



Partners for Advanced Transportation Technology Biennial Report 2010-2012



Innovations for the Road Ahead

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About PATH

California Partners for Advanced Transportation Technology (PATH), a research and development center of the University of California, Berkeley, has been a leader in Intelligent Transportation Systems research since its founding in 1986. Housed within the university's Institute of Transportation Studies (ITS), PATH executes a diversified portfolio of multi-disciplinary transportation research projects with its staff, UC Berkeley faculty, and students. PATH conducts many of these projects in collaboration with the California Department of Transportation (Caltrans). PATH also works with scholars and students from other universities, as well as researchers from private industry, state and local agencies, and nonprofit institutions from around the globe.

In 2011, the current incarnation of PATH emerged through the consolidation of two ITS research centers, California Partners for Advanced Transit and Highways and the California Center for Innovative Transportation. The new organization has brought together deep expertise in both research and deployment and is redefining the concept of "intelligent transportation systems" to meet the realities of the Information Age.

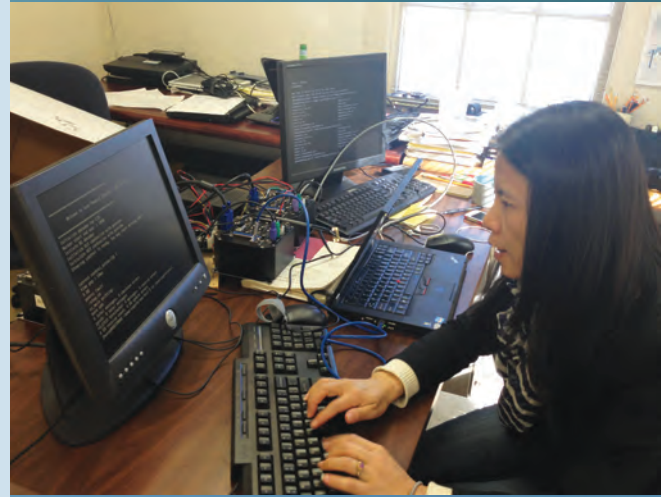
Our Mission

Our mission is to develop solutions that address the challenges of California's surface transportation systems through advanced ideas and technologies and with a focus on the greater deployment of those solutions throughout California.

Our Partners

PATH partnerships have been a key component of our success. From industry leaders such as Google, Nokia, and Nissan to public sector stakeholders such as Caltrans and the Metropolitan Transportation Commission, we have built productive partnerships with a broad spectrum of stakeholders in the transportation community. Caltrans has been, and continues to be, the primary source of support for PATH's core research and remains an important advocate for many of our activities.

For over 25 years, PATH has pioneered new technologies, researched innovative improvements in transportation safety, and partnered with countless private and public agencies, all with the goal of advancing California's transportation network. Whatever the challenge, we are committed to developing real-world solutions that make a difference in the lives of the traveling public.



Message from the Directors

Dear Colleagues,

Over the past few years PATH has grown in important ways. The integration of two transportation organizations—PATH and CCIT—under the PATH banner has enabled us to draw on a broader range of expertise than ever before, expertise reflected in the range of transportation challenges we've been able to address.

Our work is enriched both by the diverse talents of the PATH team and by collaboration with our academic and industry partners in California and around the world. But our core mission to research, develop, and deploy innovative transportation solutions would truly not be possible without our unique partnership with Caltrans. Now in its 26th year, this alliance between our two organizations has fueled improvements in data, traffic, automobiles, safety, and transit—the future of transportation—all created in California, for Californians.

As technology progresses, so does our research. For example, our Mobile Century project in 2008 evolved into our groundbreaking Mobile Millennium project, which pioneered the use of collecting and distributing real-time traffic data through cellular phones. Now, just a few years later, this technology is becoming mainstream. We continue to build upon the knowledge gained from past projects and integrate our findings to develop new solutions. One example of this is the Connected Corridors project, which will leverage what we have learned from other projects including Mobile Millennium, Hybrid Data Fusion, and Tools for Operational Planning (TOPL).

Some of our other current projects illustrate the range of innovations we've been working on, from vehicle technology to traveler information. Our Cooperative Adaptive Cruise Control project has made a significant step in both Intelligent Transportation Systems and traffic safety by adding vehicle-to-vehicle communications to adaptive cruise control. Our Smart Travel Choices project provides travelers with real-time bus and train information specific to a traveler's location to encourage commuters to use transit. Our Augmented Speed Enforcement project has created a warning system to deter speeders and help protect workers in construction zones. You'll find descriptions of more of our work in the Project Highlights section of this report.

The following pages provide an overview of our latest research, the strengths of our PATH team members, our publications that share our findings with the transportation community, and some of the challenges to come—a snapshot of our continuing efforts to improve transportation for all our state's citizens, both now and for future generations to come.

ROBERTO HOROWITZ

THOMAS WEST

Directors

California PATH

University of California, Berkeley

Page 4 Photo (top): Courtesy of Peg Skorpinski and UC Regents

Page 5 Photo (top right): Courtesy of Caltrans



Message from Caltrans

The California Department of Transportation (Caltrans) is pleased to have completed yet another successful period in its distinguished partnership with California Partners for Advanced Transportation Technology (PATH). Together, we have pursued innovative technologies that improve transportation for the benefit of all Californians.

California's economy is dependent on its transportation system infrastructure to move people, goods, and services throughout the state, to other parts of the country and to international destinations. With the state's growing population soon to exceed 37 million, we continue to look for new and creative ways to elevate the performance of our complex transportation system. We are developing new technologies and implementing solutions to increase mobility, foster economic growth, and ultimately enhance the quality of life for our citizens.

Our alliance with PATH is helping us to achieve these improvements through state-of-the-art research and by moving the findings out of laboratories and into field applications. PATH researchers have made advancements in the use of vehicle probe and loop sensor data; in real-time traveler information; in vehicle-to-vehicle communications; in modern freeway and arterial corridor system management technologies; and in the integration of traffic data that gives traffic managers and travelers more accurate and reliable information.

PATH's mission of developing solutions to meet transportation challenges through cutting-edge research and the deployment of those research products echoes Caltrans' goals of improved mobility, safety, and good stewardship. Our joint commitment to excellence and innovation has helped us maintain a leadership position in the field of transportation, and we are excited to be a partner in this world-class research endeavor.

Caltrans is dedicated to continually improving California's transportation system. We anticipate that our continued association with outstanding academic partners like PATH, will result in even more evolving innovations and breakthroughs that help solve the transportation challenges facing California into the 21st century.

COCO BRISENO

Division Chief

*Division of Research, Innovation and System Information
California Department of Transportation*



Project Highlights

Our projects reflect the depth and breadth of the work we do at PATH. With project expenditures reaching over \$6 million in both 2010 and 2011, it wouldn't be possible to share all of our research in just a few pages. Below are highlights from select projects that represent the varied work of PATH.

Cooperative Adaptive Cruise Control

Adding vehicle-to-vehicle (V2V) communications to an adaptive cruise control (ACC) system turns it into a cooperative ACC (CACC) system. The idea behind CACC is not only to have a vehicle's cruise control system maintain a proper following distance behind another car by slowing down once it gets too close, (ACC), but also to allow cars to "cooperate" by communicating with each other while in the adaptive cruise control mode. The result is that cars can follow more closely, accurately, and safely, with braking and accelerating done cooperatively and synchronously. This multi-phase project was sponsored by Nissan Motor Co. A key component in the research was an exploration of "gap setting" (selecting the distance to another car) by the test subjects from the general public who drove our original CACC test vehicles.

Hybrid Traffic Data Collection: A Roadmap for Implementation

Counting the actual volume of traffic at a location and determining its speed has long been the province of loop detectors buried in the pavement. However, the advent of GPS-equipped smartphones has given rise to the hope that "probe" data could one day supplement loop data to produce much more plentiful information. While this hope is becoming a reality, integrating probe data with traditional data sources accurately and scientifically is no simple task. In this project, PATH investigated how Caltrans might go about buying traffic probe data from vendors, how to modify and manage it to make it useful, and how to integrate it with Caltrans' existing performance measurement system.

Vehicle-Infrastructure Cooperation Using DSRC

A promising wireless technology called Dedicated Short Range Communications, or DSRC, is a communication standard used for the exchange of safety-critical and time-critical information between roadway infrastructure and vehicles. The U.S. Department of Transportation is encouraging the development of DSRC, which has been rapidly improving in recent years. Having up-to-date test beds on public roadways is essential to testing and developing the technology even further. PATH and Caltrans are upgrading their Palo Alto test bed so that it can become a key element in the national network of DSRC test beds. This location is especially crucial as several major international vehicle manufacturers have built research facilities in the area.



Smart Travel Choices

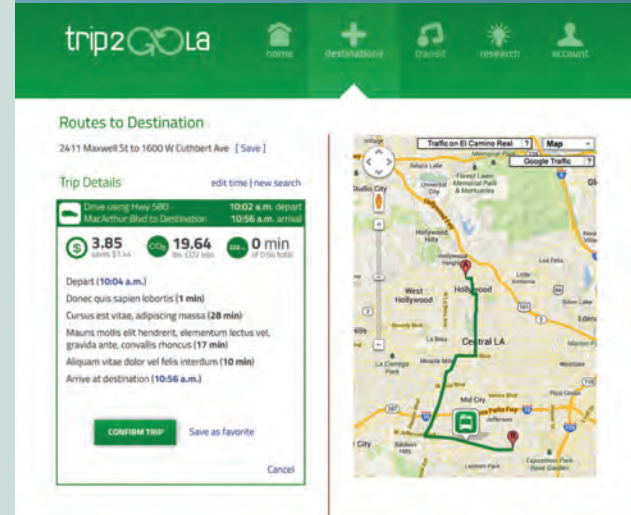
Smart Travel Choices, or STC, combines Traveler Information Systems with incentives in order to encourage commuters to shift their mode of travel from cars to transit. PATH2GO, a smartphone app developed at PATH, is a sophisticated, context-aware application that gives real-time bus and train arrival times to travelers based on their location, and includes real-time trip planning capabilities that can determine optimal routes based on cost, carbon footprint, and time of travel at that moment. This research project, originally centered in the Bay Area, is being expanded to the Los Angeles region, and includes experiments designed to uncover the triggers for changing commuter behavior in the world of smartphones using real-time traveler-specific data.

Augmented Speed Enforcement on Rural Roads

Lightly traveled rural roads have an excessive number of high-speed crashes relative to their traffic volumes. Construction zones can be especially hazardous for drivers and road workers alike. However, enforcement efforts are hampered by a lack of CHP officers and difficulties in capturing speed data. This PATH project focused on developing technology to reduce speed violations and support on-road enforcement. The augmented speed enforcement system (aSE) includes a speed camera that captures speeding vehicles, and a changeable message sign that displays the speeder's license plate number and measured speed. A web page was also developed that allows police to monitor the information collected through the system. Field testing showed the system was effective in reducing the number of speeding vehicles. The aSE system and lessons learned in this project can be considered for deployment in a variety of safety applications in both urban and rural settings where excess speed is a safety concern.

Using Probe Data for Traffic Estimation

A series of projects at PATH have addressed many aspects of the use of cell phone or probe data for traffic estimation. This data (primarily from fleet vehicles equipped with transmitters) is available from a number of commercial vendors. However, the data must be filtered, processed, and fitted, in order for it to be used by Caltrans' Performance Measurement System (PeMS). As the number of cars providing mobile data increases, its value for use in estimation, prediction, and traffic management also increases. Researchers have created prototype software to analyze probe data and improve traffic operations managers' ability to use the information garnered from it.



Project Highlights, cont.

Vehicle Assist and Automation for Full-Size Public Transit Buses

Automated, predictable curb access enables transit buses to achieve rail-like quality of service and improve operational efficiencies through tighter scheduling. A group of technologies called Vehicle Assist and Automation, or VAA, have been combined into a newly developed guidance system from PATH researchers, enabling buses to stop in fixed locations every time. Improved reliability and service make buses a more attractive transit option for travelers of all types. The system is currently in field testing in Oregon and California.

Tools for Operational Planning (TOPL)

PATH has a long history of working with Caltrans to improve its operation and management of California's roadways. Tools for Operational Planning, or TOPL, is a suite of analysis and simulation tools that enable traffic engineers to analyze major traffic corridor operational improvements such as ramp metering, incident management, arterial traffic signal control, and demand management, and to quickly estimate the benefits of such actions. TOPL is based on macro-simulation freeway and arterial models that are easily assembled, self-calibrated, and self-diagnosed using traffic data, and run much faster than real time. This project is currently extending these tools so that they can be used as part of a real time Decision Support System, which will enable traffic managers to forecast short-term future traffic conditions in a freeway corridor, sound alarms for potential trouble or stress conditions, and quickly evaluate potential deployable traffic management strategies (play-book strategies) in order to select the strategies that are most likely to improve the performance and safety of the traffic corridor. TOPL researchers continue to build on previous phases of the project, enabling the team to tackle even more advanced models and traffic scenarios.

Interstate 680 Corridor System Management Plan

Corridor System Management Plans (CSMP) are performed by Caltrans, in conjunction with all appropriate jurisdictional agencies, to assess current and future deficiencies in a transportation corridor and determine necessary future traffic management, transit, and infrastructure improvements for meeting mobility goals. Caltrans, the Contra Costa Transportation Authority (CCTA), and System Metrics Group (SMG) are developing a CSMP for the I-680 corridor between I-580 and the Benicia Bridge. The aim is to determine the best mix of strategies to improve mobility, travel time reliability, and stewardship of existing resources, based on analysis of extensive modeling and other evaluation tools. PATH is supporting this effort by providing simulation capabilities for scenario testing and planning exercises, with the goal of demonstrating that our recently developed Tools for Operational Planning (TOPL) can make CSMP development faster, easier, less expensive, and more effective than is possible with existing technologies.



Quick Clearance of Major Traffic Incidents

Traffic incidents cause a considerable amount of highway congestion, particularly ‘major’ crashes that involve lane closures, personal injury, and multiple respondents. In this study, PATH investigated the current incident clearance practices of state and local agencies in order to refine those practices for faster clearance throughout California. Researchers designed new procedures and guidelines to improve clearance times and will provide these recommendations to first responder agencies in the coming year. Researchers will also assist public agencies with advice on how to collect, process, and maintain incident data to track progress and make additional improvements in future years.

Field-Testing the Effectiveness of Adaptive Traffic Signal Control for Arterials

Adaptive traffic signal control uses real-time traffic information from road sensors to determine when a traffic light should be red or green. When effective, adaptive traffic signal controls can reduce congestion and thus improve traffic flow. The effectiveness of adaptive control depends on the control logic employed and the particular network characteristics. In this project, researchers field-tested the added value of implementing adaptive traffic signal control on the Pacific Coast Highway in Santa Monica, California. Alternative strategies—including widely used fixed time signal plans—were developed and tested to determine the most effective and cost efficient solution. Implementation guidelines for a statewide rollout are now being developed based on the results of the field-testing.

Creating Advanced Traffic Signal Controls Using Connected Vehicle Data

Adaptive traffic signal technologies offer a significant improvement over traditional signals, which mostly operate on a fixed-time schedule. However, their potential has yet to be realized as most deployed adaptive traffic signals rely on ground sensors, or loop data, to detect stopped vehicles at an intersection; data which is often not readily available. PATH researchers developed new traffic signal control strategies using data from “connected” vehicles, including vehicle-to-vehicle and vehicle-to-infrastructure technologies. The new control strategies tested well, and showed improved mobility and safety. Also, PATH researchers, in partnership with BMW, field-tested an in-vehicle driver speed advisory system. The project was able to demonstrate that the interconnection of vehicles and infrastructure can reduce fuel consumption and GHG emissions, and increase safety. Work is underway to further test the developed strategies on local arterial roads.



Project Highlights, cont.

Connected Corridors

The Connected Corridors program is a collaborative effort to research, develop, and test a framework for corridor traffic operations in California. Building our way out of congestion is no longer an option; we must coordinate our way to improved performance. Connected Corridors is therefore investigating how the components of a transportation corridor (freeways, arterial city streets, buses, rail lines, etc.) can work together efficiently so they can be managed as a cohesive, integrated system, to reduce traffic congestion and improve mobility along the corridor.

The benefits of such Integrated Corridor Management (or ICM) strategies could be profound: fewer bottlenecks, smoother traffic flow, reduced travel times, along with lower greenhouse gas emissions. Additionally, ICM can provide better real-time traveler information, enabling people to choose the best times, routes, and means of travel; an increased use of public transit; improved highway safety; and a boost to California's economic performance and overall quality of life.

To pursue these goals, Connected Corridors will leverage new technologies, many developed in California, that have changed transportation: the internet, cellular and mobile devices, GPS technology, and social networking. Building on the experience from previous PATH projects including TOPL and Mobile Millennium, the Connected Corridors team will combine these new technologies with current corridor management strategies such as ramp metering, lane management, dynamic shoulder use, and arterial signal coordination, to help both traffic managers and travelers make optimal use of the transportation network.

Since a transportation corridor typically extends through many communities and jurisdictions, our work from the beginning must be a cooperative endeavor among stakeholders along the corridor, both those responsible for managing traffic and those likely to be impacted by any changes. The Connected Corridors team is working to build a consortium of participants including Caltrans, regional Metropolitan Planning Organizations, counties, cities, and industry partners. Together, the stakeholders will identify the corridor's issues, set the overall strategic direction of the project, monitor progress toward agreed-upon goals, and ensure that the project serves the needs of Californians locally, regionally, and statewide.

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Page 11 Diagram: Courtesy of Caltrans

The PATH and Caltrans Connection

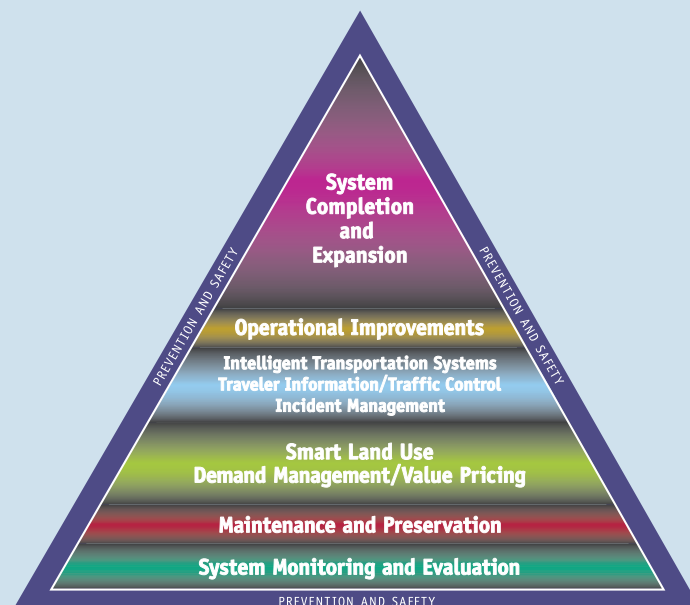
Caltrans' mission of improving mobility across California is closely aligned with the mission of PATH. In 2007, Caltrans developed five strategic goals in pursuit of becoming the highest-performing transportation agency in the country. These goals (listed below) reinforce why PATH and Caltrans remain close allies.

- **Safety:** Nothing is more precious than a life. According to the California Traffic Safety Score Card, in 2011 alone, there were close to 2,800 traffic fatalities in California. Through more advanced vehicle systems, better warnings to drivers of slowed traffic, and improved enforcement to deter speeding, we believe this number can be reduced. Additionally, we're pioneering technologies aimed at enhancing worker safety on California's roadways.
- **Mobility:** California's economy is dependent on its ability to move people. This principle is the foundation for much of PATH's research. Advancing corridor management, streamlining transit technologies, and developing incentives to change driver behavior are all projects we are currently working on to improve mobility.
- **Delivery:** For over 25 years, PATH has attracted private and public sector partners from all over the world, in part because of our ability to deliver high-quality results in a timely manner. Our people are skilled at creating clear objectives and meeting those objectives on budget and on schedule.
- **Stewardship:** We believe innovation is an important part of being good stewards. By increasing the efficiency of California's roads and highways, we can reduce the need to expand or build new roads. Decreasing congestion also decreases greenhouse gas emissions, another way we can be good stewards of our planet.
- **Service:** At PATH, we focus on service by conducting research that is of value to the traveling public. Producing high-quality work that can benefit the people of California ensures we remain a leader in the field of transportation research and true to our responsibility as a public organization.

For almost a decade, Caltrans has been pursuing various process improvements and system investments to fully implement the Mobility Pyramid philosophy (illustrated below). PATH's work focuses on four of the seven tiers of this system:

- The Augmented Speed Enforcement project is one example of our collaborative work with Caltrans on prevention and safety.
- The Connected Corridors and Smart Travel Choices projects include implementing innovative Intelligent Transportation Systems.
- Our Hybrid Traffic Data Collection and Tools for Operational Planning (TOPL) projects focus on better system monitoring and evaluation and operational improvements.

In addition, PATH strongly supports Caltrans' four core values: integrity, commitment, teamwork, and innovation. We believe these shared values are another example of why our partnership has been so successful.



Publications

As part of one of the world's leading public research institutions, PATH's graduate students, faculty, and staff engineers regularly publish and share their work through journal publications, academic papers, and peer-reviewed conferences. Below is a sample of publications from 2010 to 2012.

Journal Publications

"Arterial Travel Time Forecast with Streaming Data: A Hybrid Approach of Flow Modeling and Machine Learning," A. Hofleitner, R. Herring and A. Bayen, *Transportation Research Part B*, 2012, doi: 10.1016/j.trb.2012.03.006.

"Evaluate Bus Emissions Generated Near Far-side and Near-side Stops and Potential Reductions by ITS: An Empirical Study," J.-Q. Li, S.D. Gupta, L. Zhang, K. Zhou, W.-B. Zhang, *Transportation Research Part D*, Vol. 17, Iss. 1, pp 73-77, Jan. 2012.

"Experimental Development of a New Target and Control Driver Steering Model Based on DLC Test Data," H.-S. Tan and J. Huang, *IEEE Transactions on Intelligent Transportation Systems*, vol. 13, no. 1, pp. 375-384, Mar. 2012.

"Impact of Traffic States on Freeway Crash Involvement Rates," H. Yeo, K. Jang, A. Skabardonis and S. Kang, *Accident Analysis and Prevention*, June 2012, doi: 10.1016/j.aap.2012.06.023.

"Impacts of Cooperative Adaptive Cruise Control on Freeway Traffic Flow," S.E. Shladover, D. Su and X.-Y. Lu, *Transportation Research Record No. 2324*, 2012, pp. 63-70.

"Learning the Dynamics of Arterial Traffic from Probe Data Using a Dynamic Bayesian Network," A. Hofleitner, R. Herring, P. Abbeel and A. Bayen, *IEEE Transactions on Intelligent Transportation Systems*, 13(4) 1679-1693 February, 2012 doi: 10.1109/TITS.2012.2200474.

"A Multi-modal Trip Planning System with Real-time Traffic and Transit Information," J.-Q. Li, K. Zhou, L. Zhang, W.-B. Zhang, *Journal of Intelligent Transportation Systems*, Vol. 16, Iss. 2, pp 45-59, 2012.

"On Sequential Data Assimilation for Scalar Macroscopic Traffic Flow Models," S. Blandin, A. Couque, A. Bayen and D. Work, *Physica D: Nonlinear Phenomena*, 241 (2012), pp.1421-1440, doi: 10.1016/j.physd.2012.05.005.

"Prediction of Vehicle Activity for Emissions Estimation Under Oversaturated Conditions Along Signalized Arterials," A. Skabardonis, N. Geroliminis and E. Christofa, *Special Issue of Journal of Intelligent Transportation Systems*, May 2012, doi: 10.1080/15472450.2012.704338.

"Red Light Running Prediction Based on Inductive Loop Detectors for Dynamic All-Red Extension," L.-J. Wang, L. Zhang, K. Zhou, W.-B. Zhang, *Transportation Research Record: Journal of the Transportation Research Board*, IN: 2311, pp 44-50, 2012.

"Signal Optimization at Urban Highway Rail Grade Crossings Using an Online Adaptive Priority Strategy," G. Wu, Li. Zhang, W.-B. Zhang and M. Tomizuka, *Journal of Transportation Engineering*, Vol. 138, Iss. 4, 2012.

"Traffic Characteristics of High-Occupancy Vehicle (HOV) Lanes: Comparison of Contiguous and Buffer-Separated HOV Lanes," K. Jang, et al., *Transportation Research Record* 2012, No. 2278, pp. 180-193.

"Analytical and Grid-Free Solutions to the Lighthill-Whitham-Richards Traffic Flow Model," P.-E. Mazare, C. G. Claudeland, A. Bayen, *Journal of the Transportation Research Board* 45(10), pp. 1727-1748, Dec. 2011, doi: 10.1016/j.trb.2011.07.004.

"Convex Formulations of Data Assimilation Problems for a Class of Hamilton-Jacobi Equations," C. Claudel and A. Bayen, *SIAM Journal on Optimization and Control*, 49(2), pp. 383-402, Mar. 2011. doi: 10.1137/090778754.

"A General Phase Transition Model for Vehicular Traffic," S. Blandin, D. Work, P. Goatin, B. Piccoli and A. Bayen, *SIAM Journal on Applied Mathematics*. 71(1), pp. 107-127, Feb. 2011. doi:10.1137/090754467.

"Identification and Analysis of Queue Spillovers in City Street Networks," N. Geroliminis and A. Skabardonis, *IEEE Transactions on Intelligent Transportation Systems*, Dec. 2011, Vol. 12 (4), pp. 1107-1115, doi: 10.1109/TITS.2011.2141991.

"Intersection Crossing Times of Bicyclists: Quantitative Measurements at Diverse Intersections," S.E. Shladover, Z. Kim, M. Cao, A. Sharafsaleh and S. Johnston, *Transportation Research Record No. 2247*, 2011, pp. 91-98.

"Novel Freeway Traffic Control with Variable Speed Limit and Coordinated Ramp Metering," X. Y. Lu, P. Varaiya, R. Horowitz, D. Su and S.E. Shladover, *Transportation Research Record No. 2229*, 2011, pp. 55-65.

"Preliminary Evaluation of Operational Performance between Different Types of HOV Facilities in California: Continuous-Access versus Limited Access," G. Wu, et al., *Transportation Research Record* 2011, No. 2229, pp. 93-101.

"Traffic Signal Optimization with Application of Transit Signal Priority to an Isolated Intersection," E. Christofa and A. Skabardonis, *Transportation Research Record No. 2259*, 2011, pp. 192-201, doi: 10.3141/2259-18.

"Active Traffic Management on Road Networks: A Macroscopic Approach," A. Kurzhanskiy and P. Varaiya, *Philosophical Transactions of Royal Society, Part A*, 368, 2010.

"A Distributed Highway Velocity Model for Traffic State Reconstruction," D. Work, S. Blandin, O.-P. Tossavainen, B. Piccoli and A. Bayen, *Applied Mathematics Research eXpress (AMRX)*, 2010(1), pp. 1-35, April 2010. doi: 10.1093/amrx/abq002.



"Estimation of Freeway Traffic Density with Loop Detector and Probe Vehicle Data", T.Z. Qiu, X.-Y. Lu, A.H.F. Chow and S.E. Shladover, *Transportation Research Record No. 2178*, 2010, pp. 21-29.

"Microscopic Traffic Simulation of Vehicle-to-Vehicle Hazard Alerts on Freeway," H. Yeo, S.E. Shladover, H. Krishnan and A. Skabardonis, *Transportation Research Record No. 2189*, 2010, pp. 68-77, doi: 10.3141/2189-08.

"Performance Evaluation of Travel-Time Estimation Methods for Real-Time Traffic Applications," J. Ban, A. Skabardonis and J.D. Margulici, *Journal of Intelligent Transportation Systems*, May 2010, Vol. 14 (2), pp. 54-67, doi: 10.1080/15472451003719699.

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"Evaluation of an Animal Warning System Effectiveness-Phase Two," A. Sharafsaleh, M. Huijser, C. Nowakowski, M. Greenwood, L. Hayden, J. Felder, M. Wang, UCB-ITS-PRR-2012-2.

"Monitoring and Improving Roadway Surface Conditions for Safe Driving Environment and Sustainable Infrastructure," C.-Y. Chan, UCB-PRR-12-02.

"PeMS11: Final Report," G. Dervisoglu, J. Seeherman and A. Skabardonis, UCB-ITS-PRR-2012-01.

"Advanced Traffic Control Signal Algorithms Cooperative Agreement DTFH61-10-H-00002," A. Skabardonis, S.E. Shladover, W.B. Zhang, L. Zhang, J.Q. Li and K. Zhou, FHWA Exploratory Advanced Research, Mar. 2011.

"Bay Bridge Toll Evaluation: Final Report," E. Deakin, K. Frick, R. Cervero, A. Skabardonis, I. Barnes, K. Kingsley, J. Rubin, J. Murakami, J. Amaro and E. Jensen, Global Metropolitan Studies, Nov. 2011.

"Bicycle Detection and Operational Concept at Signalized Intersections, Phase 2," S.E. Shladover, Z. Kim, M. Cao, A. Sharafsaleh, I. Li and S. Johnston, UCB-ITS-PRR-2011-02.

"Cooperative Adaptive Cruise Control: Testing Drivers' Choices of Following Distances," C. Nowakowski, S.E. Shladover, D. Cody, F. Bu, J. O'Connell, J. Spring, S. Dickey, D. Nelson, UCB-ITS-PRR-2011-01.

"Evaluation of Automated Enforcement Technology for Managed Lanes," C.-Y. Chan, et al., PATH-PRR-2011-04.

"High Occupancy Vehicle Lane Management System: Amendment A," A. Sharafsaleh, V. Kohli, D. Edwards, G. Gomes, and P. Varaiya, UCB-ITS-PRR-2011-10.

"Limited Deployment Pilot Project: Monitoring Truck Traffic in Caltrans District 7," A. Mortazavi, W. Tabajunda, L. Fogel, S. Cho, A. Sharafsaleh, and J. Drazin, UCB-ITS-CWP-2011-01.

"Mobile Millennium: Final Report," A. Bayen, J. Butler, and A. Patire et al., UCB-ITS-CWP-2011-6.

"Operation of Traffic Signal Systems in Oversaturated Conditions: Final Report," D. Gettman, M. Abbas, H. Liu and A. Skabardonis, NCHRP Project 3-90, Transportation Research Board, Washington, DC, Mar. 2011.

"SafeTrip 21 Initiative: Networked Traveler Foresighted Driving Field Experiment," C. Nowakowski, S. D. Gupta, D. Vizzini, R. Sengupta, C. Mannasseh, J. Spring, J. VanderWerf, and A. Sharafsaleh, UCB-ITS-PRR-2011-05.

"Assessing Automated Speed Enforcement in California," C.-Y. Chan, et al., UCB-ITS-PRR-2010-21.

"Deliver a Set of Tools for Resolving Bad Inductive Loops and Correcting Bad Data," X. Y. Lu, Z. W. Kim, M. Cao, P. Varaiya, and R. Horowitz, UCB-ITS-PRR-2010-5.

"Development and Evaluation of Selected Mobility Applications for VII," S.E. Shladover, X. Y. Lu, D. Cody, C. Nowakowski, Z. Qiu, A. Chow, J. O'Connell, J. Nienhuis and D. Su, UCB-ITS-PRR-2010-25.

"Effectiveness of Adaptive Traffic Control for Arterial Management," A. Skabardonis and G. Gomes, UCB-ITS-PRR-2010-36, Aug. 2010.

"Evaluation of an Animal Warning System Effectiveness," A. Sharafsaleh, M. Huijser, T. Kuhn, J. Spring, J. Felder, UCB-ITS-PRR-2010-22.

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"Mobile Century Final Report for TO 1021 and TO 1029: A Traffic Sensing Field Experiment Using GPS Mobile Phones," A. Bayen, Dec. 2010.

"Planning the Deployment of a Commercial Motor Vehicle Virtual Weigh Station Technology Testbed," M. Miller, A. Sharafsaleh, UCB-ITS-PRR-2010-27.

"The Potential of Using Transit Infrastructure for Air Freight Movement: A Case Study in the Bay Area," R. Wang, X. Y. Lu, and K. Sivakumaran, UCB-ITS-PRR-2010-38.

"San Diego I-15 Integrated Corridor Management (ICM) System: Stage II (Analysis, Modeling, and Simulation)," M. Miller and A. Skabardonis, UCB-ITS-PRR-2010-09.

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"Optimal Control of Freeway Networks Based on the Link Node Cell Transmission Model," A. Muralidharan and R. Horowitz, *American Control Conference*, 2012.

"Analysis of Impact of Single Occupancy Hybrid Vehicles on HOV Lanes," V. Kohli, G. Gomes, and A. Sharafsaleh, *Annual Meeting of the Transportation Research Board*, 2012.

"Probabilistic Formulation of Estimation Problems for a Class of Hamilton-Jacobi Equations," A. Hofleitner, C. Claudel, and A. Bayen, *IEEE Conference on Decision and Control*, Maui, Hawaii, Dec. 2012.

19th World Congress on Intelligent Transport Systems, Vienna, Austria, Oct. 2012:

- "Overview of Platooning Systems," C. Bergenheim, H. Pettersson, E. Coelingh, C. Englund, S.E. Shladover and S. Tsugawa.
- "Multiple-Vehicle Longitudinal Collision Avoidance and Impact Mitigation Simulation for Different Scenarios," X. Y. Lu and J. Wang.
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“Automatic Inference of Map Attributes from Mobile Data,” A. Hofleitner, E. Come, L. Oukhellou, J-P Lebacque and A. Bayen, *International IEEE Conference on Intelligent Transportation Systems*, Anchorage, Alaska, Sept. 2012.

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“Multiple-Vehicle Longitudinal Collision Avoidance and Impact Mitigation by Active Brake Control,” X. Y. Lu and J. Wang, *IEEE Intelligent Vehicles Symposium*, Alcalá de Henares, Spain, June 2012.

“Effect of Bus Stop Location and Bus Dwell Time on Saturation Flow at Signalized Intersections,” J. Campbell, E. Christofa and A. Skabardonis, *Innovations in Traffic Flow Theory and Highway Capacity Symposium*, Transportation Research Board, Ft. Lauderdale, Florida, June 2012.

91st Transportation Research Board Annual Meeting, Washington D.C., Jan. 2012:

- “Assessment of the Impact of Weather on Freeway Operations in California,” Paper 12-3753, J. Seeherman, V.P. Sisiopiku and A. Skabardonis.
- “Estimation of Arterial Measures of Effectiveness with Connected Vehicle Data,” Paper 12-1493, J. Argote, E. Christofa, Y. Xuan and A. Skabardonis.
- “Impact of Peak and Off Peak Tolls on Traffic in the San Francisco-Oakland Bay Bridge Corridor,” Paper 12-4412, I. Barnes, K. Frick, E. Deakin and A. Skabardonis.
- “Individual Speed Variance in Traffic Flow: Analysis of Bay Area Radar Measurements,” S. Blandin, A. Salam, and A. Bayen.
- “Large Scale Estimation of Arterial Traffic and Structural Analysis of Traffic Patterns Using Probe Vehicles,” A. Hofleitner, R. Herring, A. Bayen, Y. Han, F. Moutarde, and A. de la Fortella.
- “Person-Based Traffic Signal Optimization for Real-Time Applications,” Paper 12-2228, E. Christofa, I. Papamichail and A. Skabardonis.
- “Probability Distributions of Travel Times on Arterial Networks: A Traffic Flow and Horizontal Queuing Theory Approach,” A. Hofleitner, R. Herring, and A. Bayen.
- “A Study on the Wave Development and Evolution Characteristics of Stop-and-Go Traffic,” Paper 12-1324, J. Suh, H. Yeo and A. Skabardonis.
- “A Three-Stream Model for Arterial Traffic,” C. Bails, A. Hofleitner, Y. Xuan, and A. Bayen.
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- “Variable Speed Limit Control Design for Relieving Congestion Caused by Active Bottlenecks,” M. Hadiuzzaman, T. Z., Qiu, and X. Y. Lu.

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- “Analysis of Adaptive Learning Algorithm for Freeway Ramp Flow Imputation,” A. Muralidharan and R. Horowitz.
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“Online Least-Squares Estimation of Time Varying Systems with Sparse Temporal Evolution and Application to Traffic Estimation,” A. Hofleitner, L. El Ghaoui, A. Bayen, *50th IEEE Conference on Decision and Control and European Control Conference*, pp. 2595-2601, Atlanta, Florida, Dec. 2011, doi: 10.1109/CDC.2011.6160832.

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“Feasibility of Using BART for Regional Air Freight Movement – Transshipment and Energy Use,” X. Y. Lu, R. Wang, K. Sivakumaran, and M. Hanson, *National Urban Freight Conference*, Long Beach, California, Oct. 2011.

“Scaling the Mobile Millennium System in the Cloud,” T. Hunter, T. Moldovan, M. Zaharia, S. Merzgui, J. Ma, M. Franklin, P. Abbeel, A. Bayen, *ACM Symposium on Cloud Computing (SOCC’11)*, Cascais, Portugal, Oct. 2011.

14th International IEEE Conference on Intelligent Transportation Systems (ITSC), Washington D.C., Oct. 2011:

- “An Adaptive Routing System for Location-aware Mobile Devices on the Road Network,” P. Borokhov, S. Blandin, S. Samaranyake, O. Goldschmidt and A. Bayen.
- “Estimation of Measures of Effectiveness Based on Connected Vehicle Data,” J. Argote, E. Christofa, Y. Xuan and A. Skabardonis.
- “Evaluation of Probe Vehicle Sampling Strategies for Traffic Signal Control,” S.E. Shladover and J.-Q. Li, pp. 1753 - 1758.
- “METANET Model Improvement for Traffic Control,” X. Y. Lu, T. Qiu, R. Horowitz, A. Chow and S.E. Shladover, pp. 2148-2152.
- “Microscopic Fundamental Relationships Between Vehicle Speed and Spacing in View of Asymmetric Traffic Theory,” H. Yeo and A. Skabardonis.
- “Optimal Decomposition of Travel Times Measured by Probe Vehicles Using a Statistical Traffic Flow Model,” A. Aueitner, R. Herring and A. Bayen.
- “Immediate Transitions for an Automated Bus Using Magnetic and DGPS Sensing Systems,” J. Huang and H.-S. Tan, pp.656-661.
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- “Energy Saving for Automatic Train Control in Moving Block Signaling System,” Q. Gu, X. Y. Lu and T. Tang.

"The Reliability of Two New Animal Detection Systems and Recommended Requirements for System Reliability," M. Huijser, T.D.H. Allen, M. Blank, M.C. Greenwood, S. Wang, L. Hayden, C. Haas, and A. Sharafsaleh, *Proceedings of the 2011 International Conference on Ecology and Transportation*, Seattle, Washington, pp. 194-202, Aug. 2011.

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- "Impact of Transit Signal Priority on Level of Service at Signalized Intersections," E. Christofa and A. Skabardonis, Vol. 16, pp. 612-619.
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"Challenges to Evaluation of CO₂ Impacts of Intelligent Transportation Systems," S.E. Shladover, *IEEE Forum on Integrated Sustainable Transportation Systems (FISTS)*, Vienna, Austria, June 2011.

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- "A Methodology for Assessing Signal Timing Plans and Control Technology Under Varying Demands and Capacities," Paper 11-0359, R. Dowling and A. Skabardonis.
- "Variable Speed Limit and Ramp Metering Design for Congestion Caused by Weaving," Su, D., X. Y. Lu, P. Varaiya, R. Horowitz and S.E. Shladover.

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- "Estimating Arterial Traffic Conditions Using Sparse Probe Data," R. Herring, A. Hofleitner, P. Abbeel, A. Bayen.
- "New Approach for Combined Freeway Variable Speed Limits and Coordinated Ramp Metering," X. Y. Lu, P. Varaiya, R. Horowitz, D. y. Su, and S.E. Shladover. *5th ICTR Conference*, Volos, Greece, Sept. 2010:
- "Model for Evaluation of Incident Management Measures for Improving Traffic Flow and Environment," P. Kopelias, A. Skabardonis and F. Papadimitriou.
- "Improved Analysis Framework for Emissions Estimation Under Oversaturated Conditions Along Signalized Arterials," A. Skabardonis, N. Geroliminis and E. Christofa.

"Characterizing Driving Skill Based on Entropy Analysis of Steering Frequency Response," H.-S. Tan, F. Bu, J. Huang, and Y.-K. Chin, *ASME 2010 Dynamic Systems and Control Conference*, Cambridge, Massachusetts, Sept. 2010, DSCC2010-4284.

"Immediate Manual-Automatic Vehicle Control Transitions Based on Dynamic Initial Conditioning," J. Huang, H.-S. Tan, and F. Bu, *Preprints of the 5th IFAC Symposium on Mechatronic Systems*, Cambridge, Massachusetts, Sept. 2010, MECHATRONICS2010-132.

"Rollover Prevention for Vehicles with Elevated CG Using Active Control," D. F. Chu, X. Y. Lu, G. Y. Li, and J. K. Hedrick, *The 10th Int. Symposium on Advanced Vehicle Control (AVEC)*, Loughborough, UK, Aug. 2010.

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- "Combining Variable Speed Limits with Ramp Metering for Freeway Traffic Control," X. Y. Lu, T. Z. Qiu, P. Varaiya, R. Horowitz, and S.E. Shladover.
- "Linear and Quadratic Programming Formulations of Data Assimilation or Data Reconciliation Problems for a Class of Hamilton-Jacobi Equations," C. Claudel and A. Bayen.
- "Lateral Control of an Articulated Bus for Lane Guidance and Curbside Precision Docking," F. Bu, H.-S. Tan and J. Huang, pp. 3854-3859.
- "Design and Field Testing of a Cooperative Adaptive Cruise Control System," F. Bu, H.-S. Tan and J. Huang, pp. 4616-4621.

"Traffic Signal Optimization with Conditional Transit Signal Priority for Conflicting Transit Routes," E. Christofa and A. Skabardonis, *12th WCTR Conference*, Lisbon, July 2010.

NATMEC, Seattle, Washington, June 2010:

- "Dual Loop Data Correction at Microscopic Level," X. Y. Lu, P. Varaiya, and R. Horowitz.
- "Integrated Data System Structure for Active Traffic Management - Planning and Operation," X. Y. Lu, and J. Palen.

"A Combined Dynamics Model for Active Roll Stability Control of Ground Vehicles," D. F. Chu, G. Y. Li, X. Y. Lu, and J. K. Hedrick, *International Conference on Mech. and Aerospace Eng. (CMAE)*, Chengdu China, Apr. 2010.

89th Transportation Research Board Annual Meeting, Washington DC, Jan. 2010:

- "An Empirical Study of Traffic Breakdown for Variable Speed Limit and Ramp Metering Control," H. F. Chow, X. Y. Lu, Z. J. Qiu, S.E. Shladover, and H. Yeo.
- "The Use of Passenger Transit Infrastructure for Goods Movement: A Bay Area Economic Feasibility Study," K. Sivakumaran, X. Y. Lu, and M. Hanson, *Transportation Research Record* No. 2162, TRB, p.44-52.
- "Queue Spillovers in City Street Networks with Signal-Controlled Intersections," paper 10-3498, N. Geroliminis and A. Skabardonis.
- "User Perception and Preference for Displaying Travel Time on CMS in the San Francisco Bay Area," Paper 10-2956, Y. Li, J. Ban and A. Skabardonis.



People

Faculty and Program Leaders

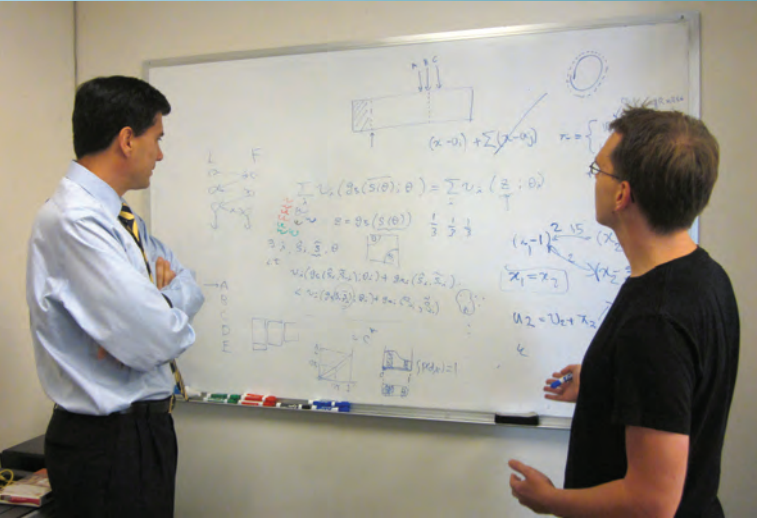
PATH is fortunate to have a number of world-renowned faculty members and program leaders guiding PATH's research. This includes Principal Investigators who personally conduct or supervise the research, program leaders who administer and oversee PATH projects, and visiting scholars from other top universities both in the United States and around the world. The faculty members' and program leaders' depth of knowledge and experience provide quality leadership and vision to the program.

Staff

PATH staff works with the faculty to administer and manage projects, as well as to oversee the PATH organization. The staff at PATH is diverse and includes administrators; analysts; financial, contract, and office managers; communication specialists; engineers and computer scientists; and human resource and purchasing liaisons. Staff researchers play an important role in conducting and supervising the organization's specialized research and scholarly training. PATH staff has worked in academia as well as in the public and private sectors, bringing a wealth of wisdom and skills to the organization.

Students

PATH students investigate, develop, and evaluate new transportation and engineering processes and equipment in order to solve specific problems. Students at PATH—including undergraduate students, graduate student researchers, and postdoctoral researchers—have wide-ranging roles and responsibilities. While the majority of students working with PATH are attending UC Berkeley, the organization also hosts international students from universities throughout Asia and Europe. PATH would not be what it is today without a long history of students researching and advancing PATH projects and programs.



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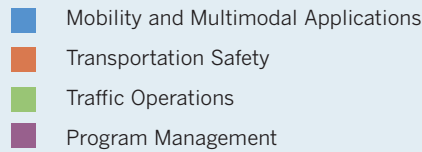
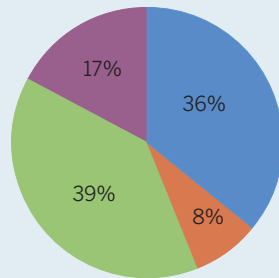


Financials

Expenditures by Research Area

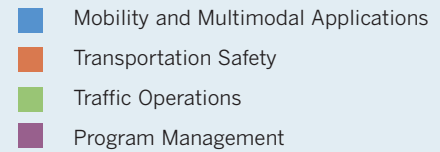
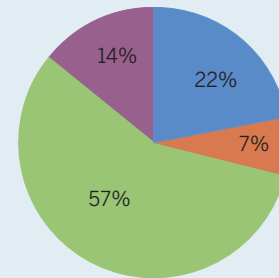
PATH's research focuses on three key areas: mobility and multimodal applications, traffic operations, and transportation safety. In both Fiscal Year 2010 and Fiscal Year 2011, over \$6 million was invested in research to improve California's transportation system. Over the same period, program management expenses, as a percentage of total program costs, were reduced from 17% to 14%. This was one of the goals of the PATH and CCIT merger.

Fiscal Year 2010-2011



Total: 100%

Fiscal Year 2011-2012

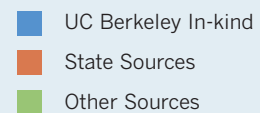
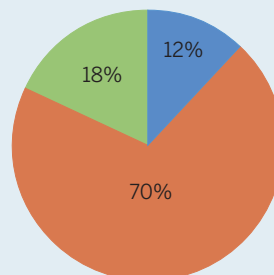


Total: 100%



UC In-kind Contribution

Approximately 70% of the research executed by California PATH is supported by California state agencies and departments. One of the cornerstones of UC Berkeley's mission is to serve the interests of California's citizenry. To honor this mission, the University provides in-kind services (such as purchasing, accounting, etc.) for state-sponsored research. In the case of PATH, UC Berkeley matches agency funding with in-kind services that equal 12% of total program funding. Thus, the total PATH program is comprised of projects sponsored by state agencies, in-kind business services, and projects sponsored by other sources including commercial firms and the federal government (that receive no in-kind support).



Looking Ahead

PATH's projects and accomplishments of the last few years and the challenges of the present point us inevitably toward the future. The mobility and safety needs of California continue to demand innovative, effective solutions that require us to look as far as we can down the road.

Our partnership with Caltrans continues to be integral to advancing our work. Together, we completed over 20 projects in the last three years, and an additional 20 projects are ongoing. This forward-looking collaboration, along with the commitment of our other partners, forms a solid basis for building vital improvements in California's transportation system.

In the coming year, the Connected Corridors program will reach important milestones, including selecting the first pilot site, collaborating with the stakeholders in the project area, and developing a working demonstration of Integrated Corridor Management (ICM). The ICM pilot will mark the beginning of a paradigm shift away from building our way out of congestion to managing and coordinating our way to improved performance. While beginning with a pilot on one corridor, the long-term goal is to apply the lessons learned and improved performance on other congested corridors in the state. Assessing the technical, organizational, and political actions required for a statewide rollout is crucial to achieving this broader goal.

The completion of the Palo Alto test bed will pave the way for new opportunities in the development of connected and automated vehicle research and will ensure California's continued leadership in this important field. One of the first uses of the test bed site will be for field operation tests for the Multi-Modal Intelligent Traffic Signal Systems (MMITSS). This project is focused on integrating information from a variety of sources, including connected vehicles, to improve traffic control systems, making them better performing and safer for pedestrians and vehicles alike.

Although many obstacles remain, fully automated and connected vehicles could one day become commonplace. From testing driver acceptance of following distances for Cooperative Adaptive Cruise Control (CACC) to using dedicated short range communication (DSRC) to expand vehicle-to-vehicle and vehicle-to-infrastructure applications, PATH remains invested in advancing new technologies for the next generation of connected and automated vehicles.

At PATH, we believe innovation and technology can be used to improve mobility, increase highway safety, and help us become better stewards of our planet. Whether addressing regional, national, or global transportation issues, we are dedicated to cultivating progressive ideas and implementing real solutions that make a difference, both now and far into the future.



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