle Detection Systems

Harry H. Cheng, Ben Shaw, Joe Palen, Zhaoqing Wang, Ping Feng, Stephen Nestinger, Bo Chen

Over the past year we have researched the development of a network-based real-time laser-based non-intrusive field-deployable detection for the delineation of moving vehicles. The primary goal of this project is to develop a roadway detection system that can be used to gather reliable travel time data non-intrusively. A powerful Rabbit 3200, instead of multi-microchips, is used to control digitally controlled potentiometers (DCP), which adjust the gain of the sensors' signals. Utilizing digitally controlled potentiometers allow for quick and easy adjustment on the highway with only the need of pushing a button. The adjustment, which used to take half or an hour, now only takes several seconds. The Rabbit 3200 is also used as a data sender to a computer through the Ethernet. The rabbit digital input ports are triggered to collect the signals by an interrupt pulse from a PWM signal, which also acts as the laser source trigger. The Rabbit 3200 will then pack all of the data into TCP packages and send them to a remote computer over a network. The Rabbit 3200 is also able to filter noise after having finished the task of adjustment. The software of the system has been modified for 8 chan-

nels. Compared with the previous 4 channel code, the new system is able to obtain more information on vehicles, including the profile of a passing vehicle. In order to improve the precision of the system, we improved the mechanical design, optical design and electric circuit design. We also use an interrupt to sample signals instead of a fixed sampling interval strategy. This method ensures every signal generated by the APD will be captured by the Rabbit 3200. The laser sources are pulsed at 10 kHz and the sampling rate of the Rabbit 3200 is synchronized to the 10 kHz laser pulse. This report describes the design and implementation of each functional component of the field-deployable system, the configuration of the field detection system, software design and implementation, and a signal calibration method to obtain higher system precision. It also demonstrates four different ways to test the field-deployable system and the results from each way of testing for future improvement.

UCB-ITS-PRR-2004-38
October 2004, 77 pp

Vehicle Detection by Sensor Network Nodes

Jiagen (Jason) Ding, Sing-Yiu Cheung, Chin-woo Tan and Pravin Varaiya

This report presents the algorithm development and experimental work of the sensor node signal processing for vehicle detection. The signals used for vehicle detection are acoustic and magnetic signals. The acoustic signals are characterized by short time FFT analysis and two acoustic vehicle detection algorithms are proposed: the Adaptive Threshold algorithm (ATA) and the Min-max algorithm (MMA). The ATA detects vehicle by searching for a sequence of 1's after slicing the acoustic energy curve using an adaptive threshold. The MMA detects vehicles by searching the local maximum in the acoustic energy curve. Real time tests and offline simulations demonstrate the effectiveness of the two algorithms. For magnetic signals, a simple threshold slicing algorithm is utilized and real time tests give good performance. Finally, FPGA implementation of ATA is also presented for power efficiency requirement and the implementation justifies the use of dedicated hardware for low power implementation.

UCB-ITS-PRR-2004-39
October 2004, 64 pp

Integrating ITS Alternatives into Investment Decisions in California

Joy Dahlgren, Douglass B. Lee, Jr.

The purpose of the study was to document the process by which decisions are made in California about implementing intelligent transportation systems (ITS) projects, and to consider

ways for "mainstreaming" ITS in the sense of evaluating ITS projects alongside non-ITS projects. The transportation planning and decision process is reviewed and described as a base for judging the efficacy of decisions with respect to the adoption of (ITS) projects. The decision process is complex and varied, involving government agencies at federal, State, regional, and local levels, but the process seems to be workable and suitable. In practice, however, critical information for making decisions does not appear to be available to decisionmakers at the points in the process when they need it. In particular, information on the impacts of ITS projects and the expected benefits appears to be missing from planning and project information documents such as Project Study Reports. Although generic claims for benefits in the form of delay savings, accident reductions, and other user or environmental benefits are sometimes provided, they are not quantified and are not specific to the particular project. Costs, on the other hand, are usually very specific, because they represent a budgetary commitment. Good decisions, however, call for better information on what benefits the specific costs will generate

UCB-ITS-PRR-2004-40
October 2004, 108 pp

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

Joy Dahlgren, Asad Khattak, Patrick McDonough, Ipsita Banerjee, Phyllis Orrick, Ashkan Sharafsaleh.

The ITS Decision website has been developed for the user who is interested in learning about various Intelligent Transportation System (ITS) technologies. Two tools have been developed that will help those users who wish to address a specific problem, obtain information relating to their particular context. These are the Expert System and the Case Based Reasoning tools. The Expert System tool queries the user on the problem context and the problem in general. It then presents information on different types of ITS technologies that may be used to address the problem. The Case-Based Reasoning tool, at present, contains information about three technologies. One of these is a transportation demand management mechanism, specifically the employer based transit pass program. The other two are Automatic Vehicle Location/Computer Aided Dispatch, and Freeway Service Patrol. A user interested in using any of these technologies enters the parameters of his context, i.e. city size, fleet size, as response to queries. The tool then presents him with cases of different locations where the specific tech-

nology has been used. The cases are presented in order of their resemblance with the input parameters. The users could access more information on any of these cases by clicking on the hyperlink.

UCB-ITS-PRR-2004-41
October 2004, 143 pp

Large-Scale Traffic Simulation Through Distributed Computing of Paramics

Henry X. Liu, Wenteng Ma, R. Jayakrishnan, Will Recker

Simulation modeling is an increasingly popular and effective tool for analyzing transportation problems, which are not amenable to study by other means. We examine the need for parallel or distributed simulation approaches from the need for computational speed-ups, availability of options towards that, and then at the need to distribute the effort to develop network simulation contexts and datasets. After an overview of the general techniques for the distributed discrete-event simulation and previous efforts on the distributed traffic simulation, we present the general architecture of the proposed distributed modeling framework. Two categories of modeling strategies, namely, light global control / independent subnets vs. heavy global control / coordinated subnets are described. We have implemented the distributed scheme of light global control / independent subnets and the implemented details, such as communication techniques and vehicle transferring across the boundary of two subnets are discussed. Unlike the previous studies using the dedicated high performance machines, our efforts are to utilize the low-cost networked PCs that are commonly available. By using the API supported by off-the-shelf Paramics software, we are able to distribute the computational load of microscopic simulation to multiple single-processor PCs without access the proprietary source codes of the simulation program. Performance testing and analysis of the implemented prototype demonstrate that the proposed framework is very promising.

UCB-ITS-PRR-2004-42
October 2004, 38 pp

Distributed Surveillance and Control on Freeways

Benjamin Coifman

Efficient management of a road network requires continuous decision-making based on conditions on the network and an understanding of the impacts of the decisions made. These conditions are usually measured with fixed-point surveillance systems, most of which are deployed in such a manner as to require communication links that are always connected and are polled at regular intervals. All of the

sensor data are typically sent to a Traffic Management Center (TMC) for assessment, yet most of the time no action is taken in response to the data, leading to unnecessarily high communication costs. To reduce communication costs without a significant loss in the quality of information received at the TMC, this report lays the foundation for an event driven communication system. The analysis considers many related aspects, first by examining the information value of specific events at the detectors. This procedure can then be used to transfer a portion of the decision making from the TMC to the field controllers, which would make the initial valuation of information and only send data that might elicit a control response or benefit comparative decisions between detector stations. Key to the distributed surveillance scheme is reliable measurements in the field, so next this report presents an analytical methodology to increase the accuracy of speed estimates from freeway traffic detectors by integrating information across lanes. The approach could also prove beneficial for conventional surveillance systems relying on fixed polling periods. The next section looks at the mechanics and algorithms necessary to realize a distributed surveillance system that aims at reducing the combined surveillance and communication costs by pre-filtering data in the field. To pre-filter data, distributed control algorithms for five communication modes were developed. The decentralized surveillance structure indeed promises a cost-effective approach that could potentially expand the coverage of a surveillance system to remote locations and help improve the decision making process of the operating agencies. As such this report specifically addresses one of the original impetus for this research, Caltrans having insufficient funds to communicate with all of the operational freeway detector stations.

UCB-ITS-PRR-2004-43
November 2004, 129 pp

Optimization and Microsimulation of On-ramp Metering for Congested Freeways

Gabriel C. Gomes

This dissertation investigates various aspect of the design and testing of on-ramp metering control systems, including optimization-based control and microscopic freeway modeling. A new technique for generating optimal metering plans is developed. As with most predictive designs, the ramp metering rates are found as the solution to a nonlinear optimization problem. In contrast to previous designs, the new approach 1) produces a globally optimal solution to the nonlinear problem, 2) requires only to solve a

single linear program, and 3) allows the enforcement of hard constraints on the on-ramp queue lengths. The price that is paid for these features is that the objective function being minimized is not Total Travel Time, but rather a member of a class of "TTT-like" objective functions.

UCB-ITS-PRR-2004-44
November 2004, 169 pp

Evaluation of Bus and Truck Automation Operations Concepts

H.-S. Jacob Tsao, Lan Zhang, Lin Lin and Deepa Batni

During the one-year project, we developed detailed operating scenarios for both urban bus automation and inter-city truck automation as well as operating scenarios for conventional alternatives. We also compared the automation operating scenarios to their conventional counterparts. To support the comparison, we developed methodologies and computer tools, which can be used for similar studies in the future. Computer tools in the form of source code are also included as deliverables.

UCB-ITS-PRR-2004-45
November 2004, 311 pp

Testing and Evaluation of Robust Fault Detection and Identification for a Fault Tolerant Automated Highway System: Final Report

Robert H. Chen, Hok K. Ng, Jason L. Speyer, D. Lewis Mingori

This report concerns vehicle fault detection and identification. The design of a vehicle health monitoring system based on analytical redundancy approach is described. A residual generator and a residual processor are designed to detect and identify actuator and sensor faults of the PATH Buick LeSabre. The residual generator, which includes fault detection filters and parity equations, uses the control commands and sensor measurements to generate the residuals which have a unique static pattern in response to each fault. Then, the residual processor interrogates the residuals by matching the residuals to one of several known patterns and computes the probability of each pattern defined hypothesis. The vehicle health monitoring system is first evaluated using simulated data generated by a high-fidelity vehicle simulation. Then, it is evaluated using empirical data recorded when driving a PATH Buick LeSabre at Crow's Landing. Finally, a real-time testing environment is developed using Linux operating system and C language. This allows the vehicle health monitoring system to be evaluated in real-time on a PATH Buick LeSabre. The realtime evaluation at Crow's Landing demonstrates that the vehicle health monitoring system can detect and identify actuator and sensor faults as expected even under

various disturbances and uncertainties including sensor noise, road noise, system parameter variations, unmodeled dynamics and nonlinearities.

UCB-ITS-PRR-2004-46
November 2004, 262 pp

Framework for Bus Rapid Transit Development and Deployment Planning

Mark A. Miller, Yafeng Yin, Tunde Balvanyos, Avishai Ceder

This report presents the results of its investigation into deployment planning for bus rapid transit systems. In this study, we conducted a macro-scale examination of bus rapid transit systems from technical, operational, institutional, and planning perspectives. We then developed the theoretical foundation for a deployment planning framework for bus rapid transit systems that specifically takes into account the unique features of bus rapid transit that differ from other transit alternatives. The planning process of a BRT system can generally be divided into three inter-related stages initially consisting of a feasibility study or major investment study in which bus rapid transit is investigated compared with other transit alternatives to find out the most cost-effective investment over a corridor; second, deployment planning that determines what BRT elements will be included in the BRT system and their deployment sequence; and finally, operations planning including designing routes and stations, setting timetables, scheduling vehicles, and assigning crew. While the first and third stages are essentially planning-specific for any transit service, the second stage deals with the special features associated with a bus rapid transit system due to its flexibility in incremental deployment of elements. The report focused on this second stage in the planning process for bus rapid transit systems in the development of the deployment planning framework, in which a systems optimization approach was used. We then demonstrated how the framework may be used in the context of a site-specific case study by focusing on the Metro Rapid Wilshire corridor in Los Angeles.

UCB-ITS-PRR-2004-47
December 2004, 168 pp

Command Modification Using Input Shaping for Automated Highway Systems with Heavy Trucks

Hong S. Bae, J. Christian Gerdes

Automated vehicles require sufficiently accurate system models in order to achieve a desired level of closed-loop performance in, for example, automated highways systems or smart cruise control systems. Parameters of the models are one of the important factors that determine the accuracy of

system modeling and, eventually, the overall performance of the closed-loop system. Current GPS sensing technology enables estimation of road grade and, consequently, simple treatment of parameter estimation from a static force balance. This work has demonstrated that road grade can be reliably estimated using synchronized two antennae GPS system or the vertical to horizontal velocity ratio from GPS speed measurements. This work also presented a new method for maintaining and improving string stability by preventing actuator saturation in automated vehicles on highways. Instead of relying on feedback controllers to deal with the issue of actuator saturation after the fact, reference commands are fed through an FIR filter called an input shaper so that harmful components in the reference commands are reduced or removed.

UCB-ITS-PRR-2004-48
December 2004, 147 pp

Assessment of Service Integration Practices for Public Transportation: Review of the Literature

Mark A. Miller

This report presents a literature review of transit service integration policies. Focus of the review is on the following topics: 1) changes in transit properties' traditional business model; 2) identification of major categories of service integration policies; 3) identification of criteria for selecting participants in project survey; 4) description of site-specific implementation of service integration policies; 5) use of advanced technologies in implementing service integration policies; 6) general topic areas for questions to include on the survey; and, 7) measures of performance for evaluating service integration policies; impacts.

UCB-ITS-PWP-2004-1
January 2004, 23 pp

An Assessment of Bus Rapid Transit Opportunities in the San Francisco Bay Area

Mark A. Miller, Dustin White

This report presents an assessment of opportunities for bus rapid transit (BRT) in the San Francisco Bay Area. Focus is on routes that partially travel on California state routes. Consideration is given to the inter-connectivity and regional aspects of BRT systems deployment. After close to 200 bus transit routes were identified, the field was reduced to bus routes with a high likelihood of being upgraded to BRT systems. The study looked at the length of the bus transit routes, service characteristics related to schedule and route structures based on passenger demand level, external factors, bus routes that function primarily as one service, and level of passenger demand.

UCB-ITS-PWP-2004-2
February 2004, 47 pp

Vehicle Modeling and Verification of CNG-Powered Transit Buses

J.K. Hedrick, A. Ni

This report presents the results of a study for developing an accurate working model of the 40-foot New Flyer bus powered by a compressed natural gas (CNG) engine. The primary objective of the study is the modeling of the vehicle dynamics using step input acceleration data. Additional areas of research include gear shifting and torque production from the CNG engine.

UCB-ITS-PWP-2004-3

February 2004, 27 pp

Traveler Response To New Dynamic Information Sources: Analyzing Corridor And Area-Wide Behavioral Surveys

Youngbin Yim, Asad J. Khattak, Jeremy Raw

This report describes a comprehensive conceptual model that is based on information processing and traveler response, and which accounts for the effect of information source, content and quality on information access and travel behavior. Data is drawn from several behavioral surveys that were conducted in the San Francisco Bay Area between 1995-1999. The surveys studied the response of the whole population, response of persons more included to use information technology, and traveler decision-making in high-benefit incident situations. The report discusses issues related access to new and conventional technologies and services, their current market penetration levels, switching behavior regarding new information sources/information service providers, desired information content, and willingness to pay for dynamic information. Opportunities and limitations of new technologies and the implications for future technology implementations are also discussed.

UCB-ITS-PWP-2004-4

February 2004, 21 pp

Demand-Responsive Transit Shuttles: Who Will Use Them?

David Anspacher, Asad J. Khattak, Youngbin Yim

In this study, the authors explore the possibility of expanding access to existing rail transit systems through demand-responsive shuttles. They analyze the effect of several factors on an individual's willingness to use a door-to-station shuttle service. Using survey data, the authors use descriptive statistics and ordered logit regression to examine the influence of several factors on peoples' willingness to use the shuttles.

UCB-ITS-PWP-2004-5

February 2004, 20 pp

PEDAMACS: Power Efficient and Delay Aware Medium Access Protocol for Sensor Networks

Sinem Coleri, Pravin Varaiya

We consider a class of sensor networks with two special characteristics. First, the nodes periodically generate data for transfer to a distinguished node called the access point. Second, the nodes are (transmit) power and energy limited, but the access point, which communicates with the 'outside world', is not so limited. Such networks might be used for instance when a geographically distributed physical process, such as traffic on a freeway or at an urban street intersection, is periodically sensed for purposes of process control. We propose a medium access control scheme, called PEDAMACS, for this special class of networks. PEDAMACS uses the high-powered access point to synchronize the nodes and to schedule their transmissions and receptions in a TDMA manner. The protocol first enables the access point to gather topology (connectivity) information. A scheduling algorithm then determines when each node should transmit its data, and the access point announces the transmission schedule to the other nodes. The scheduling algorithm ideally should minimize the delay-the time needed for data from all nodes to reach the access point. However, this optimization problem is NP-complete. PEDAMACS instead uses a polynomial-time scheduling algorithm which guarantees a delay proportional to the number of nodes in the sensor network.

UCB-ITS-PWP-2004-6

July 2004, 37 pp

Traffic Measurement and Vehicle Classification with a Single Magnetic Sensor

Sing Yiu Cheung, Sinem Coleri, Baris Dundar, Sumitra Ganesh, Chin-Woo Tan, Pravin Varaiya

Wireless magnetic sensor networks offer a very attractive, low-cost alternative to inductive loops for traffic measurement in freeways and at intersections. In addition to vehicle count, occupancy and speed, the sensors yield traffic information (such as vehicle classification) that cannot be obtained from loop data. Because such networks can be deployed in a very short time, they can also be used (and reused) for temporary traffic measurement. This paper reports the detection capabilities of magnetic sensors, based on two field experiments. The first experiment collected a two-hour trace of measurements on Hearst Avenue in Berkeley. The vehicle detection rate is better than 99 percent (100 percent for vehicles other than motorcycles); and estimates of vehicle length and speed appear to be better than 90 percent. Moreover, the measurements also give

inter-vehicle spacing or headways, which reveal such interesting phenomena as platoon formation downstream of a traffic signal.

UCB-ITS-PWP-2004-7

September 2004, 25 pp

Berkeley Highway Lab Video Data Collection System

Chao Chen, Daniel Lyddy, Baris Dundar

The goal of this project is to replace the existing analog video collection system on the roof of Pacific Park Plaza (PPP) with a digital one. This video collection system is part of the Berkeley Highway Laboratory (BHL) testbed. It records video of traffic on a continuous one-kilometer section of Interstate 80 (I-80) near Emeryville, CA. This section of I-80 features on-ramps, off-ramps, and weaving zones. The video of interactions between vehicles can be fed to a machine-vision system, which generates vehicle trajectories to be used in a variety of traffic studies. The video itself can also be used for both human and machine-vision based verification of loop data

UCB-ITS-PWP-2004-8

November 2004, 18 pp

Initial Scoping of Bay Area Smart Mobility Corridors and ITS World Congress

Susan Shaheen, Rachel S. Finson, Cynthia McCormick

The Innovative Corridors Initiative (ICI) is a multi-year project designed to encourage the early deployment of innovative technologies for Intelligent Transportation Systems (ITS) in California. ITS technologies are defined through a broad array of information and vehicle control technologies that are designed to improve traffic and transit management including safety, user choice, congestion, and incident response. For over a decade, ITS technologies have been gaining acceptance and are now utilized in every major metropolitan area in the United States to enhance transportation system management.

UCB-ITS-PWP-2004-9

November 2004, 70 pp

